J. For. 112(2):207–214
http://dx.doi.org/10.5849/jof.13-023

measurement

Using Traditional Ecological Knowledge as a Basis for Targeted Forest Inventories: Paper Birch (*Betula papyrifera*) in the US Great Lakes Region

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Traditional ecological knowledge (TEK) has been proposed as a basis for enhanced understanding of ecological systems and their management. TEK also can contribute to targeted inventories of resources not included in standard mensuration. We discuss the results of a cooperative effort between the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and USDA Forest Service's Forest Inventory and Analysis Program (FIA). At the urging of member tribes, GLIFWC staff worked with tribal gatherers to document TEK regarding desired characteristics of birch bark for traditional uses and translated this into an inventory field guide. The guide was provided to FIA, which incorporated the methods into its field manual and trained inventory crews in implementation of the protocol. Birch bark data were collected during three field seasons from 2004 to 2006. Results show birch bark supply has declined. Lessons learned from this multiyear, multistage project provide a model for future targeted inventory efforts.

Keywords: traditional ecological knowledge, *Betula papyrifera,* nontimber forest products, forest inventory and monitoring, American Indians

> *Forest inventory deals with the methods of obtaining information on volume and growth. Under present-day conditions in North America, detailed inventories are economically practicable only under special circumstances and for limited areas.*
>
> (Spurr 1952, p. 3)

> *What will be gained by placing TEK-based worldviews into a broad-based system of knowledge is the ability to access a large amount of information and experience that has been previously ignored or treated as mysticism.*
>
> (Pierotti and Wildcat 2000, p. 1339)

Inventory is fundamental to forest management. Forest inventories provide information about the current status of resources and a basis for projecting trends. Where long-term data are available, inventories help document the effects of past management, disturbance, and successional processes. Such information yields input valuable in planning management for forest-derived goods and services (LaBau et al. 2007).

Timber and fiber were and continue to be the focus of extensive federal forest inventory in the United States since the inventory's inception in the early 20th century (Spurr 1952, Husch et al. 1972). Efforts to serve a more diverse audience of resource users emerged in the 1970s (Rudis 2003, LaBau et al. 2007). Since that time, the USDA Forest Service's Forest Inventory and Analysis Program (FIA) has expanded the

Received March 22, 2013; accepted February 6, 2014; published online March 13, 2014.

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Acknowledgments: *We are grateful to the late Karen Danielsen for her foundational contributions to the study on which this article is based and to the tribal gatherers who shared their traditional ecological knowledge of birch: Mark Bisonette, Robert J. Sander, and Donald G. White (Lac Courte Oreilles Band), Russell Boyd (Mille Lacs Band of Ojibwe), Marvin Defoe, Jr. (Red Cliff Band), Jeff Savage (Fond du Lac Band), and Leon C. Valliere and Wayne M. Valliere (Lac du Flambeau Band). Our thanks go out, too, to leadership of the Great Lakes Indian Fish and Wildlife Commission who twice reviewed and provided valuable comments on the paper. Finally, we wish to thank the USDA Forest Service, Northern Research Station's Forest Inventory and Analysis Program for embracing these novel and important information needs.*

Figure 1. Birch bark crafts. Anishinaabe artisans use birch bark to make traditional crafts such as baskets (left) and canoes (right). Photos used by permission of the Great Lakes Indian Fish and Wildlife Commission.

attributes measured and analyses conducted to include data relevant for management of wildlife, recreation, range, hydrology, and other resources (Brooks 1990, Joyce et al. 1990, Rudis 1991). Most recently, FIA has sought to expand the communities it serves and meet treaty obligations by identifying resources of interest to American Indian tribes.

Birch bark, or *wiigwaas* in the language of the *Anishinaabe* (Ojibwe or Chippewa),[1] is such a resource. Some species are so fundamental to the cultural identity of a people because of their diverse roles in diet, materials, medicine, and spiritual practices that they may be thought of as cultural keystone species (Garibaldi and Turner 2004). Paper birch (*Betula papyrifera*) is a cultural keystone species for the Anishinaabe in the US Great Lakes region. The bark of the paper birch tree has furnished material and cultural resources since time immemorial. Birch bark canoes were a primary mode of transportation. Food storage containers made from birch bark help to retard spoilage and have been referred to playfully as the original Tupperware. Birch bark contributes to survival of cultural identity by providing a material on which traditional stories and images have been etched and birch figures prominently in Anishinaabe cultural tales (Densmore 1974). It also is essential to the economic welfare of skilled artisans (Figure 1). During research conducted on the Leech Lake Reservation in northern Minnesota, birch bark was the most frequently discussed craft material, with uses including baskets, picture frames, canoes, and other objects made for sale (Cone et al. 1995).

These items and more are made from the outer bark of paper birch, which can be harvested from standing live trees on a renewable basis provided the cambium remains intact (Turner et al. 2009). Indeed, American Indian gatherers report finding healthy trees bearing the evidence of bark harvests that occurred decades in the past (Mundell 2008). Bark also is harvested from trees that have been felled recently or are scheduled to be cut.

Concerns about decline in the availability of birch bark prompted GLIFWC, which represents 11 Anishinaabe tribes, and the Forest Service's FIA unit in St. Paul, MN, to collaborate on the design and implementation of a program to inventory birch bark characteristics in the Great Lakes region (northern Minnesota, Wisconsin, and Michigan). Methods were based on the traditional ecological knowledge (TEK) of gatherers in GLIFWC member tribes and previous GLIFWC work on birch (Meeker et al. 1993, Danielsen 2002), combined with Western science (Rudis 2003) to achieve three goals: (1) maximum usefulness of results to tribes, (2) objectivity of birch bark assessments, and (3) integration of TEK with previously established FIA protocols (USDA Forest Service 2003).

In the remainder of this paper, we review the nature of TEK and the value of combining it with scientific inventory techniques in support of culturally appropriate management of forest resources. We then describe the process whereby birch bark inventory methods were developed, with special emphasis on the role of TEK. After describing implementation of the birch bark inventory protocol and our analytical methods, we present summary findings. We conclude by exploring future directions for the work and lessons learned for incorporating TEK into targeted inventories.

TEK and Forest Inventory

In 1999, Berkes proposed a now classic definition of traditional ecological knowledge as 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 (p. 8).

Management and Policy Implications

Forest products like specialty woods for musical instruments and materials for crafts have important economic and cultural value. However, extensive inventories typically cannot assess supplies of these resources. Combining traditional ecological knowledge (TEK) and mensuration science can address such shortfalls and provide a basis for policy and management.

Integrating TEK and Western science is best accomplished through an iterative process in which all parties respectfully share information and adapt the protocol as lessons are learned. A partnership of the Great Lakes Indian Fish & Wildlife Commission (GLIFWC) and USDA Forest Service to design a targeted inventory for paper birch (*B. papyrifera*) bark in the US Great Lakes region offers a model of how this can be accomplished for targeted inventories.

Results from 3 years of data collection on birch bark, combined with standard inventory data, show declines in the resource. Silvicultural practices designed to increase number, size, and age of paper birch trees, especially in northern hardwood stands, could enhance future supplies of birch bark. More immediately, artisans can be invited to harvest birch bark before timber harvests through contacts with tribal natural resource departments and intertribal organizations. Done properly, birch bark can be removed from standing live trees without causing mortality and skilled individuals also may be invited to harvest bark from forests where no cutting is planned.

TEK incorporates direct experience, as well as long-term observations by individuals and across generations. Human beings are regarded as part of the natural community, with a responsibility to respect and care for nature as both a pragmatic and spiritual obligation (Berkes 1999, Kimmerer 2000, Pierotti and Wildcat 2000, Houde 2007). While generally not systematized, TEK sometimes draws on in situ experimentation (Berkes 1999, Emery 2001), in which practitioners test harvest techniques, propagation methods, and other practices, observing their effects through time. Traditional management systems based on TEK have been shown to promote productivity of desired species at scales from the individual specimen to landscape (Anderson 1996, Kimmerer 2000, Emery 2001, Kimmerer and Lake 2001, Deur and Turner 2005).

The combination of TEK and Western science has been proposed as one basis for contemporary ecosystem management (Bengston 2004, Mason et al. 2012). Such an association, it is suggested, could contribute insights into ecosystems (Pierotti and Wildcat 2000), new ideas for modeling them (Kimmerer 2000), and data useful in understanding variations in habitat requirements throughout a species range (Diamond and Emery 2011). It may provide information on benchmarks and practices for restoration (Kimmerer 2000), strategies for adaptive management (Berkes 1999), and incorporation of indigenous perspectives into forest management (Youngbear-Tibbetts et al. 2005), as well as input for development of policies related to management of individual species and groups of species (Emery 2001).

Combining TEK and Western science is not a simple additive process. It requires building relationships of trust through respectful exchange of information and cross-cultural learning, from formulation of research questions or management problems to interpretation of results and identification of appropriate actions (Mason et al. 2012). In particular, recognizing the centrality of ethics and cosmology or worldview to TEK (Houde 2007, Reo and Whyte 2012, Leonard et al. 2013) and the imperative for indigenous peoples to retain sovereignty with respect to cultural knowledge (National Congress of American Indians 2013) are fundamental to successful, ethical partnerships.

To our knowledge, a melding of TEK and Western science for forest inventory has not been explored previously. In the case of cultural keystone species or ecosystems not typically included in extensive forest inventories, such an approach may be essential. Broadly speaking, TEK identifies and furnishes understanding of culturally meaningful characteristics. Western science offers a basis for translating those characteristics into measurable properties, assuring accurate measurements, and producing sound statistical analyses. TEK and Western science each contribute standards for judging whether field measurements and analyses capture the desired values. Finally, both are essential to interpretation that is rigorous *and* culturally appropriate.

The TEK on which the birch bark inventory discussed here rests is grounded in the world view of the Anishinaabe people. It encompasses spirituality, ecology, experiences, and teachings. To the Anishinaabe people, all things are related and connected with each other. This principle can be called *indinawemaagonidog,* or all of our relations. This references the relationships among people and with the rest of creation (plants, animals, sky, earth, etc.).

Common misunderstandings about TEK include who may possess it, what it embraces, and how long it takes to develop. It is true that TEK is a body of knowledge and that one accumulates more with experience and learning. But it is not only passed along to certain individuals and it is not limited to specific animals or locations. Another misconception is that a certain amount of time must pass before something becomes a tradition. There is no set amount of time. The essence of Anishinaabe TEK is acknowledgment of relationships between all of creation and behaving in a respectful manner that preserves our resources.

Respectful behavior is guided by Anishinaabe *inaakonigewin,* that is, true Indian law or natural law. This term references the teachings of why things are done in certain ways. As one grows and receives teachings, one begins to learn how to behave or act. There are always choices and consequences of those choices. Anishnaabe inaakonigewin (true Indian law or natural law) helps guide choices and maintain sustainable behavior within the natural world.

Sometimes TEK is conceptualized strictly in terms of personal life stories, leaving out sacred stories. However, it is the sacred stories that validate everyday experiences and traditional practices. *Aadizookaanan* (sacred teachings) stories represent the collective wisdom and teachings of the Anishinaabe people, as told through the tales of the Ojibwe cultural hero and trickster Nenabozho. Personal or family experiences are known as *dibaajimowin.* These are personal life stories or experiences that relate back to and reference the central library of aadizookaanan (sacred teachings). Together dibaajimowin (personal or family experiences) and aadizookaanan (sacred teachings) embody the overall knowledge base of an Anishinaabe person. TEK is a combination of both (Geniusz 2009).

Fishermen on a lake about to harvest a sturgeon offer an example. One of the fishermen places a copper cup filled with food and tobacco in the lake as an offering. As he does, he acknowledges his overall knowledge base and remembers: Why copper? Why food? Why tobacco? How does this all relate to the sturgeon we are about to harvest? By this action and thought process, he deepens his TEK, thinking back to how dibaajimowin (personal or family experiences) and aadizookaanan (sacred teachings) are related.

Developing a TEK-Based Field Guide

Efforts to create a targeted birch bark inventory protocol for the Great Lakes region were grounded in the integration of Anishinaabe TEK with Western science. Methods were developed through an iterative process involving tribal gatherers, GLIFWC, and FIA (Table 1) under the auspices of a memorandum of understanding (MOU) between GLIFWC member tribes and the Forest Service.

In the early 2000s, GLIFWC staff began hearing from member tribes that artisans were experiencing increasing difficulty finding birch bark for traditional crafts. They suspected this was the result of changes in forest management in the region. Another possible explanation was that older gatherers were no longer able to travel as far from roads as they had previously.

In response, GLIFWC staff identified eight gatherers from five member tribes who had decades of experience finding, choosing, harvesting, and using birch bark. In 2002 and 2003, these experts shared information about bark characteristics needed for specific uses and their strategies for finding and identifying trees likely to have such bark. Interviews were conducted indoors and in forest stands where birch was present. Information provided by these TEK experts was collected through audio recordings, photographs, and

Table 1. Steps to integrate traditional ecological knowledge and Western science for birch bark inventory.

Task	Participants		
	TEK experts	GLIFWC	FIA
Identify and interview TEK experts	X	X	
Identify birch bark characteristics		X	
Validate characteristics	X	X	
Translate characteristics to discrete variables		X	X
Develop measurements for variables		X	X
Produce field guide		X	X
Train field crews			X
Implement protocol			X
Review & revise protocol		X	X
Analyze data			X
Interpret results	X	X	X
Develop management recommendations		X	X

interview notes. In keeping with their status as expert consultants, tribal gatherers were compensated for their time and acknowledged by name in the resulting report (Danielsen and White 2003).

GLIFWC staff synthesized information from all interviews and identified frequently mentioned characteristics. This resulted in a list, which was shared with the TEK experts to be sure it captured the processes they used to assess bark. Value statements such as "good bark" or "desirable bark" were avoided. As the gatherers pointed out, all birch bark is good for something.

GLIFWC staff then embarked on discussions with FIA to incorporate these characteristics into the regional inventory protocol. The goal was to express birch bark information needs in terms of discrete variables that could be assessed objectively by a forestry professional with no experience harvesting birch bark. As is common with cross-cultural and interdisciplinary efforts, finding a common language was a challenge. The vocabularies of TEK and forest mensuration differ substantially. Photographs provided one bridge between these approaches. GLIFWC supplied images of the characteristics to help FIA staff literally get the picture of the information being sought. Discussion then focused on translating the list of characteristics gatherers use to choose birch bark into a corresponding list of measurable attributes.

One result of this process was the development by GLIFWC staff of an illustrated guide to field methods for assessing birch bark (Danielsen and White 2003). The protocol proposed collection of data on trunk curvature, branching, evidence of past harvest, and bark texture for paper birch trees measuring 5 in. or larger in dbh in each of two sections, 4–8 ft and 8–16 ft above the ground. With respect to bark texture, crews would be asked to record categorical values for lenticels, branch scars, exfoliation, blemishes, and fungus, as well as lichen and moss (see Appendix). The guide included photographic illustrations of each potential value and a sample data sheet. On completion, the GLIFWC field methods guide was provided to FIA.

Implementing and Revising the Inventory Protocol

The GLIFWC field methods guide served as the basis for a birch bark assessment protocol in the fiscal year 2004 FIA core field guide (USDA Forest Service 2003). To provide context for field crews, the birch bark protocol was prefaced by language drawn directly from the GLIFWC report explaining the significance of birch bark to the Anishinaabe people, protocol objectives, and considerations in its development. The FIA protocol regrouped bark attributes and possible values for them but otherwise was unchanged from the GLIFWC field methods guide.

2004 FIA crews reported finding implementation of the protocol difficult. Collecting unique data on a species altered routines and extended the length of the workday. Field personnel felt a lack of confidence in their ability to assign values that would be both accurate and reliable. This was particularly true for curvature and years since bark harvest. In the case of the latter, individual crews reported rarely seeing trees from which bark had been harvested, experience which might have generated a greater level of comfort when assessing that attribute. Some crew members also wondered if the data would actually be put to use. In response to feedback from crews, changes were made to the field manual used in fiscal years 2005 and 2006.

The evolution of field guide illustrations for curvature offers an example of the need for an adaptive, iterative approach to incorporating TEK in targeted inventories. Curvature is an important characteristic affecting potential uses of birch bark. TEK experts indicated they walk around a tree examining its vertical straightness, as well as several other characteristics, before deciding whether it will be suitable for their purposes (Danielsen 2002). To operationalize the TEK process for inventory, GLIFWC staff developed a three-variable classification for trunk curvature (0 = no curvature, 1 = moderate curvature, and 2 = extreme curvature) and included photographic illustrations for moderate and extreme curvature in their field guide (Figure 2, after Danielsen and White 2003). However, 2004 crews reported finding it difficult to judge the degree of curvature based on the photographs. In response, a supplement to the 2005 FIA field manual included schematic drawings expressing curvature in terms of measurable distance from pith to the outside bark of the tree (Figure 3, after USDA Forest Service 2005).

Over the 3 years of the targeted birch bark inventory, data were collected on 22,594 plots, with a total of 12,544 live and standing dead paper birch trees measured on 9,757 of these plots. Collection of birch bark data was discontinued after the 2006 season, following a national-level decision to evaluate the usefulness and costs of regional variables. Although this interrupted collection of birch bark data, it provided an opportunity to analyze data from the first 3 years of protocol implementation and consider future directions.

Analytical Approach

Our analyses use standard FIA data and methods, combined with the birch bark inventory data obtained during the 2004–2006 field seasons, to quantify the Great Lakes birch bark resource and provide context for those numbers. We use standard FIA estimates of live birch trees 5 in. dbh[2] and larger and total birch timber volume[3] to analyze trends in the birch resource as a whole. All estimates are calculated using standard FIA stratified estimation methods as described by Bechtold and Patterson (2005) and implemented in software presented by O'Connell et al. (2013). Volume estimates

Figure 2. Photo illustrations of moderate curvature (left) and extreme curvature (right). Photographs like these were provided to 2004 FIA field crews. Photos used by permission of the Great Lakes Indian Fish and Wildlife Commission.

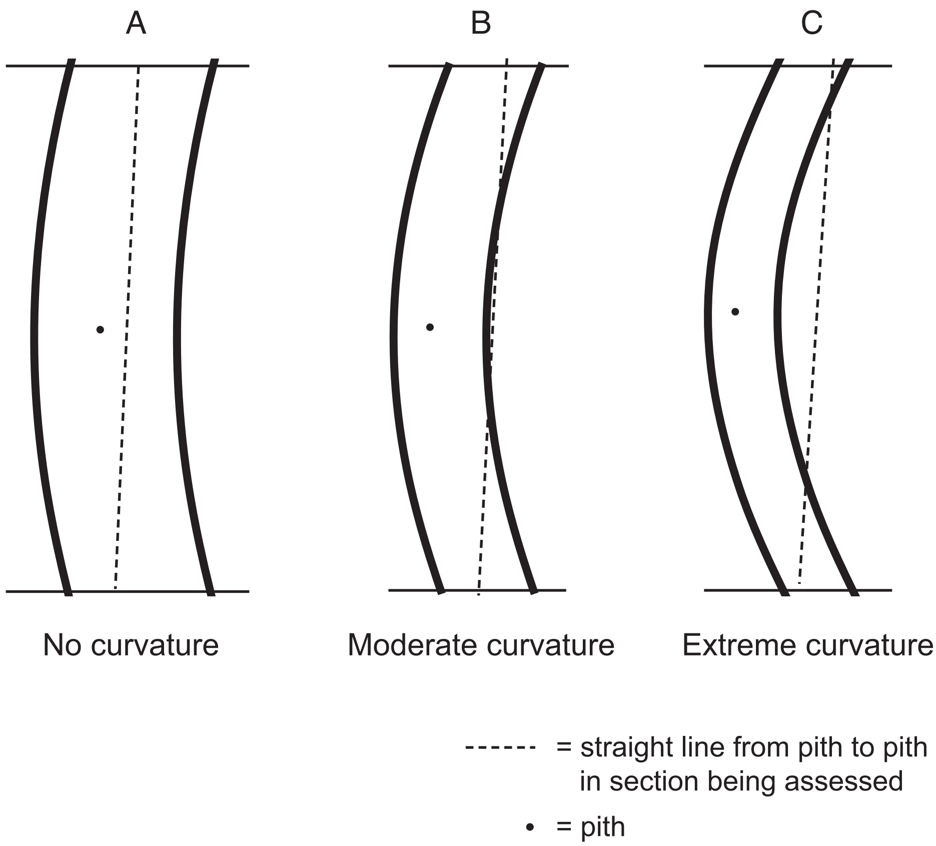

Figure 3. Schematic drawings of birch tree curvature. In 2005 and 2006, FIA crews were given drawings like these, which depicted degree of curvature in terms of location of a line from pith to pith at the top and bottom of the section being assessed in relation to pith and outer bark at the center of the section: (A) < 1/2 distance, (B) ≥ 1/2 distance but not beyond outside bark, and (C) extends beyond the outside bark.

are based on methods presented in Hahn (1984). Results reported here are for timberland only. Defined as those forestlands capable of producing at least 20 ft^3 of wood per acre per year and not excluded from timber harvesting, timberland makes up over 95% of the total forest area in the region. While the birch resource on other forestlands is important, it is located primarily in parks, wilderness areas, natural areas, and remote lands where harvesting generally is prohibited or impractical.

For analysis of the bark resource, we define harvestable bark as the surface area of the bole between 1 ft and 9 ft above the ground of all live birch trees 5 in. dbh and larger. With the exception of those seeking bark for canoes, harvesters seldom use material outside this 8 ft section of the tree. A simple geometric model was used to compute total harvestable bark area. The model considers the 8 ft bole section to be two conical frustums, the first being the section from 1 ft aboveground to 4.5 ft (where dbh was measured) and the second being the section from 4.5 ft to 9 ft The bottom section has a length of 3.5 ft and end diameters of dbh and $dbh^*\hat{R}$ where $\hat{R}$ is the estimated ratio of stump diameter to dbh. The upper section has a length of 4.5 ft and end diameters of dbh and $dbh - 4.5\ \hat{T}$ where $\hat{T}$ is the estimated taper per foot (in inches) of the bole above breast height. Data from diameter observations taken in a series of timber utilization studies conducted across the Lake States by FIA from 1975 to 1995 were used to obtain estimates of the average taper for these two sections. This utilization data provided estimates of 1.2465 for $\hat{R}$ and 0.1493 for $\hat{T}$ with standard deviations of 0.1649 and 0.0810, respectively. This provides the observation of harvestable bark (SA = surface area in square feet) of a paper birch tree with observed dbh to be

$$SA = \pi\left[\left(\frac{d_s}{24} + \frac{dbh}{24}\right) \times \sqrt{\left(\frac{d_s}{24} - \frac{dbh}{24}\right)^2 + 3.5^2} + \left(\frac{dbh}{24} + \frac{d_t}{24}\right) \times \sqrt{\left(\frac{dbh}{24} - \frac{d_t}{24}\right)^2 + 4.5^2}\right]$$

where $d_s = dbh\,\hat{R}$ is the predicted diameter at the bottom of the first section and $d_t = dbh - 4.5\ \hat{T}$ is the predicted diameter at the top of the second section. Substituting the fitted parameter values produces the prediction equation

$$SA = \pi[dbh \times (\sqrt{0.0000009245(dbh)^2 + .1073} + .375) + .1260]$$

Table 2. Saplings on Lake States timberland. Estimated number of live trees 1–5 in. dbh in 2005 and 2010 and percentage change of selected early successional species commonly associated with paper birch.

	Million live saplings on timberland		
Species	2005	2010	Percentage change
Paper birch	734	799	8.8%
Balsam fir	3,662	3,989	8.9%
Red maple	2,403	2,560	6.5%
Quaking aspen	5,408	5,048	−6.7%
Bigtooth aspen	727	738	1.6%
Jack pine	372	370	−0.5%
Other species	14,516	15,430	6.3%
All species	27,821	28,933	4.0%

Number of saplings can only be estimated in a consistent manner for 2005 and 2010. Prior inventories use different methods to tally and measure trees less than 5 in. dbh making analysis of longer-term changes in number of small diameter trees unsound.

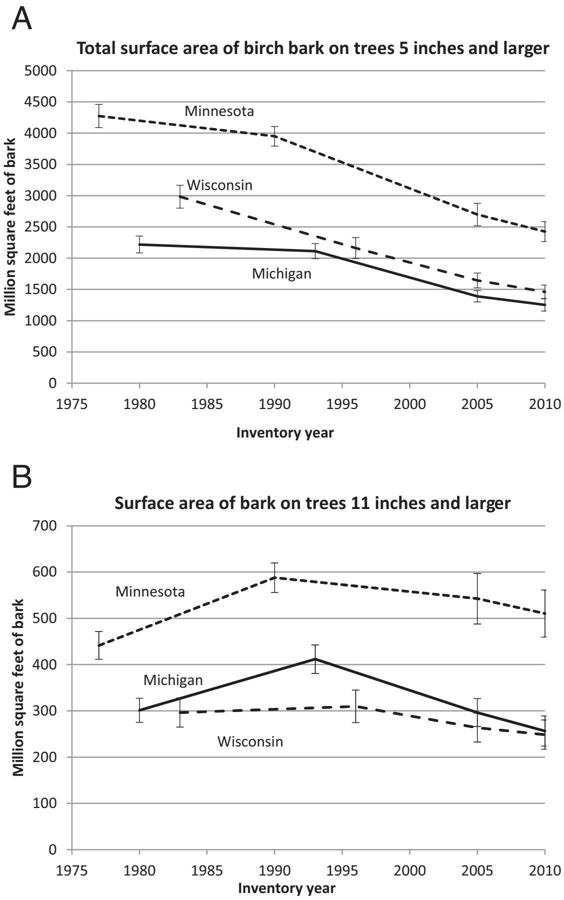

Figure 4. Trends in birch bark supply on Lake States timberland. (A) Estimated total surface area of birch bark on the lower 8 ft of live paper birch trees 5 in. dbh and larger (top). (B) Estimated birch bark surface area on trees 11 in. dbh and larger (bottom). Vertical bars indicate 95% confidence intervals for each estimate. (See analytical methods section for the model used to estimate birch bark surface area.)

We employ this model[4] following standard FIA procedures for estimates of user-defined attributes (O'Connell et al. 2013) to produce estimates for total harvestable bark in 1980, 1990, 2005, and 2010.

Results

Results of our analyses show trends in the birch resource and relationships between stand-level measurements and bark characteristics. Because our primary intent here is to focus on the integration of TEK and scientific inventory methods, we present highlights of those analyses and their implications. More detail on analytical results is available at Moser et al. (in press).

Our findings confirm the observations of TEK experts that birch supplies have decreased. Estimates of the total paper birch resource for live trees 5 in. dbh and larger on timberland show declines of 45% in total numbers of trees and 37% in timber volume. Over the same period, the total timber resource (all species of trees) increased across the region, with timberland area increasing from 45.9 million acres to 51.9 million acres (a 13% increase) and volume rising from 53.4 to 72.1 billion cubic feet (an increase of 35%). Thus, both the overall birch resource and its relative proportion of the total timber resource have declined.

There is potential for this decline in birch to reverse itself, however. Over the 5 years from 2005 to 2010, the total number of live birch saplings on timberland has increased by 8.8%. As shown in Table 2, this increase compares favorably with that for red maple (*Acer rubrum,* 6.5%) and balsam fir (*Acer balsamea,* 8.9%), both of which are early successional species typically found in association with paper birch. Lower rates of change in sapling numbers were seen for quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), and jack pine (*Pinus banksiana*). An exploration of the factors that will affect development of these saplings into larger trees is beyond the scope of this study. However, we note that, in addition to biology, stumpage prices can be expected to drive change in the birch resource.

As the overall birch resource has declined so too has the availability of harvestable birch bark. Harvestable birch bark surface area fell 46% during the 30-year period from 1980 to 2010 (Figure 4A). Between the 1990 and 2010 inventories alone, harvestable bark on large trees (11 in. dbh and larger), such as those needed for canoe making, decreased 22% (Figure 4B). The 2005 and 2010 inventories show decreases in bark volume on large and small diameter (5—11 in. dbh) birch trees of 8.2 and 11.0%, respectively, over these 5 years.

Despite reduced supply, relationships between observed bark characteristics and stand-level measurements may aid gatherers in finding bark that meets their needs. Our analyses show that smooth bark (texture code = 1; see Appendix) is significantly more common on birch trees in stands where other species dominate. However, extent of exfoliation, a characteristic that relates to bark tightness and brittleness and adversely affects the ease with which large pieces of bark can be harvested, does not show a similar relationship to dominant tree species.

Discussion

Iterative process remains important in later stages of a TEK-based inventory. Next steps in the birch bark protocol include reviewing results of analyses with tribal gatherers who participated in earlier phases of the research to assure that interpretation is culturally informed and has the full benefit of TEK. Such a review will serve as another check on whether measurements and analyses are capturing the desired values.

Identifying ways to increase efficiency also will be a goal of future GLIFWC-USDA Forest Service review of the inventory protocol. For example, our analyses suggest that measurements in the lower 8 ft of a tree correlate strongly with those in the upper portion, such that the latter might be eliminated. Review of measurements, data recording, and the field guide in tandem with the results of analyses may reveal other opportunities to increase efficiency while enhancing reliability. Providing field crews with additional training on the appearance of previously harvested trees and information on the uses of birch bark also may increase confidence in their ability to accurately assess bark attributes. One option for delivery of this information is a short video featuring GLIFWC staff and TEK experts, designed to help crews appreciate their part in a larger effort.

Decisions on the future of the targeted birch bark inventory await review of its history and results, their usefulness to GLIFWC members, and budgetary realities. However, results to date already have provided information useful in understanding the status of the birch bark resource.

Conclusions

Forest inventories are driven by the goals of forest management. As the goals of forest management have changed from a primary focus on timber and fiber production, extensive inventory has embraced a broader array of forest values and user communities. Given its national responsibility, FIA necessarily operates at a large scale, with an extensive sampling scheme. However, treaty obligations and related considerations sometimes constitute the kinds of special circumstances Spurr (1952) believed necessary to justify targeted inventories.

Where this is the case, our experience with birch bark offers a model and lessons learned. When an inventory is undertaken to provide information for a community with special concerns, it is desirable to include community experts from design through interpretation of results, with TEK and Western science recognized as complementary sources of information. Willingness to work in an iterative fashion and inclusion of team members with intercultural skills help assure success integrating the contributions of experts who rarely interact and may not have a shared vocabulary. Field testing measurements and protocols allows for modifications to increase accuracy and efficiency. Thorough training and guidelines for crews are important, especially where variables are novel. If a targeted inventory is an addition to existing protocols, the match between sample size and goals deserves careful consideration. Finally, successful implementation requires attention to budgets for actual time spent and financial costs.

Bridging differences between TEK and western mensuration science requires patience and commitment on all sides. While challenging, the work described here demonstrates that it can be done. Linking TEK and Western science for forest inventory will broaden the scope of forest management and the people who benefit from it.

Endnotes

1. The Anishinaabe words in this article are those used by the GLIFWC as instructed by GLIFWC Advisory and Guidance Input Group of Elders (known as GAAGIGE, meaning "forever grateful"). Spelling comes from Nichols and Nyholm (1995).
2. In standard FIA protocols, 5 in. is the minimum dbh used to calculate volume.
3. Timber volume is the volume of sound wood in live trees 5 in. dbh and larger.
4. It should be noted that there is not a large difference between this observation of bark area and one that assumes the 8 ft. section is a cylinder of diameter equal to dbh (1.6% more bark than the cylinder for a 5 in. dbh tree and 4.5% more for a 20 in. dbh tree).

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Appendix

Table A1. Attributes and data value codes with definitions for birch bark inventory. Photo illustrations were provided for all potential data values (Danielsen and White 2003).

Variables	Codes	Definitions
Curvature	0	No curvature
	1	Moderate curvature
	2	Extreme curvature
Branching	0	Absent
	1	Present
Past harvest	0	No bark harvest
	1	<1 yr
	2	1–<3 yr
	3	3–<6 yr
	4	6–<10 yr
	5	>10 yr
Bark texture	1	0–25% rough bark
	2	26–50% rough bark
	3	51–75% rough bark
	4	76–100% rough bark
Lenticels	1	Fine
	2	Coarse
Branch scars	0	Absent
	1	Present
Exfoliating bark	0	Absent
	1	<50% exfoliating bark
	2	>50% exfoliating bark
Blemishes	0	Absent
	1	Present
Fungus	0	Absent
	1	Present
Lichens and moss	0	Absent
	1	Present