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Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest

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Abstract

The potential for traditional and local ecological knowledge to contribute to biodiversity conservation has been widely recognized, but the actual application of this knowledge to biodiversity conservation is not easy. This paper synthesizes literature about traditional and local ecological knowledge and forest management in the Pacific Northwest to evaluate what is needed to accomplish this goal. We address three topics: (1) views and values people have relating to biodiversity; (2) the resource use and management practices of local forest users, and their effects on biodiversity; (3) models for integrating traditional and local ecological knowledge into biodiversity conservation on public and private lands. We focus on the ecological knowledge of forest users belonging to three groups who inhabit the region: American Indians, family forest owners, and commercial nontimber forest product harvesters.

We argue that integrating traditional and local ecological knowledge into forest biodiversity conservation is most likely to be successful if the knowledge holders are directly engaged as active participants in these efforts. Although several promising models exist for how to integrate traditional and local ecological knowledge into forest management, a number of social, economic, and policy constraints have prevented this knowledge from flourishing and being applied. These constraints should be addressed alongside any strategy for knowledge integration. Also needed is more information about how different groups of forest practitioners are currently implementing traditional and local ecological knowledge in forest use and management, and what the ecological outcomes are with regard to biodiversity.

Keywords: Traditional ecological knowledge; Pacific Northwest forest management; Biodiversity conservation; American Indians; Family forest owners; Nontimber forest product harvesters

1. Introduction

The potential for traditional and local ecological knowledge to contribute to biodiversity conservation has been widely recognized, as reflected by Article 8(j) of the United Nations Convention on Biological Diversity, which states that the knowledge and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity should be respected, preserved, and applied (Multilateral, 1993). In the Pacific Northwest, there is interest in learning more about traditional ecological knowledge and how it can be integrated into forest biodiversity conservation (Nelson et al., 2006). Despite support for the concept, applying the ecological knowledge of local people to biodiversity conservation is not easy.

In this paper, we synthesize literature on traditional and local ecological knowledge related to forest management among American Indians, family forest owners, and commercial nontimber forest product harvesters in the Pacific Northwest to critically evaluate what is needed to accomplish this goal. We argue that (1) integrating traditional and local ecological knowledge into forest biodiversity conservation is most likely to be successful if the knowledge holders are directly engaged as active participants in these efforts; (2) more information is needed about how different groups of forest practitioners are currently implementing traditional and local ecological knowledge in forest use and management, and what the ecological outcomes are with regard to biodiversity; (3) although several promising models exist for how to integrate traditional and local ecological knowledge into forest management, the social, economic, and policy constraints that prevent this knowledge

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from persisting and flourishing should be addressed alongside any strategy for knowledge integration. Our literature synthesis focuses on Washington, Oregon, and northern California, but our findings are broadly applicable for integrating traditional and local ecological knowledge into biodiversity conservation elsewhere.

1.1. Definitions

We adopt Berkes (1999) definition of traditional ecological knowledge (TEK) as a cumulative body of knowledge about the relationships living things (including people) have with each other and with their environment, that is handed down across generations through cultural transmission. TEK includes knowledge, practices, and beliefs that are more-or-less integrated with one another. It is dynamic and evolves as people build on their experiences and observations, experiment, learn from others, and adapt to changing environmental conditions over time. TEK is place-based and geographically specific, and is most often found among societies that have engaged in natural resource use in a particular place over a long time period, such as indigenous peoples (Berkes, 1999).

However, new knowledge is created all the time, and indigenous peoples are not the only ones who have ecological knowledge of value. This more recent local ecological knowledge (LEK) is defined here as knowledge, practices, and beliefs regarding ecological relationships that are gained through extensive personal observation of and interaction with local ecosystems, and shared among local resource users. Local ecological knowledge may eventually become TEK. We discuss both traditional and local ecological knowledge here, recognizing that both can have value for biodiversity conservation, whether developed over a few years or over centuries.

There is a debate in the literature about what makes traditional and local ecological knowledge different from western scientific knowledge, and whether the criteria used to distinguish them are valid (Agrawal, 1995; Ellen and Harris, 2000). We agree that separating ‘‘traditional’’ from ‘‘western scientific’’ knowledge creates a false dichotomy, but recognize some general distinguishing characteristics. Western scientific knowledge tends to be driven by theoretical models and hypothesis testing, and generated using the scientific method; not necessarily utilitarian; often generalizable and not always local; generated by research institutions; and documented and widely disseminated in written form. TEK and LEK tend to be driven by a desire for utilitarian information that will help people survive and maintain a natural resource-based livelihood; generated through practical experience with the natural world in the course of everyday life; locally based and specific; and transmitted orally or through demonstration (less true for commercial harvesters) (Ellen and Harris, 2000).

We use the term ‘‘forest practitioners’’ here to refer to people who spend time in forests and derive a portion of their economic livelihood from them, have social or cultural ties to forests, operate at a small, nonindustrial scale, and hold TEK or LEK about the forests they spend time in. Forest practitioners belonging to three groups are the focus of this synthesis: American Indians, family forest owners, and commercial nontimber forest product (e.g., wild mushrooms, ferns, boughs) harvesters. Not all members of these groups can be considered forest practitioners given this definition, and the depth of TEK and LEK held by individual practitioners will vary, as will their individual behaviors. Forest practitioners also possess varying degrees of western scientific knowledge; these knowledge systems are not mutually exclusive. There is also a great deal of cultural diversity within the three groups. In the interest of covering three different groups we do not examine variation within them, but rather speak in general terms about them. Forest practitioners also belong to other forest user groups in the Pacific Northwest, such as loggers and tree planters. We focus on American Indians, commercial nontimber forest product (NTFP) harvesters, and family forest owners because we found the most literature about them.

1.2. The relevance of traditional and local ecological knowledge for biodiversity conservation

Why consider traditional and local ecological knowledge in biodiversity conservation efforts? Forest practitioners spend a great deal of time in forests observing, experiencing, experimenting, working, and tinkering. In the process, they learn things that could be of value to western scientists and other forest managers; they are a potential source of experimental, anecdotal, and/or observational data on forest ecosystems. A main proposal of this paper is that partnerships in which forest practitioners, western scientists, and forest managers share their knowledge are likely to provide a better understanding of the natural environment and how to conserve biodiversity than these groups could achieve alone.

Another reason to consider TEK and LEK in biodiversity conservation stems from the observation that commercial timber production on private industrial and public lands in the Pacific Northwest – based on western science, belief, and value systems – have emphasized the production of a small number of commercially-valuable species on short rotations in plantations using even-aged management techniques, with negative effects on the structure, composition, and function of forest ecosystems (Carey, 2006; Wilson and Puettmann, 2007). In contrast, many forest practitioners have an interest in managing forests for a broad set of species and values, often with an emphasis on the forest understory or on ecosystem services. For example, over 200 species of nontimber forest products are known to be harvested on private and public lands in the region (Alexander and Fight, 2003), and this number could be much higher because 370 commercial nontimber forest product species are known to occur in Oregon alone (J. Weigand, personal communication, 2006). Indigenous peoples of the Pacific Northwest coast traditionally used about 300 plant species for food, medicine, materials, and other purposes, and some of these uses persist today (Deur and Turner, 2005a). And, family forest owners are known to manage their forests for a diversity of values. Forest management for a diversity of products, uses, and values is more likely to maintain biodiversity than forest management for commercial timber production based on short rotations and a small number of species (Carey, 2006; Camus et al., 2006).

Since the 1990s there has been a surge of interest in ecological restoration in the Pacific Northwest (Apostol and Sinclair, 2006). Some land managers have called for restoring forests to the conditions that prevailed prior to European settlement, or to conditions and processes within their historic range of variability (Kenna et al., 1999; Apostol, 2006). The forests encountered by early non-native settlers were shaped by both biological and cultural forces over thousands of years; they were not ‘‘wilderness’’ (Maffi, 2004; Anderson, 2005; Deur and Turner, 2005a,b). If presettlement forests are the reference ecosystems that are the goal of restoration and biodiversity conservation, understanding how past forest use and management practices based on TEK influenced biodiversity in forest ecosystems could provide valuable information about how to recreate these reference ecosystems today (Kimmerer, 2000; Anderson, 2005).

Traditional and local ecological knowledge emerge through processes of cultural adaptation to the environment. It is in the self interest of forest practitioners to use resources sustainably to ensure their long-term survival in specific locations. Numerous resource use and management practices based on traditional and local ecological knowledge that contribute to conservation – either intentionally or unintentionally – have been documented from around the world (Berkes et al., 1994, 2000; Minnis and Elisen, 2000; Peacock and Turner, 2000; Carlson and Maffi, 2004; Anderson, 2005). And there is a notable geographic overlap between the world’s biological and cultural diversity ‘‘hotspots’’ (Maffi, 2005). Learning if and how TEK and LEK maintain and restore forest biodiversity can contribute to biodiversity conservation efforts.

Forest practitioners work with and shape biodiversity. Their forest use and management practices may have significant effects because they use and/or control substantial areas of forest land. Family forest owners own roughly one-fifth of all forest land in the Pacific Northwest, much of it in low elevation areas that provide important habitat not often protected on public lands, which lie mostly at higher elevations (Johnson et al., 1999; Creighton et al., 2002). Indian lands cover nearly four million acres in Washington, Oregon, and California (USDA, 1997), and many western tribes have off-reservation rights reserved by treaty to use and harvest on federal forest lands at customary locations. Commercial nontimber forest product harvesters make extensive use of public lands and large private forest lands. To be successful at conserving forest biodiversity, it is necessary to work at large scales and across ownerships with those whose activities influence it.

1.3. Organization

We focus on three topics relating to traditional and local ecological knowledge among forest practitioners that we believe are relevant for forest biodiversity conservation. First we consider their views and values relating to biodiversity, including how these views intersect with western scientific concepts of biodiversity. We recognize biodiversity as something that is conceptualized and interpreted differently by different people, and explore these differences and what they imply for biodiversity conservation. Second, we examine the resource use and management practices of forest practitioners, and their effects on forest biodiversity. By learning about the management techniques people employ on the ground and their ecological effects, forest managers may expand their repertoires and discover new ways of achieving specific management goals. Third, we explore how TEK and LEK can be shared between forest practitioners and other forest managers, and integrated into forest biodiversity conservation efforts. We also discuss some of the challenges to knowledge integration.

The majority of the literature synthesized here has been published in peer-reviewed publications. Non-peer-reviewed literature was used only when we were unable to find much information on a topic in published, peer-reviewed journals or books. More information is likely available from websites, in non-peer-reviewed documents, and in ethnographies written about individual American Indian tribes. There are 28 federally recognized tribes in Washington, 10 in Oregon, and 107 in California (USDI, 2005), in addition to a number of tribes that have not been federally recognized. It was beyond the scope of this synthesis to read the literature pertaining to each of these tribes; we relied instead on literature summarizing what is known about their traditional ecological knowledge. We also include some examples from western British Columbia First Nations.

We conclude by presenting our findings from this synthesis about how to integrate traditional and local ecological knowledge into forest biodiversity conservation more effectively. Our hope is that by synthesizing this information and making it more accessible, it will be easier for western scientists, forest managers, and other forest practitioners to collaborate in biodiversity conservation across forest ownerships and landscapes, and to conserve biodiversity more effectively by drawing on and integrating the knowledge of others.

2. Views of biodiversity

Many different definitions of biodiversity exist in the literature. The definition adopted by Marcot (2007) is based on Noss’s (1990) conceptual framework, which incorporates three biological levels of organization – genes, populations/species, and communities/ecosystems – and three dimensions: composition, structure, and function. But biodiversity may be perceived and conceptualized differently by different people. These different views have implications for biodiversity conservation efforts. For example, if peoples’ views and values relating to biodiversity differ, there may be conflicts about what the goals of biodiversity conservation should be, creating barriers to collaborative conservation. A review of the literature indicates that forest practitioners do conceptualize biodiversity differently, but that these concepts are at least partially consistent with western scientific ideas.

2.1. American Indians

Little has been published about how American Indians in the Pacific Northwest perceive biodiversity or identify it as a value to be managed for. There is, however, a body of information on American Indian views of the natural world. According to this literature, people and the biophysical world are viewed as interconnected and forming part of one integrated system in which each thing (e.g., animal, plant, mineral) affects everything else (Jostad et al., 1996). Generally speaking, it is important to maintain the balance of this system, a perspective that is similar in several respects to systems theory in modern ecology (Pierotti and Wildcat, 2000). The spiritual and sacred values associated with forests are held to be important, and there is a belief in respecting and caring for the natural world (Jostad et al., 1996; Kimmerer, 2000; Bengston, 2004). Kimmerer (2000) characterizes American Indian views of biodiversity as encompassing human and nonhuman entities (which can include plants, animals, minerals, and landscape features), their spiritual consciousness, and the web of reciprocal relations that exist between them. A nationwide analysis of news articles about natural resource management written by American Indians and published in American Indian newspapers and magazines found that a holistic, ecosystem-based view has long prevailed about the management of forests and their resources—a view that is consistent with the ecosystems approach to forest management that emerged in the 1990s (Bengston, 2004).

In addition to a systemic view of nature, many American Indians view active human manipulation as necessary for maintaining the ecological integrity of forests. For example, the idea that human use and tending of plants ensures their abundance and quality is pervasive, creating a reciprocal relationship between plants and people (Anderson, 1993, 2005). In many cases there is a related belief that natural resources should be used or they might not return. Sustainable use is a way of honoring the earth's gifts; if these gifts are not used, they might not be offered again (Jostad et al., 1996).

2.2. *Family forest owners*

The state of our understanding of family forest owners' views of biodiversity in the Pacific Northwest is similarly sparse. There are a few studies that explore owners' views on topics that can be considered surrogates for biodiversity—for example, wildlife habitat, forest health, riparian quality, and ecosystem management (Hairston-Strang and Adams, 1997; Wright, 2000; Creighton et al., 2002; Rickenbach and Reed, 2002). These and studies conducted elsewhere in the U.S. (e.g., Brunson et al., 1996; Jacobson, 2002; Dutcher et al., 2004; Belin et al., 2005), suggest that family forest owners are aware of aspects of biodiversity – including species diversity, structural diversity, ecological time scales, and landscape context – and may be predisposed to developing local knowledge.

In a study of family forest owners in one watershed in the Willamette Valley, Oregon, Fischer and Bliss (2006) found that the owners in their sample were knowledgeable about the concept of biodiversity and believed that they should steward the biodiversity of their forests through management. However, their notion of biodiversity appeared to be quite generic, rather than specific to the native ecotype of their lands. Some owners, for example, saw diversity in brush-filled regenerating clear-cuts, while others saw diversity in mature stands of mixed conifers and hardwoods. Insofar as they recognized diversity of species, structures, and scales, the owners in the study viewed biodiversity in much the same way as conservation biologists. However, they implemented their knowledge of biodiversity differently. They promoted species richness at the expense of evenness, marginalizing ecotype-associated forms of biodiversity. The Fischer and Bliss (2006) study illustrates the importance of understanding the context of owners' LEK; owners that manage production forests may operate with different assumptions about biodiversity than owners managing for mature native forests that provide aesthetic enjoyment.

As with American Indians, family forest owners do not believe that management interferes with the ''naturalness'' of their forests; rather, they believe their forests are better off because of their interventions. In their view, management is not an interruption to the course that forests follow in their evolution; it is a helpful, guiding force.

2.3. *Commercial nontimber forest product harvesters*

There is little in the way of literature that documents commercial NTFP harvester views of biodiversity, and not many commercial harvesters use the term. The general attitude among many harvesters is that more diversity is better when it comes to commercial needs (Jones et al., 2004). Few if any forest industry sectors depend on as many species or have such a diversified economy as that of commercial NTFP harvesting. Often the household economy of commercial harvesters includes the harvest of a diversity of NTFPs (Love et al., 1998; Emery, 2001; Jones and Lynch, 2002). Though most harvest at least a few species, many harvest dozens throughout the year. For example, some harvesters specializing in fungi may pick upwards of fifteen different edible commercial species throughout the Pacific Northwest. In the case of wild seed harvesters the number of species collected can reach into the hundreds (Jones et al., 2004).

With some notable exceptions such as morel mushrooms the year following a forest fire, few commercial NTFP species do well in the wake of major landscape disturbances like clearcutting, road building, and grazing. Many commercial harvesters voice frustration with land managers over disregard for the diversity of NTFPs they are harvesting, often demonstrated by the destruction of species-rich gathering sites resulting from nonharvester activities. Thus, harvesters have a vested interest in diversity, and view managing forests to support a diversity of NTFP species as important.

2.4. *Discussion*

Based on the literature, there are some clear areas of overlap between western forest managers' notions of biodiversity, and those of forest practitioners who are American Indians, family forest owners, and nontimber forest product harvesters in the Pacific Northwest. For example, all appear to favor forest management to support species/population and community/ecosystem-level diversity, and the composition dimension of biodiversity, though the composition desired by each group varies depending on what they value. In addition, all care about and have an interest in forest conservation.

Forest practitioners from the three groups actively use and manipulate forest resources to meet their needs and values. NTFP harvesters generally do not view their harvest activities as being detrimental, and many American Indians and family forest owners hold a belief that forests are better off because of their interventions, and in the case of American Indians, that forests need these interventions to maintain biodiversity. These views contrast sharply with those advocated by some conservation biologists who believe that biodiversity must be protected through preservationist approaches that prohibit resource use and remove humans from the landscape (e.g., Kramer et al., 1997; Oates, 1999; Terborgh, 1999; Terborgh and van Schaik, 2002). These contrasting views imply very different strategies for biodiversity conservation.

3. Forest management practices and their ecological effects

How do forest practitioners in the Pacific Northwest use and manage forests, and how do these practices maintain or restore biodiversity, if they do? American Indian forest use and management practices have been more extensively documented than those of family forest owners and commercial nontimber forest product harvesters.

3.1. American Indians

Most of the literature about American Indians' TEK relating to forest management characterizes how they managed forest resources in prehistoric and historic times, with information on contemporary forest management being much more sparse. The same is true for Canadian First Nations, for whom a fair amount of literature is also available. Authors who write about these past practices believe that they did maintain some components of biodiversity (Boyd, 1999a,b; Peacock and Turner, 2000; Turner et al., 2003; Deur and Turner, 2005a,b; Anderson, 2005). Moreover, some assert that biodiversity was dependent on active environmental management by indigenous peoples, and has declined locally with the disappearance of indigenous management practices (Peacock and Turner, 2000; Anderson, 2005).

Fire was an environmental management tool commonly used by indigenous peoples in California and the Pacific Northwest in the past, although not all tribes used fire and not all environments were shaped by it (Blackburn and Anderson, 1993; Gottesfeld, 1994; Boyd, 1999b). There is substantial historical and ethnographic evidence that prescribed fire was widespread in historic and prehistoric times, but there is little physical evidence of past anthropogenic fire (Lepofsky, 2004). Burning was not limited to California and the Pacific Northwest; indigenous peoples throughout the United States used fire to manipulate and manage the environment (Stewart, 2002; Vale, 2002; Williams, 2003).

Indigenous peoples used fire for many different purposes. The most common use of fire prehistorically and historically related to food production. Burning disrupted forest succession and reduced the dominance of coniferous forests (which were relatively poor in food plant species), maintaining open habitat (such as prairie in coastal forests) where desirable food plants grew (Kimmerer and Lake, 2001). It also created a mosaic of habitat patches in different successional stages, which increased food security by enhancing the diversity of food resources, and creating a buffer against fluctuations in the abundance of individual food species. Burning also increased the abundance and productivity of food plants such as camas (*Camassia* spp.), other bulb and root species, and berries, such as huckleberries (*Vaccinium* spp.) (Gottesfeld, 1994; Boyd, 1999a). In addition, it removed detritus that reduced plant vigor and productivity, recycled nutrients, and stimulated new growth (Anderson, 2005). Fire controlled insects and diseases that damaged important foods like acorns (Boyd, 1999a; Peacock and Turner, 2000; Anderson, 2005). In addition, game such as elk and deer were drawn to burned areas for forage, improving hunting opportunities. Fire was also used to drive game animals during a hunt, and for gathering grasshoppers (Boyd, 1999a; Stewart, 2002).

American Indians and First Nations used fire for other purposes as well. For example, burning increased the abundance and quality of materials used in basketry, such as bear grass (*Xerophyllum tenax*), willow (*Salix* spp.), hazel (*Corylus cornuta*), and redbud (*Cercis occidentalis*) (Anderson, 1993; Ortiz, 1993; Boyd, 1999a). Straight rhizomes and stems without lateral branching are preferred for basketry, and burning enhances these features (Anderson, 1993). Burning also prevented the accumulation of fuel that could lead to catastrophic fires, and was done to create fuel breaks (Stewart, 2002; Boyd, 1999b). By the early 1900s, anthropogenic fire had virtually disappeared from the forests of the western U.S. because non-native settlers believed it was destructive and unsafe, and policies enforced its suppression.

Burning was not the only forest management practice indigenous peoples employed in the Pacific Northwest. Other techniques they used to enhance desirable plant species included planting or broadcasting seeds; transplanting bulbs and other propagules, shrubs, and small trees to make them more abundant and accessible; modifying soils and digging to enhance the growth of root vegetables; removing undesirable plants that competed with valued plants; selective harvesting; pruning or coppicing berry bushes and other shrubs to enhance their productivity and to encourage certain patterns of growth; pruning trees and shrubs near desired plants to reduce competition; rotating harvest locations; and diverting water for irrigation and to reduce erosion (Blackburn and Anderson, 1993; Anderson, 2005; Deur and Turner, 2005a). Although such practices are not as widespread today, many of them persist on a much-reduced scale (Anderson, 2005; Deur and Turner, 2005a; Senos et al., 2006).

By regulating the size, intensity, frequency, and location of anthropogenic disturbances, American Indians and Canadian First Nations are believed to have manipulated biodiversity

(Peacock and Turner, 2000). Indian burning practices influenced forest composition, and the distribution and abundance of many tree and shrub species (Kimmerer and Lake, 2001). These practices set back succession and promoted habitat heterogeneity by maintaining mosaics of vegetation types in different stages of succession. Burning and other vegetation management practices also multiplied the presence of ecotones (Lewis, 1993; Turner et al., 2003). Several researchers believe that habitat and species diversity were maintained as a result (Boyd, 1999b; Peacock and Turner, 2000; Turner et al., 2003; Deur and Turner, 2005a,b; Anderson, 2005). Others note that the effects of indigenous burning must be understood within the context of how climate and natural disturbance processes affected vegetation conditions, which may not be distinguishable, at least for prehistoric times (Whitlock and Knox, 2002).

Some American Indians having reservation lands in the Pacific Northwest also engage in commercial timber production, which took hold there in the late 1800s (McQuillan, 2001). Throughout most of the 20th century, timber production on reservation lands in the Pacific Northwest was largely controlled by the Department of the Interior, Bureau of Indian Affairs (BIA) and therefore governed by federal laws and regulations, influenced by evolving concepts of professional forestry, and mirrored forestry practices on public lands. There was little unique or culturally distinct about it (IFMAT, 1993; McQuillan, 2001).

Following the Indian Self-Determination and Education Assistance Act of 1975, many tribes established their own forestry operations and natural resource management staffs. There has been a major transition over the past decade from BIA to tribal control of and responsibility for forest management. It is unclear from the literature whether traditional and local ecological knowledge have played a more prominent role as a result. According to IFMAT (2003), American Indian groups having a greater degree of control have forests and forest management practices that are better aligned with their own management goals and vision. Although tribes have their own individual goals for forest management, common themes include a priority on protecting forest resources including water quality and quantity, valuing the scenic beauty of forests, and a desire to pursue sustainable forest management in an integrated way that supports multiple uses and values. Actual forest management practices have not always been consistent with these values, however (IFMAT, 1993, 2003). In some places, timber harvesting has caused a simplification of stand structure and loss of species resulting from even-aged harvest practices, and old-growth forest habitat has been lost from some landscapes (IFMAT, 1993). Elsewhere, tribes like the Confederated Tribes of Warm Springs in Oregon have received Forest Stewardship Council certification, signifying socially, economically, and ecologically sustainable forestry practices.

3.2. Family forest owners

Family forest owners commonly hold multiple management objectives for their forest lands, ranging from wildlife habitat, scenic views, and recreation to long-term investment and timber income (Bliss and Martin, 1989; Clawson, 1989; Huntsinger and Fortmann, 1990; Johnson et al., 1997). Their objectives vary with ownership size (Huntsinger and Fortmann, 1990; Sampson and DeCoster, 1997), length of tenure, age, income level, and residence on the property (Ostrum, 1985). They typically prioritize amenity objectives over timber production (Huntsinger and Fortmann, 1990; Jones et al., 1995; Brunson et al., 1996), yet the opportunity to harvest timber for income remains important (Johnson et al., 1999). Past research has indicated that most commercial timber on family forest lands eventually is harvested because of changes in ownership, market prices, and owner objectives (Carpenter, 1985; G. Lettman, personal communication, January 2002). However, the effects of recent trends in owner objectives on harvest practices have not been explored in the literature. A survey of family forest owners in Washington state characterized the management practices of over 50% of owners as agroforestry (a combination of livestock grazing, windbreaks, special forest product harvesting, forage production, and orchard intercropping) that many said increases biological diversity (Lawrence et al., 1992).

Family forest owners use their local ecological knowledge to manage biodiversity in several ways. They experiment with planting patterns to foster favored wildlife species and view qualities, and to explore new species arrangements. For many, diversity indicates a healthy forest. To achieve this diversity, they cultivate a variety of native species in addition to the primary commercial species on their tree farms (Fischer and Bliss, 2006). Owners are also known to set aside stands of hardwoods, brushy areas, and wide riparian corridors instead of converting them to plantations (Jacobson, 2002; Dutcher et al., 2004; Fischer and Bliss, 2006). In Oregon, some owners have used prescribed fire to reduce fuels and control invasive species, mimicking historic disturbance processes (Stanfield et al., 2003; Fischer, 2005).

Although little research has been done on the direct impacts of family forestry on biodiversity, one landscape analysis conducted in Oregon suggests that family forest owners may enhance forest habitat diversity (Stanfield et al., 2003). The study found that nonindustrial private ownerships provide a mixture of young to medium-aged conifer stands, extensive hardwood stands, and a high proportion of nonforest land including meadows and fallow fields. This mixture contributes ecological diversity to landscapes otherwise dominated by conifer plantations on private industrial forest lands, and maturing stands of Douglas fir on public lands (Bliss, 2003).

3.3. Commercial nontimber forest product harvesters

Commercial harvesters have an economic incentive to investigate, understand, and practice sustainable harvesting (Love and Jones, 2001; Jones and Lynch, 2002). There is clearly a strong interest among many harvesters in learning about how resource stewardship can sustain their livelihoods. Many harvesters attempt to steward the resources they harvest through behaviors such as: (1) engaging in productivity experiments by trying different harvest techniques, spreading seeds and relocating plants, and watering; (2) monitoring environmental change through observation, writing, photography, mapping, and videotaping; (3) treading lightly in harvest areas; and (4) imposing harvest level restrictions on themselves (Love et al., 1998; Jones and Lynch, 2002).

One example of how harvesters use their knowledge for biodiversity conservation and stewardship comes from the wild mushroom arena. Though studies suggest harvesting mushrooms is generally akin to picking fruit and unlikely to negatively impact productivity (Arora, 1999; Pilz et al., 2004), many harvesters nonetheless observe a number of informal rules about how to harvest. For example, harvesters who regularly return to patches of mycorrhizal mushrooms like chanterelles (*Cantharellus formosus)* and boletes (*Boletus edulis*) often visit their patches numerous times before, during, and after a season to check their conditions and the conditions of the surrounding habitat (McLain, 2000; Love and Jones, 2001). Though they lack the knowledge and power to stop clearcuts, thinnings, burning, and spraying which can harm or destroy their patches, they often exercise restraint in harvesting until they feel the conditions are suitable. For instance, small mushrooms will be left to grow larger, and some large mushrooms may be left in a patch on the chance they may increase productivity (Love et al., 1998).

Among floral green harvesters on the Olympic Peninsula, Ballard (2004) and Ballard and Huntsinger (2006) found that harvesters with less than 8 years of experience described more intensive harvest practices than more experienced harvesters. Furthermore, the more experienced harvesters managed their patches for multiple species to maintain year-round harvesting options and a diversified income. They also practiced resource rotation, leaving some areas to lie fallow and recover for future harvests. Lastly, Ballard found that more experienced harvesters showed understanding of and interest in the concept of succession management, whereby silvicultural practices are implemented that simultaneously achieve timber production goals while producing quality harvestable salal and other floral greens at various stages.

Little research has been conducted on the ecological effects of commercial NTFP harvest practices (Ballard, 2004 is one exception). Harvesting is non-mechanized for most NTFPs, and is generally considered low impact for many species. An exception might be mosses, some of which have longer regeneration rates than most other NTFP species (Peck, 2006). Nonetheless, unlike nearly all forms of timber extraction, NTFP extraction impacts are often confined to the species being harvested, with seemingly low impact on the diversity of other ecosystem species. Additional research is needed to understand whether and how harvester practices – like productivity experiments – increase the abundance of species being harvested, and improve the overall ecological habitat and biodiversity of harvest areas.

3.4. Discussion

Forest practitioners are applying traditional and local ecological knowledge as they use and manage Pacific Northwest forests. The extent of this knowledge and its use is not well known, however, because research documenting the contemporary forest management practices of forest practitioners is limited. Even more limited is documentation of the ecological outcomes of these practices, which are often assumed to maintain biodiversity despite a lack of scientific evidence, and without careful scrutiny of issues like scale, and which components of biodiversity are being maintained (e.g., ecosystem structure, function, composition; genes, populations, species, communities, ecosystems). Although the causal relationship between culturally diverse forest management practices and biodiversity may well be a positive one, this relationship has not yet been adequately assessed in the Pacific Northwest.

4. Challenges to integrating traditional and local ecological knowledge into biodiversity conservation

Integrating TEK and LEK into forest biodiversity conservation will be difficult if this knowledge does not persist and flourish. As evidenced by the literature, considerably more information is available about TEK for forest management from historic and prehistoric times than for contemporary TEK and LEK. This finding is partly attributable to the fact that many social, economic, and political factors have constrained its use. In the case of American Indians, loss of access to traditional land and resource use areas, and the prohibition of indigenous forest management practices assumed to be destructive (like burning) have reduced opportunities to implement TEK (Anderson, 2005). Tribes having reservation lands are in a stronger position in this regard, but many American Indian groups do not have a land base, and therefore depend on public and other private lands to obtain the forest resources they need. Ecological change resulting from the cessation of traditional forest management practices, habitat conversion, commercial timber production, and grazing have meant that the forest resources upon which many social, economic, and cultural practices were based have declined (London, 2002; Anderson, 2005; Deur and Turner, 2005a). As forest resources, access to them, and rights to manage them diminish, so does the TEK associated with these resources.

Family forest owners own the forest lands they manage. Tenure security provides an opportunity for them to develop and apply experiential knowledge by experimenting with different practices and conditions in their forests. Nevertheless, family forest owners are subject to regulations and policy requirements, and are the targets of mixed messages about how they should be managing their forests (Sampson and DeCoster, 1997), which affect their ability to use local ecological knowledge. For example, family forest owners have been the targets of conflicting assistance programs. In an attempt to increase production, programs such as the Forestry Incentives Program have sought to help family forest owners reforest and improve the stands on their properties. Because of the ecological importance of family forests, programs have also tried to help owners improve habitat and ecological processes through financial and technical assistance, as in the Forest Stewardship Program and companion Stewardship Incentives

Program (Sampson and DeCoster, 1997). At the same time, land-grant university extension foresters, agency foresters, and family forest interest groups often promote Douglas fir (*Pseudotsuga menziesii*) plantation management through their programs (Sampson and DeCoster, 1997; Best and Wayburn, 2001), sometimes at the expense of native biodiversity (Fischer and Bliss, 2006). All of these programs try to influence the way in which family forest owners manage their forests. How these influences affect the use of local ecological knowledge is unknown.

Economic pressures also affect family forest owners' management practices. In particular, the decline of large-dimension timber harvesting from federal lands and the globalization of the forest products industry have caused processors to retool for smaller-diameter timber (Best and Wayburn, 2001; Bliss, 2003). Family forest owners now face limited markets for small quantities of logs of diverse sizes and species. As a result, they are under more pressure to grow timber in plantations on short rotations, which are less biodiverse.

A few commercial NTFP harvesters own their own forest land, but most do not. If they do own or rent land it is rarely enough to sustain commercial harvesting. Thus, harvesters are highly dependent on federal and state lands and large private lands, though it is difficult to negotiate access to the latter. Consequently, harvesters are limited in how much they are allowed to manage, and how much experimentation they can conduct on lands they do not own. With insecure tenure, the management practices they do implement may be rendered ineffective by others who also harvest nontimber forest products in the same locations.

A management trend over the last decade that is most likely affecting harvester populations and their ability to use LEK is that public and private lands have both been decreasing harvester access through gates, permits, and other means (McLain, 2000; Lynch and McLain, 2003). This can have the effect of concentrating harvesters into smaller areas of forests, and cause harvesters to abandon stewardship and conservation practices intended to improve harvest levels. Those harvesters who do not wish to abandon these practices will settle for smaller quantities, or simply stop harvesting in an area altogether if it is not economically possible to sustain themselves. In fact, although no economic monitoring is done on the status of NTFP industries in the Pacific Northwest, many NTFP businesses have collapsed over the years resulting in fewer commercial harvesters, less diversity of products, and smaller quantities of NTFPs being removed. Such conditions make it difficult to implement local ecological knowledge for managing NTFPs. However, interest in NTFPs remains strong and management for their productivity, together with the creation of more economically favorable harvesting conditions, would likely see this trend reversed.

5. Applying traditional and local ecological knowledge to biodiversity conservation

Traditional and local ecological knowledge for forest management in the Pacific Northwest has been poorly documented, and is difficult to implement because of numerous social, economic, and political constraints. Because this knowledge is valuable and in some cases, eroding, some researchers believe it should be documented and stored (see Agrawal, 1995). Some forest practitioners are reluctant to share their knowledge, however because of concern that others will not use it responsibly or in a manner that benefits the knowledge holders, and there are concerns over intellectual property rights (Posey and Dutfield, 1996). It also takes time to understand the knowledge, practices, and beliefs that comprise the systems of ecological knowledge maintained by others in order to represent it adequately, requiring long-term research (Sillitoe, 1998). Moreover, such accounts are rarely framed in a manner that addresses scientific questions relating to forest management. Also problematic are the facts that by nature, traditional and local ecological knowledge are (a) dynamic and change over time, (b) locally specific, and (c) dependent on a specific cultural context that gives them meaning (Agrawal, 1995; Sillitoe, 1998). Consequently, documenting this knowledge, storing it, and relying on it as a data source for forest biodiversity conservation may be problematic because it can become stagnant and irrelevant over time, and lose meaning out of context.

Furthermore, TEK and LEK are not easy to generalize at different scales or at widely varying locations (Agrawal, 1995; Sillitoe, 1998). Trying to gain access to them in written form and treating them as a set of technical facts to be applied to forest management problems elsewhere is inappropriate. TEK and LEK are more than an empirical stock of information, procedures, and blueprints that can be inventoried, packaged, and transferred from one place or group to another (Ellen and Harris, 2000; Ingold, 2004). They include the skills and range of strategies people draw on to address the environmental circumstances they find themselves in – which may call for adjusting procedures and adapting knowledge – because resource management is an interactive process. TEK and LEK are applied by combining the knowledge and skills that are a product of a forest practitioner's cultural history and learning, and expressing them in the context of prevailing environmental circumstances currently affecting resource use and management (Ingold, 2004). There is value in recording and documenting this knowledge to capture and help restore the cultural heritage of forest practitioners, but there may be limitations on applying the TEK and LEK found in scientific journal articles, books, newsletters, and other written formats on the ground.

Integrating TEK and LEK into forest biodiversity conservation is most likely to be successful if forest practitioners are directly engaged as active participants in these efforts. The form that this engagement takes may vary considerably, and is subject to negotiation (Sillitoe, 1998). It will also depend on how forest practitioners share and communicate their knowledge. TEK and LEK are typically transmitted through oral rather than written communication, through demonstrations, and through shared experiences. We discuss models of knowledge integration for biodiversity conservation currently being tried to identify approaches that hold promise, detailing examples for each of the three groups of focus in this paper.

5.1. American Indians

We identified five models of knowledge integration from the literature on American Indian TEK: collaborative species-specific management, comanagement for landscape-scale ecological restoration, integrated scientific panels, formal institutional liaisons, and ecological modeling. For additional models and examples that demonstrate the use of TEK in ecological restoration projects in the Pacific Northwest, see Senos et al. (2006).

Collaborative species-specific management between American Indians and other forest managers occurs when they work together to actively integrate TEK into forest management to protect or restore certain species having cultural or economic value to American Indians. In most of the cases from the Pacific Northwest, this kind of collaboration has occurred between tribal members, western scientists, and forest managers who work together and combine their knowledge to manage species on public lands.

Beargrass (*Xerophyllum tenax,* an important basketry material) restoration on the Olympic Peninsula provides one example. There, tribal members, forest managers, and University of Washington scientists have collaborated to design and implement treatments on the Olympic National Forest and Quinault Indian reservation that use prescribed fire to restore open-canopied beargrass habitat once maintained by Indian burning practices (Wray and Anderson, 2003; Shebitz, 2005). Traditional land management practices based on TEK about historic landscape structure and burning techniques (i.e., the season, frequency, and intensity of the burn) have been introduced. Elsewhere, fuel specialists, timber planners, and cultural resource managers have collaborated with California Indian basket weavers to design prescribed burns that enhance beargrass and other important basketry plants on national forests in northern California (Ortiz, 1993; Anderson, 2005). These projects have been motivated by a desire to restore species having cultural value to American Indians, and in the process restore habitat types and associated species that have declined in the absence of fires.

Comanagement occurs when local resource users establish a formal, power-sharing partnership with the state that enables them to assume an active role in, and share responsibility for, resource management and decision-making (Stevenson, 2006). One example of a comanagement project is the Maidu Stewardship Project in northern California (formalized under a stewardship contract between the U.S. Forest Service and the Maidu Cultural and Development Group). There, the Maidu have been given authority to apply traditional forest management practices – including burning, tilling, pruning, and selective harvesting – to restore about 2000 acres of national forest land to pre-European settlement conditions (Little, 2002; London, 2002; Thompson, 2006). TEK is supposed to be used in the analysis, planning, and implementation of forest management projects (London, 2002).

Integrated scientific panels are formal panels having a mix of western scientists and indigenous peoples holding TEK who work together to jointly address specific resource management problems by undertaking activities like analyzing existing data and developing recommendations for how to manage natural resources. The Scientific Panel for Sustainable Forest Practices in Clayoquot Sound, Canada (located off the west coast of Vancouver Island, British Columbia) provides one example of this model (Ministry of Sustainable Resource Management, 2004; Mabee and Hoberg, 2006). In response to controversy over harvesting old-growth forests, the Panel – which consisted of natural scientists and First Nations elders – reviewed forest management standards in Clayoquot Sound. It developed new standards and recommendations for sustainable forest management in the region based on a combination of traditional ecological and western scientific knowledge which were subsequently adopted, including creation of a comanagement body composed of the Province of British Columbia and Nuu-chah-nulth for natural resources.

Formal institutional liaisons are institutions that serve as intermediaries between indigenous peoples and others who are interested in their TEK, and would like to learn more about it and its potential for application in natural resource management. These institutions are typically composed of people who represent indigenous groups but who may or may not be members of those groups. They work to transfer TEK and integrate it into natural resource management in socially and culturally appropriate ways. One example is the Indigenous Peoples Restoration Network, whose members work with indigenous nongovernmental organizations and people undertaking ecological restoration projects to promote the appropriate use of TEK in restoration (IPRN, 2006). Although the Network is not based in the Pacific Northwest or solely focused on forest management, it is a model that could be replicated regionally.

Ecological modeling has been proposed as an approach for integrating TEK into management and restoration in national parks (Anderson and Barbour, 2003). This approach combines ethnoecological assessments with ecological modeling to simulate indigenous resource management practices, and field experiments to test the models. The results of the tests can be used to develop management prescriptions for specific places that could be implemented by forest managers, or collaboratively with tribes. We are not aware of any case examples that have implemented this approach.

5.2. Family forest owners

Few prominent examples of cooperation between family forest owners, scientists, and other land managers exist to serve as models for integrating their local ecological knowledge in biodiversity conservation efforts (Knight and Landres, 1998; Rickenbach and Reed, 2002). While recent research suggests that cooperatives may provide an appropriate infrastructure for cooperation based on owners' values (Campbell and Kittredge, 1996; Rickenbach et al., 2005; Rickenbach et al., 2006), it is too early to tell whether they could serve as models for knowledge integration because factors underlying owners' decisions to participate are still not well understood. Family forest interest groups such as the Oregon Small Woodlands Association currently serve as forums for cooperation and knowledge sharing among family forest owners. Unfortunately, studies have not examined the utility of such forums for cooperation between owners and other groups. Nor have studies examined factors in owners' willingness to participate.

Watershed councils have brought owners, scientists, environmentalists, and other public and private land managers together in ecosystem management efforts, most notably in Oregon as a result of the Oregon Plan for Salmon and Watersheds (Rickenbach and Reed, 2002). Studies suggest a number of factors in watershed councils' ability to engage family forest owners. Habron (1999) found that owners' perceptions of watershed councils' ability to reduce bureaucracy, enhance communication and understanding, and build local capacity are central factors in their attitudes toward watershed councils. Cheng (1999) suggests the perception that other members share owners' sense of place is important. Rickenbach and Reed (2002) assert that owners' perceptions that other members share their stewardship ethics, concerns about property rights, and preferences for an action orientation determine their willingness to join watershed councils. However, the newness of watershed councils has limited owners' willingness to participate, and, in turn, researchers' abilities to assess their usefulness for knowledge sharing.

Conservation efforts facilitated by land grant university extension programs hold the potential to serve as models for cooperation and sharing LEK. For example, the Willamette Valley Ponderosa Pine Conservation Association (WVPPCA) – founded in 1994 by a land-grant university forestry extension program, timber companies, and family forest owners – has helped to reestablish the historic range and genetic diversity of the Willamette Valley race of the ponderosa pine (*Pinus ponderosa*) by planting millions of seedlings each year for conservation and timber production. LEK is developed through experiential learning based on landowner trials with growing the pine. Their knowledge of what works and what does not is shared with other members of the organization. The WVPPCA has not focused on recreating the range of conditions that were characteristic of the habitat type; instead it has worked with family forest owners to integrate ponderosa pines into their individual management approaches (R. Fletcher, personal communication, 2006). As a result, the program's value for biodiversity conservation remains to be seen. Nevertheless, the WVPPCA provides an important lesson for the integration of local ecological knowledge. It has encouraged owners to plant an unfamiliar species having almost no present market value for long-term conservation and economic gain, building on the dual goals family forest owners have of biodiversity protection in a manner that incorporates utilitarian production values. Organizers attribute the project's success to two things: its peer-to-peer approach of linking forest owners with each other through tours, experimental trials, and meetings; and its flexibility to work within the framework of owners' existing goals and practices (R. Fletcher, personal communication, 2006).

While cooperatives, interest groups, watershed councils, and efforts such as the WVPPCA can serve as examples for cooperation, their utility for integrating local ecological knowledge into biodiversity conservation is unclear. More research is needed on the factors in owners' willingness to participate and share knowledge before these examples should be viewed as models for knowledge integration. The current scarcity of models for cooperative knowledge sharing may be explained by owners' history of engaging in independent decision-making (Sample, 1994); managing and marketing their products independently (Rickenbach et al., 2005); prioritizing privacy (Finley et al., 2006); and practicing forestry by themselves or with neighbors rather than outsiders, even in cross-boundary planning efforts (Jacobson, 2002). Nevertheless, some family forest owners are willing to cooperate with each other (Jacobson, 2002; Finley et al., 2006). Although these characteristics may reveal a tendency to not get involved in collaborative groups (which can work against knowledge sharing), they may also be indicative of other constraining factors. For example, Rickenbach et al. (2006) suggest that the reason owners manage and market their products independently is that other alternatives are largely absent.

5.3. Nontimber forest product harvesters

In the last decade a movement has begun to promote more participatory approaches in forestry. Participatory research, citizen science, and collaborative conservation are participatory approaches that have had excellent success in other sectors such as fisheries and water quality monitoring (Pilz et al., 2006). As workshops and research indicate, commercial NTFP harvesters are in many ways an ideal group to involve in participatory research such as biological inventory and monitoring (Lynch et al., 2004; Ballard et al., 2005; Ballard and Huntsinger, 2006). Participatory research and monitoring hold promise as models for knowledge sharing and integration between commercial NTFP harvesters and others. In participatory research and monitoring, western scientists, land managers, and harvesters work together to gather data about NTFPs and their ecological relationships, and management impacts on them. The participants offer their own interpretations of the data, theories relating to findings and trends, and management solutions. Through direct interaction in the research and monitoring process, LEK is shared and integrated into forest management.

An example of a participatory research project that facilitated knowledge exchange comes from Ballard (2004) and Ballard and Huntsinger (2006) who conducted a 2-year study of salal (*Gaultheria shallon*) harvesting impacts on the Olympic Peninsula in Washington state. Ballard started by developing relationships with local harvesters, who helped define the research question: How do different harvest intensities affect salal regrowth and sustainability? The harvesters helped select the study site, develop methods for measuring plant regrowth in relation to commercial harvest, and collect, weigh, measure, and record the data with the researcher. The harvesters were Latino, many with limited English, and many of whom were migrant workers. Harvesters were paid US$ 10–12 per hour, an amount slightly higher than they made picking salal. They spent from 2 to 8 hours per day, for a varying number of days, collecting and recording data with the ecologist. Several U.S. Forest Service technicians from the Olympic National Forest were also trained to collect data, often in teams with the harvesters, facilitating cooperation and co-learning between participants.

Harvesters had neither the expertise nor the desire to conduct a statistical analysis of the data, so the researcher compiled the results. Harvesters did meet with the researcher to offer their interpretations of the data, which were presented as large bar graphs showing harvest yield results. With instructions on how to read bar graphs and harvesters who served as Spanish translators, harvesters discussed in small groups why some results differed from their hypotheses, why sites responded differently to the same harvest treatments, and how the results could be used for management recommendations. This participatory process resulted in a project that both integrated western scientific and local ecological knowledge, and addressed management questions important to harvesters and land managers, an outcome that could not have been achieved by ecologists alone (Ballard et al., 2005; Ballard and Huntsinger, 2006). As this case demonstrates, participatory monitoring could also involve harvesters in project design, data collection, and analysis.

5.4. Discussion

What most of the models described here share in common is an approach that actively engages forest practitioners, western scientists, and forest managers in on-the-ground projects that encourage interaction and knowledge sharing in the process of identifying goals, designing approaches, and implementing projects for forest management to conserve biodiversity. Knowledge sharing may occur in formal or informal ways, but by working together and sharing ideas, management approaches emerge that integrate different forms of knowledge.

Two things needed to make such efforts successful are understanding the communication and operating styles of the people that hold TEK and LEK, and establishing a foundation of trust to work from. The communication and operating styles of forest practitioners may be quite different from those of western scientists and agency forest managers, with lack of sociocultural understanding between groups creating a potential barrier to understanding these different styles. In the case of the Maidu Stewardship Project for example, Forest Service bureaucratic processes – such as contracting and reporting requirements, timelines, budgets, and business plans – have been difficult for the Maidu to comply with, creating a barrier to comanagement (Little, 2002). People trained in ethnographic methods, facilitation, and who have established relationships with the forest practitioners involved in such efforts may be well equipped to help out.

Respecting others' knowledge and using it in appropriate ways is critical for trust- building. There are examples in which TEK and LEK have been shared with public land managers, and then misused or disregarded, to the detriment of the knowledge holders (London, 2002; R. McLain, personal communication, 2006). This undermines trust and makes it unlikely that people will share their knowledge again in the future. Lack of trust also stems from a history of forest management policies and practices on public lands that have made it difficult for some forest practitioners to obtain the resources they depend on for their livelihoods. For example, NTFP harvesters, who generally lack the power and organization to protest disadvantageous policies, may instead avoid forest managers and scientists, which works against knowledge integration.

We present different models of knowledge integration for each group of forest practitioner as a reflection of the available literature, and do not imply that the models are only suitable to the group for which it was discussed. Most models would work equally well for a number of different groups. For example, participatory research and monitoring could include diverse groups of forest practitioners, as could collaborative species-specific management, comanagement for ecosystem restoration, and integrated scientific panels. The appropriateness of the models to particular groups may be influenced by land ownership, however.

6. Conclusions

By defining the scope of our synthesis to include both TEK and LEK, and forest practitioners from three different groups, we emphasize the point that many different people use and manage forests—be it on private lands they own or have access to, reservation lands, or public lands. It is worth identifying who is actively engaged in local forest use and investigating the ecological knowledge they hold. To date, most of the literature on TEK and LEK from around the world has focused on indigenous peoples and farmers. Their ecological knowledge is valuable, but so too is that of other forest practitioners, who should not be overlooked.

Different groups conceptualize biodiversity differently, though there are some areas of overlap between western scientific notions and those of Pacific Northwest indigenous peoples, family forest owners, and NTFP harvesters; and, all share an interest in forest conservation. Where views about biodiversity and how to approach its conservation diverge, it is important to understand how differences can be reconciled to find common biodiversity conservation goals that people are willing to collaborate to achieve.

TEK and LEK persist, develop, and flourish through application. Yet they cannot be implemented if forest practitioners lack access to and some control over forest resources, or face economic and policy constraints that inhibit their use. Thus, serious efforts to integrate other knowledge systems for biodiversity conservation must be about more than finding the right or best models for knowledge sharing and application. They must also address fundamental structural issues – such as land tenure, the imposition of unfavorable forest management practices and policies, and market conditions – that threaten to undermine the viability of these knowledge systems and their implementation in diverse forest landscapes.

It is also important to assess how well the kinds of models for integrating TEK and LEK into forest management discussed here are working, and to continue experimenting with new models, being sensitive to which are best suited for different groups. Few models and examples exist for groups other than American Indians, and those described in the literature lack assessments of how well TEK and LEK were actually integrated in forest management; what made for success or lack thereof in knowledge sharing and application; and what difference including TEK and LEK made on the ground.

Knowledge integration is impossible unless forest practitioners are willing to share their knowledge with western scientists and forest managers. They are unlikely to do so unless it is in their interest; thus, identifying incentives for, and mutual benefits from, knowledge sharing are important. For example, many harvesters would welcome the opportunity to have sustained access to resources, especially forms of access that afford some protection such as zoning, stewardship contracts, or small leases allowing them to steward a harvest area for an extended period of time. Institutionalizing commercial harvester relationships with forest management could help facilitate interactions and trust building that would lay the foundation for sharing knowledge. For family forest owners, working with scientists, natural resource agencies, and other landowners may help protect species before they become threatened or endangered, safeguarding owners from future regulation under the Endangered Species Act. And, owners may be able to make biodiversity conservation efforts more sensitive to their interests by participating with other stakeholders. For American Indians, engaging in forest management on federal lands provides an opportunity to manage for and enhance the nontimber forest species and habitat types that have economic and cultural importance to them.

Active forest management for diverse objectives and products may maintain and restore biodiversity. Several researchers (see Maffi, 2005, for a review) assert that cultural diversity and biodiversity are linked, and that these links provide an opportunity for conservation. Biodiversity supports a broad range of cultural practices and adaptations, which in turn create demand for, and forest management to maintain, a broad range of species. This synthesis obscures the cultural diversity that lies within broad categories of forest practitioners. To fully understand and appreciate the links between cultural diversity and biodiversity, it is necessary to look at the multiplicity of knowledge, practice, and belief systems held within cultural groups, and how they are expressed on the landscape. It is also necessary to examine their outcomes in order to address the question of whether active forest management for a broad range of species having economic and cultural value to a diverse group of forest practitioners can do more for biodiversity conservation than a hands-off, preservationist approach that seeks to recreate ''natural'' forest landscapes, as opposed to biocultural forest landscapes.

Research to improve understanding and documentation of existing traditional and local ecological knowledge for forest management is needed for the three groups discussed in this paper, as well as others. Such research should do more than describe ecological knowledge systems; it should examine how this knowledge is being actively implemented and with what ecological outcomes, to understand how it might contribute to biodiversity conservation. Equally important is to expand efforts to engage local forest practitioners in joint forest management, for it is through practical application that this knowledge emerges and comes to life, and can be shared in an ongoing, interactive, and meaningful way.

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