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## **Integrating Traditional Ecological Knowledge with Western Science for Optimal Natural Resource Management**

Serra Jeanette Hoagland  
Liaison officer, Biologist, PhD

Traditional ecological knowledge (TEK) has been recognized within indigenous communities for millennia; however, traditional ecological knowledge has received growing attention within the western science (WS) paradigm over the past twenty-five years. Federal agencies, national organizations, and university programs dedicated to natural resource management are beginning to realize the critical need to incorporate different ways of knowing into their natural resource management decisions. Furthermore, Native American tribes on a national scale are assuming greater leadership through self-determination and self-governance and continue to serve as models for sustainable forestry and resource management by incorporating components such as traditional ecological knowledge, community support for integrated resource management plans, and a holistic, dedicated, long-term vision for the environment. This paper reviews recent literature on the integration of TEK and WS and proposes a dualism theory for conservation in the twenty-first century where TEK and WS are applied equally in natural resource management.

*Keywords: Traditional Ecological Knowledge; Western Science; Environment; Natural Resource Management; Native Americans*

The planet is in immense ecological stress and human societies currently face unprecedented challenges such as climate change, species extinctions, pollution, and deforestation, to name a few (Travis 2003; Bellard et al. 2002; Hu 2014). Natural ecosystems are being altered beyond their capacity and the dynamic ecological patterns and processes that have been created over the last 4.6 billion years are now at risk. Green infrastructure, ecological conservation, carbon sequestration, carbon emission reduction projects, ecological restoration, and other technologies have been implemented to mitigate the global ecological crisis we face. However, there is a fundamental, missing piece that is severely underutilized and considered in our dire state. It involves a very basic concept of combining traditional ecological knowledge and indigenous worldviews with modern western science to create environmentally sustainable solutions. The wealth of knowledge about the local environment within tribal communities is vast and diverse. It has developed over thousands of years and been passed down through a multitude of generations in oral teachings (Berkes, Colding, and Folke 2000). Traditional

ecological knowledge complements western science and is increasingly being recognized by natural resource managers and scientists throughout the world (Trosper and Parrotta 2012; Menzies and Butler 2006). On the other hand, western science can be credited for numerous innovations and technological advances in fields ranging from engineering to medicine to natural resource management. Combined, these two knowledge sources may provide powerful solutions to our most dynamic and complex environmental problems.

I will focus on the indigenous peoples of Canada and the United States throughout this paper. It will critically evaluate traditional ecological knowledge and western science by comparing and contrasting the two paradigms and discuss how the different paradigms inform decision making and implementation of natural resource management actions. I will provide recommendations for integrating both knowledge systems to achieve sustainable natural resource management actions and reinvigorate the Wampum Theory. The Wampum Theory recognizes two distinct worldviews and cultures working in harmony, and comes from concepts I borrowed from Mason et al. (2012) and Ransom and Ettenger (2001). The Wampum Theory, applied in natural resource management, includes an equitable, complementary balance between two different paradigms: western science and traditional ecological knowledge.

This paper also discusses traditional ecological knowledge and tribal natural resource management simply because texts, reviews, and analysis regarding traditional ecological knowledge are less common than western science applications in the primary literature. This emphasis does not indicate superiority of one paradigm over the other. It simply provides more review and substantial evidence to support the notions of incorporating traditional ecological knowledge and western science in natural resource management fields. I acknowledge that western science is further along in its published documentation and development for incorporation into natural resource management than traditional ecological knowledge. The intent of this paper is not to review western science but rather review how western science and traditional ecological knowledge can be complementary.

### **Definitions of Traditional Ecological Knowledge**

There are many definitions of traditional ecological knowledge, but one of the most commonly used definitions, provided by Berkes (1999), states that TEK is “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, and about the relationship of living beings (including humans) with one another and with their environment.” TEK is abstract, qualitative, inclusive, intuitive, diachronic, and is formed from communal knowledge gained over time through practice and application (Gadgil, Berkes, and Folke 1993; Mason et al. 2012). It is traditionally shared through oral accounts, is highly synonymous to adaptive management, and provides a holistic view of managing for multiple resources (Berkes, Colding, and Folke 2000). TEK remains dynamic by allowing knowledge to be updated as new information arrives (Menzies and Butler 2006), and is integrated with information that “cannot be understood in isolation” (Menzies and Butler 2006).

Another broadly accepted definition from Donogue, Thompson, and Bliss (2010) defines TEK as the “reflection of cultural norms and practices that influence how tribal members steward and coexist in natural environments.” TEK is often guided by a land-use ethic held by indigenous people that supports interactions with nature in a respectful manner and in a way that allows for all creatures to coexist (Anderson and Moratto 1996).

TEK is considered a subset of indigenous knowledge and is defined by Menzies and Butler (2006) as “cumulative and long-term, dynamic, historical, local, holistic, embedded, moral, and spiritual.” An example of a traditional ecological knowledge moral attribute is preventing any waste and avoiding greedy use of environmental resources (Menzies 2006). Nelson (1983) discusses the two distinct knowledge systems within TEK. The first, objective and ecological, identifies specific information such as technical animal biology and life histories of particular species. This information is mainly used for resource management. The second is based on the elaborate spiritual “system of supernatural concepts for explaining and manipulating the environment,” which is fundamental to Koyukon survival.

### **Knowledge Transmission**

A simple definition of knowledge transmission is the process or act of transmitting, spreading, or distributing information. An example of indigenous knowledge transmission is described by Basso (1996). Basso humbly explains the important lessons he learned on his second day of working in the field with western Apache people studying and documenting Apache place-names and their significance. Basso mispronounces an Apache place name and, after a few attempts, disregards the importance of saying the words and states to his teacher, “I’ll work on it later.” This is taken as offensive and disrespectful by the Apache teacher, who then says in Apache to the translator:

What he’s doing isn’t right. It’s not good. He seems to be in a hurry. Why is he in a hurry? It’s disrespectful. Our ancestors made this name. They made it just as it is. They made it for a reason. They spoke it first, a long time ago! He’s repeating the speech of our ancestors. He doesn’t know that. Tell him he’s repeating the speech of our ancestors! (Basso 1996)

This highlights several lessons in knowledge transmission for traditional ecological knowledge within indigenous communities. This story emphasizes the importance of patience, respect, and care in applying acquired knowledge. Apache place names are critically important in identifying past conditions and were formed by those who came before us. It is imperative when learning any form of language or TEK to respect the knowledge as it was created and understand the belief that it can still be heard by the original creators. Nelson (1983) also describes other Natives’ complex ability to navigate and understand the landscape, specifically referring to the Koyukon. He defines this as “mental mapping,” that includes hundreds of specific place names known by Koyukon adults and elders. Geographic location information is maintained within the community and is transferred orally or through experience. Knowledge pertaining to western science is typically transmitted through formal education and reading materials created by the research experts, rather than through oral teachings and field-based experiences, such as those listed in Basso (1996) and Nelson (1983).

### **Tribal Natural Resource Management**

Traditional ecological knowledge informs natural resource management with the Gitga’at, an indigenous community of Hartley Bay in British Columbia. This community harvests red laver seaweed for food. The harvesting methods applied by the community can represent and “provide a model for sustainable resource use based on principles of respect, reciprocity, and cooperation” (Menzies and Butler 2006). In this case, as with others, there is a strong human responsibility to care for resources. The indigenous

communities have intricate knowledge of the life cycle, ecology, behavior, and uses for numerous different foods and resources. It only seems logical to look to them for help and information in regards to caring for these resources.

Nelson (1983) provides an extensive overview of Koyukon worldview and traditional practices that influence how the indigenous community in Alaska manages their resources. Koyukon perspective encompasses an all species approach; “no species is too insignificant to be mentioned” (17). In Koyukon territory, each species is associated with a particular role, personality, and certain cultural taboos. Cultural taboos often relate to a species behavior or ecology. For instance, Koyukon people tend to stay away from eating sucker fish because they do not want to inherit certain traits, like thievery, that the animal is thought to possess. In Koyukon tradition, women are prohibited from stepping on, eating, or skinning particular animals such as the wolf. Animals are viewed as very similar to humans and thus are treated with great reverence and respect. The only difference between humans and animals to the Koyukon is that humans have an “eye flutter” (Nelson 1983). In fact, in what is known as “Distant Time” in Koyukon tradition, animals were previously human and they spoke human languages. There was a point in the past where certain animals died and became the animals that exist today. However, the transformation “left a residue of human qualities and personality traits in the north-woods creatures.” These traditions and cultural underpinnings, which define the ways humans interact with animals, are fundamental to their natural resource management practices.

Indigenous perspectives and traditions greatly influence forest management on the Menominee Indian Reservation in Wisconsin (Trosper 2007). Many acknowledge that sustainable forestry, which includes long rotations, single tree selection, and long-term monitoring, originated on the Menominee Indian Reservation (Dockry 2013; Trosper 2007; Gordon et al. 2013). Legislation over one hundred years ago allowed the tribe to self-govern their forest management practices. Some of the Menominee forest management policies that are driven by cultural mandates include the following: an appropriate harvest rate, the use of selection harvests, establishment of a diverse and ample growing stock, long-term monitoring requirements, and a maintenance of forest goals over industrial goals (Trosper 2007). Today the Menominee forest stands as internationally recognized flagship sustainable tribal forestry program and it provides employment for many tribal community members (Hoagland 2012).



*Tribal forest and natural resource managers meeting on the Menominee Indian forest for the Indian Forest Management Assessment Team, III site visit, February 2012.*



*Menominee Tribal Enterprise proudly displays their motto on the side of a truck, “The leader in sustainable forest products for over 100 years.”*



*A tribal employee stands against a pine designated for single tree selection harvest. Uneven, aged silvicultural practices such as these promote forest health and sustainable harvest while providing economic opportunities for the tribe and individual tribal members.*

Additionally, traditional ecological knowledge influences tribal natural resource management by the Salish and Kootenai tribes in Montana. These tribes have “burners” in their society who are tribal fire specialists. They are responsible for knowing fuel conditions and knowing when “to start a fire so that it would produce the desired results” (Mason et al. 2012). When burners stimulate low-intensity forest fires it creates uneven aged conditions and promotes healthy ecological forest conditions that are more indicative of pre-European times (Becker and Corse 1997). In addition to the Salish and Kootenai tribes, many other indigenous cultures see fire as a beneficial tool for maintaining productive, healthy ecosystems (Kimmerer and Lake 2001; Ray, Kolden, and Chapin 2012; Huffman 2013; Stan, Ireland, and Fule 2014).

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### **Non-Tribal Natural Resource Management**

Non-tribal natural resource management decisions are largely based on scientific findings and must often go through a rigorous public review process. In Yaffee's book, *The Wisdom of the Spotted Owl* (1994), he describes that the majority of environmental decision making revolved around lengthy political and bureaucratic processes that attempted to balance federal agencies' mandates for timber harvesting (and local timber-dependent economy's societal needs) with the needs to achieving owl conservation. Once the northern spotted owl was listed as a threatened species, the recommendations regarding forest and owl management were supported by scientific analyses. Non-tribal federal and state agency management decisions are also based on adaptive management principles, which create flexibility in planning so that when new information becomes available implementation plans can be updated accordingly (Grumbine 1994).

One of the failures of modern resource management has been a lack of recognition of the long-term effects on the indigenous peoples (Menzies and Butler 2006). Historically, sustainable practices are supported in non-tribal natural resource management paradigms but often it is at the cost of Native peoples. At the turn of the century, around the 1890s, the government called for selective fishing practices to help recover declining salmon fisheries. However, beginning in 1878, regulations were implemented with the expressed goal of eliminating the live-capture fishing technologies utilized by First Nations peoples. By 1894, First Nations peoples were "prohibited from taking fish by spear, trap, or pen—dip nets were allowed with permission" (Gifford 1989 in Menzies and Butler 2006). This non-tribal, natural resource management decision was a direct act of cultural assimilation when the indigenous sustainable fishing practices became illegal. Additionally, the government prohibited sustainable mushroom harvesting practices used by the First Nations (Rsimshian, Nisga'a, and Gitksan) to allow for more industrialized use of the resource. These non-tribal restrictions hurt the Native people who use these resources.

### **Traditional Ecological Knowledge as a Science**

An interesting perspective provided by Dr. Thomas Alcoze in Cobern and Loving (2000) acknowledges that Native American traditional ecological knowledge can be considered Native science. Alcoze cites how tribes would use various plants for medicinal purposes and that today two hundred pharmaceuticals have been documented with Native American medicinal tradition origins. He continues by commenting that tribes were not publishing in scientific journals, but were in fact practicing science. Others have also noted and commented on the concept of Native science as well (Cajete 1999; Cajete 2004).

Science curricula often "portray science as located within, and exclusively derived from, a western cultural context. The implicit curriculum message is that the only science is western science..." (Hodson 1993; Alcoze 2000). Western science has foundational principles in the scientific method, which generally involves the following steps: observation, developing hypothesis, testing hypothesis, analyzing results, and defining conclusions. It is concrete, quantitative, exclusive, intellectual, reductionist, clinical ("value free"), controlling, and synchronic (short time series and broad generalizations) (Mason et al. 2012 as adapted from Berkes 1993). Knowledge is gained through data collected by researchers and

scientists, then shared through publication. Western science is documented in written format and is not as locally established, created, and defined as traditional ecological knowledge. As Menzies and Butler (2006) explain, WS is “externally formulated, and rarely site specific.” It is also systematic and compartmentalized so that one system is thoroughly researched and explained with little reference to other systems.

### **The Differences in Traditional Ecological Knowledge and Western Science**

A table created by Mason et al. (2012) provides a thorough summary of the differences between traditional ecological knowledge and western science. One important distinction between TEK and WS is that traditional ecological knowledge is rapidly disappearing and many scholars and Native people are concerned about losing traditional ecological knowledge. There is a critical need to capture traditional ecological knowledge from indigenous communities and reinvigorate the knowledge of tribal communities to promote sustainable environmental management. Many indigenous communities have already lost significant amounts of TEK and, overtime, TEK may disappear completely (Tsuji 1996). Some have acknowledged that the loss of traditional ecological knowledge is a result of the rapid loss of Native languages (Saynes-Vásquez et al. 2013). Furthermore, not only is TEK at risk, but the health and livelihoods of indigenous people, who are the bearers of this knowledge, are also at risk due to the numerous environmental and social problems. One such example is the costal indigenous group’s heavy reliance on seaweed as a food source. Since seaweeds absorb heavy metals and other toxic pollutants, they absorb the toxins added to our oceans everyday via pollution. Tribes that rely on this food source are often unable to harvest it due to these toxins. Thus, the cultural traditions revolving around seaweed harvest are slowly disappearing along with the ability to use the resource (Menzies and Butler 2006).

Although there are many differences between the two knowledge systems, there are similarities that should not be overlooked. Both intend to improve our understanding of the world and are based on repeated observations. Menzies and Butler (2006) recognize that traditional ecological knowledge and western science are both a “process of observation, inference, verification, and prediction that is common to both modes of apprehending the ecological systems within which human beings live.” Secondly, both TEK and WS have broad applications in natural resource management (Berkes, Colding, and Folke 2000). However, most of our current management decision making processes are guided by western science (Huntington 2000).

### **Traditional Ecological Knowledge and Western Science Working Together**

Emery et al. (2014) provide a recent example of integrating traditional ecological knowledge with western science. A team of scientists and traditional gatherers associated with the Greater Lakes Indian Fisheries and Wildlife Commission (GLIFWC) partnered together to integrate TEK into birch inventory analysis. This cooperative effort resulted in improved field methods and protocol for monitoring birch, which is a culturally significant plant for many tribes in the Great Lakes region. Tribal gatherers shared their traditional ecological knowledge related to birch trees, which included accurate descriptions for finding, choosing, and harvesting birch bark. To fully integrate WS and TEK, Emery et al. (2014) recommended including team members with intercultural skills to “help assure success integrating the contributions of experts who rarely interact and may not have a shared vocabulary.”

Furthermore, Housty et al. (2014) used an indigenous led grizzly bear monitoring program to help conserve the species. The noninvasive approach to monitoring grizzly bears was driven by Hieltsuk values, and the research project explicitly followed *Gvi'ilas*, or Heiltsuk traditional law. Their results showed a declining bear population that was possibly being driven by the declining salmon population. Housty et al. (2014) advocated for integrated scientific research using culturally appropriate methods. A similar article (Polfus et al. 2014) compared traditional ecological knowledge and western science caribou habitat models and noted that, “TEK-based habitat models can effectively inform recovery planning for this imperiled species.” Polfus et al. (2014) emphasize the importance of incorporating local knowledge in conservation planning. These instances show that traditional ecological knowledge and western science are able to work together and create successful results.

### **Dualism Theory: Traditional Ecological Knowledge and Western Science Used Together in Natural Resource Management**

Many others have commented on and proposed similar theories about the importance of combining traditional ecological knowledge and western science (Armatas et al. 2016; Mason et al. 2012; Menzies 2006; Nelson 1983, etc.). Lertzman (2010) acknowledged that TEK and WS were simply the best of both worlds and may provide the foundational base through which we identify solutions to our most complex environmental problems. One without the other will not accomplish broad scale environmental protection, and applying only one paradigm can make the environmental situation worse. Some classic examples include wildfire suppression, tamarisk introduction, and the broad scale use of the chemical DDT, an insecticide that negatively impacted bird and other wildlife species for decades. Simply stated, science without wisdom is science without a conscious. As Larry Mason (Indian Forest Management Assessment Team author and retired University of Washington professor) said, “We have an immense amount of cumulative western scientific information and knowledge to do anything, but without wisdom it’s a crapshoot.” Similar to needing both left and right hands to manipulate something tangible or both left and right feet to move towards a goal, environmental conservation will move nowhere until we fully integrate the two paradigms.

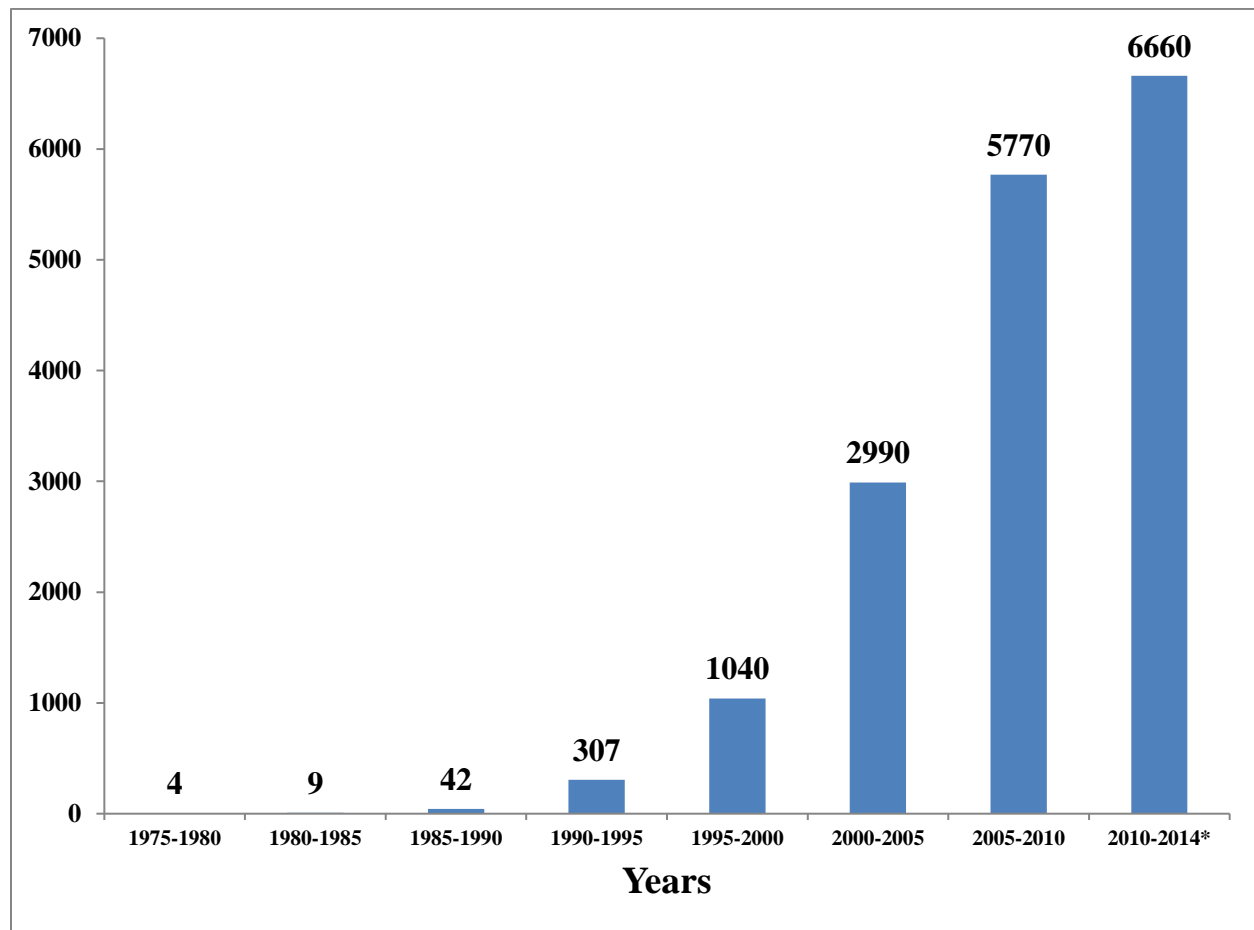
The future of our environment will depend on our ability to create sustainable environmental solutions, and, fortunately, sustainability is at the foundation of traditional ecological knowledge. Menzies and Butler (2006) acknowledge the local indigenous communities in Canada and recognize that “having lived in these territories for millennia and having used the local resources into the present time, First Nations communities have a well-developed understanding of the local environment and their own impact on local resources.” An example of a sustainable fisheries practice involves the Sto:lo people who use dip nets and canyon nets, which allows the use of live capture techniques and minimizes the number of non-target species by catch. The emphasis in this practice is on the quick release of non-target species to help eliminate removal of other fish species from the environment (Menzies and Butler 2006). As acknowledged by Nelson (1983), the “Koyukon people and their ancestors have sustained themselves directly from their surroundings” for millennia. In fact, most of Koyukon principles revolve around avoiding waste. They only harvest what they can use and they never “kill something for fun” (Nelson 1983). Indigenous communities see and suffer the consequences of their environmental decisions, and therefore, they must be extremely diligent and careful in their planning in order to not diminish resources (Gordon 2012; Gordon et al. 2013; Nelson 1983).



Some of our best scientific methods for reconstructing past centuries are still in their primitive stages of development and often lack accuracy and verification. Place names may be another valuable way to cross-reference historical reconstructions (Basso 1996). Historical accounts that provide a long-term view of the landscape and the place names with the ecological significance of those areas can be a powerful tool for documenting change and predicting future conditions. This integration of the two systems could provide a solution for a problem western science has been struggling to solve.

Combining traditional ecological knowledge and western science can be a challenge, and there are dangers involved that require consideration. Menzies and Butler (2006) provide a cautionary note in that the “danger of TEK research is that it can simply make TEK a tool of WS, rather than a complementary approach to resource management.” Data sensitivity and proprietary rights of traditional ecological knowledge are critically important to establish. The best method is to have the indigenous community decide who is able to utilize and speak for different aspects of TEK. The need to validate traditional ecological knowledge is an act of colonization in itself because it carries an underlying assumption that TEK is intended to complement western science (Menzies and Butler 2006). Several scholars note that combining traditional ecological knowledge and western science is “incommensurable” (Nadasdy 2003) since knowledge requires experience and the fundamental experience of indigenous people is drastically different from European contexts.

We have surpassed the traditional ecological knowledge dark ages; a time when individuals like Aldo Leopold in his article, “Piute Forestry vs. Forest Fire Prevention” (1920) created poor, stereotypical images of Native Americans and traditional ecological knowledge by stating, “It is, of course, absurd to assume that the Indians fired the forests with any idea of forest conservation in mind.” Leopold was actively fighting in support of Forest Service management practices of fire suppression and discrediting the traditional light-burning practices of the California Indians. Fortunately, some perceptions have changed and we are making progress in incorporating traditional ecological knowledge and western science for natural resource management decision making. In a recent analysis for the Native American Fish and Wildlife Society Southwestern Sectional meeting in August 2014, I observed trends in traditional ecological knowledge publishing. I used the Google Scholar search engine to identify the number of scientific publications that included TEK from 1975 to current publications. I compiled information for every five-year interval during the time frame and used the search term “traditional ecological knowledge.” Articles with the exact phrase were returned and I calculated the total for each time period. The following chart displays the increase in academic interest overtime in traditional ecological knowledge applications.



*Increasing number of returned articles by Google Scholar with the exact phrase, “traditional ecological knowledge” in five year intervals from 1975 to 2014.*

### **Future Recommendations for Traditional Ecological Knowledge and Western Science**

Huntington (2000) recommends incorporating traditional ecological knowledge into western science by using multidisciplinary approaches, which include methods such as semi-directive interviews, field based experiences, collaborations, and workshops to facilitate research. Others have identified indigenous research methods that focus on incorporating indigenous worldviews, developing ethical relationships with the community (with equal participation of all members), and information dissemination that directly engages the indigenous community (Lavallée 2009; Wilson 2001). Snively (2006) recommends incorporating input from indigenous communities into science curriculum development. Until this is accomplished, indigenous students will not be attracted to the sciences because they are “inaccessible and culturally irrelevant” (198). Also, the typical view of western science as controlling and manipulating the ecosystem directly conflicts with the cultural views of many indigenous people and students. It’s no wonder that only three percent of indigenous students are enrolled in science-related educational programs (Snively 2006). Kimmerer (2000) also recognizes the need to incorporate traditional ecological knowledge into biological education to provide students with a more holistic understanding of the environment with multicultural perspectives that may lead to new insights and discoveries that promote sustainability.

Many see traditional ecological knowledge as a beacon of hope and are noticing that TEK can be a “solution to a myriad of problems” (Menzies and Butler 2006). Western science experts are recognizing that TEK can provide missing answers to current research questions and help guide appropriate future ones (Menzies and Butler 2006). Dr. Mike Dockry, Citizen Potawatomi, and US Forest Service scientists stated traditional ecological knowledge can help throughout the entire western science research process from developing hypotheses to understanding complex results (Mike Dockry, pers. comm.).

There has been an influx in federal agency interest in incorporating traditional ecological knowledge into management practices. The US Department of Interior Fish and Wildlife Service (FWS) created a TEK fact sheet and identified tribal liaisons within their department. The US Department of Agriculture Forest Service (USFS) and Natural Resource Conservation Service (NRCS) have recognized the value of TEK in various agency sponsored documents. Even more encouraging is the recently established Tribal Engagement Roadmap created by the USFS Research and Development branch that explicitly states that traditional ecological knowledge can help the USFS understand and solve current and future natural resource management challenges. The Environmental Protection Agency (EPA) and Bureau of Land Management (BLM) have provided similar commitments to incorporating TEK into management decisions. Lastly, national organizations such as the Ecological Society of American (ESA) and The Wildlife Society (TWS) have developed specific working groups of committees focusing on incorporating traditional ecological knowledge. It is apparent that we are making steps in the right direction, but we still have a long journey ahead.

### **Conclusion: The Future is Bright**

There is great potential for environmental conservation if we incorporate equitable representation of traditional ecological knowledge and western science in natural resource management. As mentioned by Menzies (2006), the knowledge held by people who use the resources in an intimate and highly dependent fashion is “worth understanding...these people do indeed have something useful for us to learn.” Additionally, as Koyukon elders advise, “There is a native way and a white man’s way, and the two can coexist comfortably” (Nelson 1983). Lastly, Turner and Spalding (2013) reference a 2003 quote by Gitga’at elder Tina Robinson who stated, “We might go back to this, the way the world is going.”

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