No data were collected for this study (i.e., theoretical, review, opinion, editorial papers).

The headlines were stark. Massive forest wildfires raged on two continents with all signs pointing to late 20th century and ongoing climate change as a contributing factor (Barbero et al. 2015, Smith et al. 2020): “California Wildfires Near Tragic Milestone: 4 Million Acres Burned”; “Powerful Brush Fires in Australia Cause Deaths, Force Evacuations”.

Equally striking was the realization that the people who had inhabited those regions for millennia had practiced fire management of forested landscapes for generations (Anderson and Moratto 1996, Klimaszewski-Patterson and Mensing 2020), and their understanding of the role of fire in the ecosystems they depended on appears to hold important insights and potential solutions to mitigate the impacts of wildfires when they inevitably occur (Lake and Christianson 2019): “To Manage Wildfire, California Looks to What Tribes Have Known All Along”; “What Aboriginal Australians can teach us about managing wildfires”.

These are only recent and high-profile acknowledgments of the value of Indigenous Knowledges to understanding and managing ecosystems for the benefit of their human and non-human members. Indigenous Knowledges, also called Traditional Ecological Knowledges (TEK), Native Science, or Indigenous Ways of Knowing (Cajete 2000, Berkes 2018, Buell et al. 2020), have also been credited with better management of wildlife (Waller and Reo 2018, Gagnon et al. 2020, Popp et al. 2020), marine fisheries and ecosystems (Ban et al. 2020, Walsch et al. 2020), ecological/environmental assessment, ecosystem management and conservation of biodiversity (Berkes et al. 2000, Ford and Martinez 2000, Alessa et al. 2016, Baptiste et al. 2017, Reo and Ogden 2018, Hill et al. 2019, McElwee et al. 2020, Tran et al. 2020, Wheeler and Root-Berstein 2020), and development of sustainable agroecosystems (Lincoln et al. 2014, Seixas et al. 2018). Food sovereignty and ethnobotany are fundamentally matters of traditional ecological knowledge (Nelson 2008, Turner 2014, Carroll 2015, Settee 2018). Indeed, Indigenous Knowledges span the entire domain of human inquiry, from molecules to galaxies, and how they intersect with each other and with human experience (Redvers 2019). This is by no means a comprehensive list, even of recent reports, and should instead serve as an entry point into the extensive literature that spans all human-inhabited regions and biomes and all aspects of ecology, from individual behavior and population dynamics (many of the previous citations) to climate change adaptation (Jantarasami et al. 2018, Tribal Adaptation Menu Team 2019, Petzold et al. 2020).
What is Traditional Ecological Knowledge?

These papers tend to offer some explanation of what TEK is, but most decline to suggest a single, simple definition or term. Berkes (2018) provides a lengthy explanation of the challenges in defining TEK and selecting terminology; he and others provide broad overviews of the meanings associated with “Traditional Ecological Knowledge” or “Indigenous Ways of Knowing.” In all cases, the hallmarks of Indigenous Ways of Knowing begin with the close association of Indigenous peoples with a place over many generations and development of cultural practices, beliefs, and values based on a holistic view of the interconnections and reciprocal relationships within ecosystems, extending to sustainable human use of resources (see Berkes 2018 and the previously listed papers for variations). Berkes (2018, p. 8) offers this as a working definition:

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

He goes on to note that

> Traditional ecological knowledge is a way of knowing; it is dynamic, building on experience and adapting to changes. It is an attribute of societies with historical continuity in resource use on a particular land.

The U.S. National Park Service (https://www.nps.gov/subje cts/tek/descr iption.htm) contributes the following synthesis that captures these recurrent themes:

> Traditional Ecological Knowledge (TEK) is the on-going [emphasis added] accumulation of knowledge, practice and belief about relationships between living beings in a specific ecosystem that is acquired by indigenous people over hundreds or thousands of years through direct contact with the environment, handed down through generations, and used for life-sustaining ways. This knowledge includes the relationships between people, plants, animals, natural phenomena, landscapes, and timing of events for activities such as hunting, fishing, trapping, agriculture, and forestry. It encompasses the world view of a people, which includes ecology, spirituality, human and animal relationships, and more.

The definition used in the Fourth National Climate Assessment (NCA4 2018) (http://www7.nau.edu/itep/main/tcc/docs/resources/Indigenous%20Peoples%20Terminology%20for%20NCA4_2021.pdf) is succinct: “Indigenous knowledges, in brief, refers to Indigenous peoples’ systems of observing, monitoring, researching, recording, communicating, and learning that are required, as for any group, to support survival and flourishing in an ecosystem and the social adaptive capacity to adjust to or prepare for changes.”

Finally, the TEK section offers this concise definition of TEK: Adaptive ecological knowledge developed through an intimate reciprocal relationship between a group of people and a particular place over time (https://www.esa.org/tek/sample-page-2/).
We offer multiple TEK definitions to provide a more complete account of how it is conceived and to illustrate the centrality of certain themes. For those who are learning about TEK for the first time, it is important to think carefully about these definitions and avoid preconceptions and superficial attempts to align Indigenous Knowledges with more familiar concepts from “Western” (i.e., Eurocentric) thinking. For example, it should be clear that TEKs are not simply another long-term dataset, but rather knowledge systems encompassing both information about species and ecosystems acquired over many human generations and ways of gathering, transmitting and using that information that are woven into and inseparable from the cultures and identities of Indigenous peoples (Stricker et al. 2020). One implication is that TEKs and their value for understanding ecological phenomena are ethically accessible only through collaboration or partnership with Indigenous peoples themselves and only in a manner that provides benefits for and respects their right to share only what they are willing (Jantarasami et al. 2018, Ramos 2018, Buell et al. 2020, Carroll et al. 2020). The same holds true if TEKs are to be included in ecology education; it cannot be separated from the people and culture from which it is derived (Four Arrows 2013, pp. 75–81). With this caveat, ecologists and environmental scientists are increasingly aware of the value of Indigenous Knowledges and the potential benefits of expanding “mainstream” science to include complementary knowledge systems (Buell et al. 2020, Gagnon et al. 2020, Learm 2020, Popp et al. 2020). It has been said that restoration ecology is the “acid test of our ecological understanding” (Bradshaw 1987). Perhaps this is even more true for Indigenous Knowledges that have withstood the test of time and enabled the survival, resilience, and prosperity of the people who relied on this way of knowing for generations.

**A Brief History of the TEK Section in the Ecological Society of America**

(Much of this section is based on communications from Dr. Judith Vergun)

The TEK section was founded nearly 20 years ago to (1) promote the understanding, dissemination and respectful use of traditional ecological knowledge in ecological research, application, and education, (2) to encourage education in traditional ecological knowledge, (3) to stimulate research which incorporates the traditional knowledge and participation of Indigenous people, (4) to increase participation by Indigenous people in the Ecological Society of America, (5) to foster understanding of indigenous and local knowledge in relationship to place, and (6) to facilitate communication among people with diverse ways of knowing, both within ESA and between ESA and other communities” (Mission Statement, https://www.esa.org/tek/sample-page-2/).

At the time the TEK section was established, ESA recognized the relevance of TEK and knew of the interest among members; however, the need for a TEK section was apparent years earlier. In 2001, with the support of Dr. Jane Lubchenco (ESA President 1992–1993), Dr. Judith Vergun led the effort to create and finally launch the TEK section in 2002. Prior to that, Judith had worked for years in her home institution, Oregon State University, to help create and then direct the NSF-funded Native Americans in Marine and Space Sciences (NAMSS) Program, for which (among other efforts) she and the program were awarded a Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring.

That work and other TEK programs in the early 1990s built support in tribal communities for involvement in University programs and professional societies and created a pipeline for native students, which, in turn, provided evidence to ESA that a TEK section was needed (Vergun, personal communication). In fact, one of her students, Dr. Frank Lake, joined ESA at that time as a student and went on to a distinguished (and ongoing) career as an ecologist with the U.S. Forest Service. Dr.
Lake also recently (2012–2016) served as Vice-Chair and then Chair of the TEK section, which all clearly demonstrates the benefits to ESA and ecological science of establishing the section. Dr. Vergun assembled a small team of ESA members to help plan the new section, and one, Dr. Robin Kimmerer, became the first section Chair. Dr. Kimmerer is a well-known author of the inspiring book, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants* (Kimmerer 2013), that weaves her life story into an engaging narrative illuminating the value and values of Indigenous Knowledge. Dr. Kimmerer shared elements of this story in her plenary address at the 2019 annual meeting of ESA in Louisville, KY (https://esa.org/louisville/plenary-session-videos/; https://youtu.be/xKmKFJzviz0).

In the years that followed, the TEK section regularly organized workshops, special sessions, organized oral sessions, field trips, and symposia at ESA’s annual meetings (https://www.esa.org/tek/past-activities/). Sessions (“Sense of Place”) often focused on something specific to the location of the meeting, such as sessions on wild rice when the meeting was held in Wisconsin and other place-based sessions in other meeting locations. Other themes over the years included ecological education, environmental justice, restoration and sustainability, and “Bridging Western Science and Indigenous Traditional Ecological Knowledge Ethically: What Works and What Doesn’t” (https://eco.confex.com/eco/2007/techprogram/P4984.HTM), topics that remain relevant and urgent today!

In addition, section leaders have been featured speakers in prominent spotlights, including Dr. Kimmerer, as noted previously, and Frank Lake, who was invited to present at the Diversity Luncheon in 1999, even before the section was formally created (Lake, personal communication). That talk brought attention to the role of TEK when working with tribes and other Indigenous peoples. The ESA journal *Ecological Applications* further highlighted the relevance of TEK to ecology the following year in its Invited Feature on Traditional Ecological Knowledge, Ecosystem Science, and Environmental Management (Ford and Martinez 2000).

**Recent Activities of the TEK Section: ESA Annual Meeting 2020**

Most recently, the section organized a symposium and workshop for the 2020 annual meeting, originally planned for Salt Lake City, but ultimately convened online because of COVID-19. The conference theme was “Harnessing the ecological data revolution,” and we titled our symposium “Honoring the Power of Indigenous Science Data to Revitalize Ecosystems, Communities, and Cultures” (https://eco.confex.com/eco/2020/meetingapp.cgi/Session/17266). Our purpose was to highlight the work of Indigenous scientists working in diverse systems, all of which illuminated the nature and value of including place-based traditional knowledge in modern ecological research. We were honored with contributions from three speakers, including Dr. Frank K. Lake (Karuk descendant) with the U.S. Forest Service, James Rattling Leaf, Sr. (Rosebud Sioux) of the University of Colorado-Boulder and the USGS North Central Climate Adaptation Science Center, and Dr. Clint Carroll (Cherokee) of the Department of Ethnic Studies at the University of Colorado, Boulder. Unfortunately, because of the extreme fire activity on the U.S. west coast, Dr. Lake was unable to join the live sessions, but attendees were able to view his slides co-authored by Tony Marks-Block of Stanford University on fire management effects on California hazelnut (https://eco.confex.com/eco/2020/meetingapp.cgi/Paper/87739, see Marks-Block et al. 2019). Their research revealed that fuel reduction burns can provide co-benefits in reducing fire risk and simultaneously increasing production of stems used in a culturally important practice, basketry.
This is a clear example of how re-establishing a long-standing, local Indigenous practice would improve ecosystem management (Lake and Christianson 2019).

The title of James Rattling Leaf’s presentation, “The decade of traditional knowledge: Opportunities to build greater understanding between the western science and traditional knowledge paradigm,” (https://eco.confex.com/eco/2020/meetingapp.cgi/Paper/82066) spoke to a possible path to a more inclusive and collaborative future in environmental policy and decision-making. He argued that, although we must acknowledge past injustices resulting from European colonization of North America and elsewhere and the persistent harm they have created, bridging knowledge systems in an appropriate and respectful way will enable greater prospects for responding to climate change, protecting biodiversity, and improving human health and prosperity. In his presentation, James highlighted ongoing examples, including the Rosebud Sioux Tribe’s climate adaptation planning project and collaborative work with the USGS North Central Climate Adaptation Science Center, remote sensing work with NASA and USGS as part of the NativeView program (https://www.nasa.gov/audience/forstudents/5-8/features/F_Native_Views_Space_5-8.html, Marcus 2010), and creation of the GEO Indigenous Alliance (https://appliedsciences.nasa.gov/our-impact/news/geo-indigenous-alliance-founder-addresses-earth-data-providers). He also noted how collaborative efforts led by tribes have led to progress in renewable energy, natural hazards mitigation, work on intergenerational transmission of cultural knowledge and values, and tribal data sovereignty. He concluded with the compelling message that embracing both “western” and Indigenous Knowledge represents a “third way,” one in which the combination provides value that is “more than the sum of the parts.”

Dr. Clint Carroll, like Dr. Lake, returned to the specific, place-based context of Indigenous Knowledge in his talk on “Knowing the land: Indigenous strategies for revitalization and adaptation” (https://eco.confex.com/eco/2020/meetingapp.cgi/Paper/88223). Like James Rattling Leaf, Dr. Carroll offered a holistic assessment of the interconnected challenges faced by Indigenous communities because of historical injustices (settler colonialism, forced removals and relocations, and attempted assimilation), development, and climate change. Despite these disruptions, Cherokee people have adapted and continue to adapt through revitalization of traditional knowledge, particularly in relation to the use of plants for foods and medicines (Carroll 2015). TEK again helps to improve the human and environmental condition.

In addition to the symposium, we organized a workshop to address the questions that arise for those considering or curious about collaborative projects with tribes. The workshop title describes our goal: “Working Together For A Better Future: How to Establish and Maintain Successful and Durable Partnerships between Indigenous Communities and Non-Indigenous Collaborators” (https://eco.confex.com/eco/2020/meetingapp.cgi/Session/17663). The potential benefits of a broader, more diverse foundation for ecological knowledge, that is, a TEK-inclusive ecology, or the “third way” noted by James Rattling Leaf, are only attainable through respectful, appropriate, and equitable partnerships with Indigenous Knowledge holders and researchers. Such relationships, like all team efforts, work when all team members contribute and all benefit and require time and trust to develop. For reasons noted previously, Indigenous peoples have well-founded concerns about the motives and durability of partnerships with non-native parties. The workshop leaders offered attendees substantive advice on how to create the conditions for success. Dr. Julie Thorstenson (Cheyenne River Sioux), the executive director of the Native American Fish and Wildlife Society, discussed the history of her organization...
and its role in conservation and natural resource management. For anyone interested in working with or for tribes, the NAFWS is an important point of contact. She emphasized that each tribe (574 federally recognized tribes in the United States at the time of the ESA 2020 Meeting) is unique and that it is essential to build relationships with key people in the tribe and underscored the need for respect and the opportunity for mutual learning.

Kim Greenwood with the U.S. National Park Service has many years of experience in working with tribes and incorporating Indigenous Knowledges into natural resource management. She also emphasized the imperative for respectful and mutually beneficial relationships, where tribal sovereignty and decision-making are respected, and reciprocity is a critical element. The NPS website (https://www.nps.gov/subjects/tek/index.htm) provides extensive information and guidance on working with tribes and appropriate use of TEK. Dr. Serra Hoagland (Laguna Pueblo), a wildlife biologist with the U.S. Forest Service and liaison to the Salish Kootenai College in Montana, also has extensive experience conducting research with tribes. She offered a detailed set of guidelines for building successful partnerships, beginning with listening. She emphasized the importance of careful listening to identify tribal research needs and values, to maintain humility, humor (also noted by the other workshop leaders), and regular communications, and to practice reciprocity or contributing something of value and not simply extracting information. Dr. Hoagland and her colleagues recently published an excellent account of many aspects of working with tribes (Stricker et al. 2020).

Despite our inability to meet and interact in person in 2020, the TEK symposium and workshop appear to have generated considerable interest among ESA members, judging by the turnout in the 30-minute live Q&A sessions with >150 attendees at the symposium live event and >100 for the workshop. ESA also added a networking event “Engaging with Indigenous People” to the schedule, co-moderated by past-president Dr. Laura Huenneke, James Rattling Leaf, and Robert Newman. That occurred on the last day of the conference and had ~60 attendees. The Indigenous Phenology Network also organized a symposium (Indigenous Phenology: New Mindsets for Working among Worldviews), which further expanded the TEK perspective at the conference, and most of their speakers joined the TEK section’s live Q&A sessions, too. The range of experience and expertise in native science was noteworthy and encouraging. The conversations at all of these live events were wide-ranging and thoughtful.

Finally, it is worth mentioning that one of our presenters (and now Chair of the TEK section), James Rattling Leaf, was also the recipient of an ESA Diversity and Inclusion scholarship and spoke at the Committing to Diversity Panel on the first day of the conference. His contribution set the stage very well for the other TEK events, as he spoke to some of the challenges in bringing native students and scholars into universities and organizations such as ESA and in building relationships with tribes.

After nearly 20 years as a section, it is clear that the TEK section has a strong future. We will continue to expand awareness of and appreciation for TEKs in the mainstream scientific community and promote best practices for creating a more inclusive ecology. These efforts should be sustained and year-round, not limited to annual meetings. Our recent Water Cooler Chat (https://www.esa.org/exploration-of-modern-indigenous-knowledge-and-the-power-of-indigenous-and-western-science/) showed the high level of interest in ESA and the opportunity for continued, thoughtful engagement. In the wider community, TEKs continue to be highlighted in major national and international reports (e.g., Jantarasami et al. 2018, Seixas et al. 2018, National Fish, Wildlife, and Plants Climate Adaptation...
To keep the conversation going, the section has several events planned for the 2021 annual ESA meeting, including a symposium (Traditional Ecological Knowledge: Connecting Past and Future, People and Place, and Ways of Knowing), a workshop (Reciprocity of Indigenous Knowledge in Ecology Education: Towards a More Inclusive Ecology), and a new contribution to our special session series (Sense of Place—Vital Connections Tribal Culture & Ecology). The leadership team is currently planning a webinar series and looking ahead to a more in-depth workshop for a time when we can again meet in person. ESA will see more TEKs and more Indigenous ecologists, and we all will benefit from that expanded vision.

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Notes

1 https://www.npr.org/2020/10/02/919554698/california-wildfires-near-tragic-milestone-4-million-acres-burned
2 https://www.npr.org/2020/01/02/792976328/powerful-brush-fires-in-australia-create-their-own-weather
3 https://www.npr.org/2020/08/24/899422710/to-manage-wildfire-california-looks-to-what-tribes-have-known-all-along
4 https://www.pri.org/stories/2020-08-27/what-aboriginal-australians-can-teach-us-about-managing-wildfires

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