Exploring Relationships Between Non-Human Relatives in Riparian Cedar Swamp Ecosystems of Baraga County, Michigan

Andrew Kozich, Carissa LaFernier, Sydni Voakes
Keweenaw Bay Community College

Patrick LaPointe, Gene Mensch
Keweenaw Bay Indian Community Natural Resources Department

Riparian (stream-side) wetlands provide critical links between aquatic and terrestrial ecosystems. We examined dynamics of cedar swamps in northern Michigan as a preliminary exploration of relationships between species of high ecological and cultural value to the Keweenaw Bay Indian Community. Northern white cedar (Thuja occidentalis; Ojibwa: giizhik) is one of the four sacred medicines to Anishinaabe peoples. It lives in damp environments where its dense foliage can create cool, shady micro-climates that help regulate stream temperature. Coldwater streams, in turn, provide critical habitat for brook trout (Salvelinus fontinalis; Ojibwa: maazhamegoons), a traditional staple food for Anishinaabe. We compared various factors influencing stream temperatures and found canopy cover to be the most tightly correlated, although species composition had little effect.

Key words: cedar swamp, northern white cedar, riparian wetlands, brook trout, Keweenaw Bay Indian Community, Anishinaabe

And then there is the next one. The cedar tree, that was another one that was asked, "How will you help the Anishinaabe?" Nanabosh asked. "Oh there are a lot of ways I can help the Anishinaabe," he said. "When somebody has a child, when a couple has a child, they will use my wood to make the cradleboard," he said. "I will give him all the love that I have to offer to the child. I shall bestow many visions onto him for the duration that he is in the cradleboard. And he shall dream too. The child will have healthy bones, have a straight spine, strong and straight bones just be totally healthy if one uses the cedar. I have many uses that I can give them, when they want to make medicine from my being a tree. When someone is making a canoe that is one use that will be used to make the strips of cedar on the bottom when someone makes it. They can make a cedar bark covering for their shelter when they want to stay warm during the winter." That is the one, the cedar bark, that will be utilized for a roof covering. And also these trees they will make other things like rice knockers, how it was said. This is where it will come from. "There are many ways I can help the Anishinaabe. I shall care for them too" (Jones, 2013; pp. 106-107).

Introduction

The Anishinaabeg are one of the largest Indigenous groups in North America with nearly 150 different bands living throughout their homeland in present-day United States and Canada (Benton-Banai, 1988). Anishinaabeg are often known by various regional names such as Chippewa, Ojibwe (or Ojibway/Ojibwa), Odawa (or Ottawa) and Bodewadomi (or Potawatomi). In Anishinaabe teachings, plants represent life. They have spirits as humans and animals do. Plants are relatives who have gifts to offer, and humans' relationships with them should be respectful and reciprocal. Plants do not need us, but we need them (Geniusz, 2009; Johnston, 1976; Kimmerer, 2015).

Giizhik (northern white cedar; *Thuja occidentalis*) is one of most sacred plants in Anishinaabe culture and is one of the four sacred medicines alongside asemaa (tobacco), mashkwadewashk (sage), and wiingashk (sweetgrass) (Benton-Banai, 1988; Johnston, 1976). In addition to its utilities described in the story above, cedar represents health and the continuity of life and is used for purification of the body and spirit (Johnston, 1976). Cedar is omnipresent at ceremonies such as sweat lodges, drum circles, and powwows. Its medicinal properties as a tea are helpful in treating coughs, headaches, and blood ailments (Danielson, 2002; Dickman & Leefers, 2016; Meeker et al., 1993). Cedar leaves are often placed in shoes to ensure safe travels and are hung above doorways to purify homes (Benton-Banai, 1988).

Cedar's many cultural values appear matched by its ecological values. It belongs to the genus *Arborvitae*, which means "tree of life" in Latin (Barnes & Wagner, 2004; MSU, 2015). Cedar provides critical winter cover and food for waawaashkeshi (white-tail deer; *Odocoileus virginianus*) and other animal species. It is a strong, slow-growing tree that is very tolerant of shade and can thrive in habitats that are too harsh for many other species, including acidic soils, swamps, and on rocky cliffs exposed to wind (Barnes & Wagner, 2004). When toppled by wind (common in wet habitats due to shallow root systems), cedar are remarkable survivors; branches respond by growing upright and eventually developing their own root systems to continue as individual trees (Barnes & Wagner, 2004; Danielson, 2002; Kost, 2002; Pregitzer, 1990).

In the northern Great Lakes region, cedar is most often found in forested wetland habitats commonly known as "cedar swamps". These diverse ecosystems are also known as "northern conifer wetlands (Dickmann & Leefers, 2016), "rich conifer swamps" (Kost, 2002), and "lowland swamps" (Pregitzer, 1990), among other names. Cedar swamps are common along lakeshores and particularly adjacent to streams, where they represent an example of a riparian (streamside) wetland community. Because streams are found in depressed floodplains, riparian cedar swamps are often fed by cold groundwater moving down gradient and at shallow depths relative to the surface (Kost, 2002). The constant supply of groundwater, which is typically rich in nutrients, results in high biodiversity and rich, peat-accumulating soils across these ecosystems (Kost, 2002; Pregitzer, 1990). Cedar are adapted to the seasonally variable hydrologic conditions and are often the dominant tree species, creating dense shade that provides cool, damp micro-climate conditions that benefit many other species that are adapted to shade and moisture. Mosses, lichens, and liverworts are common in cedar swamps, as well as over 30 plant and animal species that are considered rare (Kost, 2002).

In riparian swamps, cedar provides life-giving functions and services to aquatic species too. The shade created by cedar's dense foliage helps regulate stream temperatures by minimizing heat and evaporation from sun exposure (Johnson, 2004; Kost, 2002). One of the primary beneficiary species of this cooling effect is maazhamegoons (brook trout; *Salvelinus fontinalis*). Brook trout are coldwater species that require water temperatures below 70° F (Jobling, 1981). Canopy cover is critical for keeping stream temperatures below this threshold, maintaining year-round suitable habitat, in climate zones characterized by summer temperature extremes such as those of the Great Lakes region (Nuhfer et al., 2015). Brook trout also benefit from the habitat structure provided by cedar. Streams often undercut banks below cedar trunks and roots, providing valuable cover for brook trout (Anglin & Grossman, 2013; VanDusen et al., 2005). Downed cedar trunks and branches, common in riparian settings, create shade and pools of deeper water required by brook trout (Kost, 2002). Thus, in riparian swamp ecosystems a strong relationship exists between cedar and brook trout.

Of course, relationships between different species have long been recognized and valued by Anishinaabe peoples (Danielson, 2002; Geniusz, 2009; Johnston, 1976; Kimmerer, 2015; Wilson, 2008). Relationships in cedar swamp ecosystems are rich and complex, extending beyond the already-cited examples of humans, trees, deer, mosses, fish, and water, which is considered the lifeblood of mother earth (Benton-Banai, 1988; Johnston, 1976). Subtle changes to cedar swamps could disrupt their natural balance and result in negative ecological and cultural impacts. Well-established concerns include the effects of climate change, careless timber harvesting, and reduced cedar regeneration due to over-browsing by deer (Chimner & Hart, 1996; Comte et al., 2012; Cornet et al., 2000; Forester et al., 2009; Kost, 2002; Pregitzer, 1990; Rooney et al., 2002; VanDusen et al., 2005). Interestingly, damages from over-browsing are largely attributable to unnaturally high deer populations from the drastic reduction of an important relative and predator, ma'iingan (gray wolf; *Canis lupus*).

The mixed-methods research described in this article was exploratory in nature and is intended to help better-understand relationships in riparian cedar swamp ecosystems of the northern Great Lakes region. The study site was the L'Anse Indian Reservation in Michigan, home of the Keweenaw Bay Indian Community (KBIC), focusing on Menge Creek (Figure 1). In this area, riparian cedar swamps are common and brook trout are a staple food for Anishinaabe peoples. Brook trout stewardship is also a major component of the KBIC Natural Resources Department (KBIC-NRD) fisheries program, stocking over 40,000 fingerlings annually in coldwater streams across the reservation. With many potential threats to cedar swamp ecosystems, it was important to understand as much as possible about relationships and incorporate knowledge from the sciences and Indigenous perspectives into stewardship plans. The research team included faculty and students from the Environmental Science Department at Keweenaw Bay Ojibwa Community College (KBOCC), a KBIC-NRD fisheries biologist, and a KBIC-NRD field fisheries technician. Two 2020 KBOCC student capstone research projects were linked to this work. Three members of the research team were enrolled KBIC Tribal members.

Our objectives in this preliminary stage of research were to examine relationships between Menge Creek water temperature and canopy species composition, canopy density, and groundwater inflow. We also conducted a community survey to synthesize community perspectives on the importance of brook trout habitat. To truly reflect community-based research, we viewed the survey as an important component of the project, especially since previous related work found very deep values (and concerns) related to local water and fishery resources (Kozich, 2016; Kozich et al., 2019; Kozich et al., 2020).

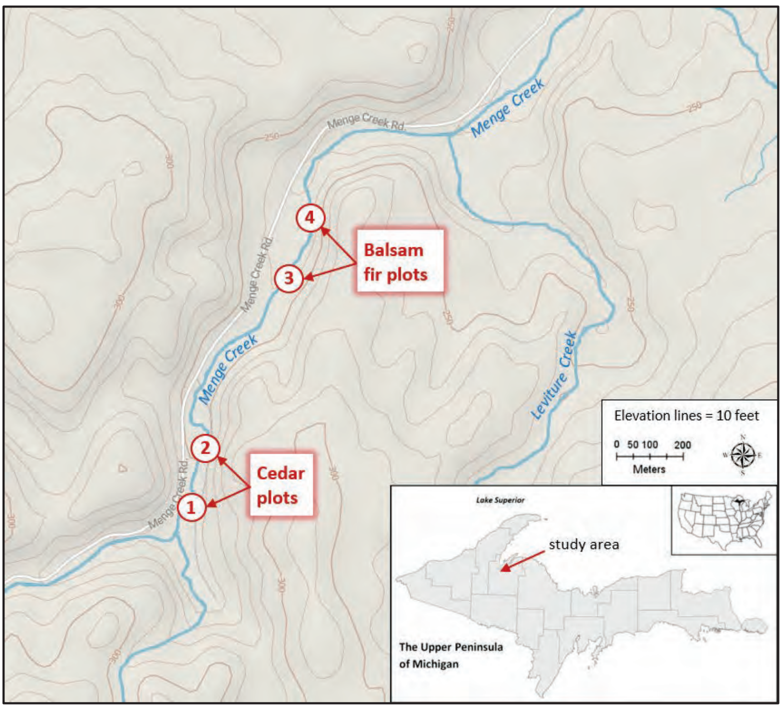
As part of an externally funded research project, all protocols were ultimately designed, informed, and approved by the KBIC, specifically including the KBIC Tribal Council and the KBOCC Institutional Review Board. Applications of this work are intended to support Indigenous knowledge, sovereignty, and nation-building. Survey respondents participated willingly and without compensation and were informed of our research objectives. Field study sites were treated respectfully. As with all KBOCC community-based research, findings will be shared with all relevant community partners, particularly those involved in natural resource stewardship.

Methods

Several preliminary steps and assumptions were required with field research methodology to measure variables with as much control as possible. We began by accessing topographic data from U.S. Geological Survey maps to identify potential locations for at least four sampling plots along Menge Creek. We sought a stretch of the stream where all plots would lie between surface water confluences, as inflow from tributaries could potentially alter downstream Menge Creek temperatures. Next, we sought locations with relatively steep floodplain gradients, assuming that adjacent hillsides would result in groundwater seepage into the stream (known as a 'gaining stream'). With these steps we assumed that surface water temperature and groundwater inflow would be as consistent as possible across all sample plots.

Figure 1

Location of Sampling Plots in Baraga County, Michigan



Note. Plot sizes are not to scale (image modified from www.usgs.gov).

We identified a 1.5 kilometer stretch of Menge Creek appearing on maps to meet these criteria. Upon site inspection we confirmed that the stretch was indeed suitable. Saturated, peat-accumulating forested wetlands adjoined the stream throughout this stretch, with visual evidence of groundwater infiltration to the stream. Anecdotal observations of canopy differences between upstream and downstream portions of this stretch allowed us to establish sampling plot locations where we could compare the potential influence of species composition on stream temperature. We established plots 1 and 2 as 'cedar plots', 200 meters apart; approximately one kilometer downstream we established plots 3 and 4 as 'balsam fir plots', again 200 meters apart (Figure 1). Across sampling locations, typical stream depth ranged from 10 to 40 centimeters, with a width of 2-3 meters and a discharge of 0.2 m^3/second. Throughout this stretch the stream features a sandy substrate and numerous pools caused by downed trees.

We used standard forestry techniques to characterize canopy features at all plots, which entails U.S. standard units of measurement. Circular sampling plots were centered at the middle of the stream channel with a radius of 37.25 feet, resulting in 0.1 acre plots. Within each plot we identified and measured all trees with a DBH (diameter at breast height; approximately 4 feet from the ground) of 1 inch or greater. This resulted in a dataset of 329 trees across all plots.

Trees at each plot were sorted into two groups to provide added detail. Those with a DBH of 4 inches or greater were considered 'overstory trees', likely exuding the greatest ecological influence on the vicinity. Trees with a DBH between 1 and 4 inches were considered 'midstory trees', offering a glimpse into likely long-term successional trajectories (i.e., future characteristics) of the forest communities. We used a spherical densiometer to assess canopy density at each plot center, recorded as percent cover. We also estimated canopy height using a Suunto model 1030 clinometer. Canopy data collection occurred in August and September 2019.

We used Onset HOBO model Pro V2 submersible temperature dataloggers to record temperatures for the stream, groundwater, and sub-canopy air at the center of each plot. Dataloggers were programmed to record temperature readings every two hours. Stream dataloggers were zip-tied to bricks and placed at depths ensuring that they would remain submerged throughout the study period. Groundwater dataloggers were buried 0.5 meters deep in saturated peat and muck at a distance of 4 meters from the stream bank. Air dataloggers were suspended by the nearest suitable tree branch to the plot center at a height of approximately 2 meters above the stream. For our purposes, air temperature was used as a proxy for the influence of canopy density and its role in providing a cooling effect in the vicinity of streams.

Dataloggers were left in place for 19 days in September 2019. Between the 12 loggers, a total of 2736 temperature datapoints were recorded and internally stored. After retrieval, dataloggers were returned to the KBOCC science lab for data upload using proprietary HOBO hardware and software. Analysis was conducted using Microsoft Windows Excel.

Data allowed us to test two exploratory hypotheses that we formulated based on relevant literature: 1) stream temperature will be significantly different between cedar dominated plots and balsam fir dominated plots; and 2) stream temperature will be more closely correlated to groundwater temperature than air temperature.

To enrich this research, a student assistant conducted a community survey linked to our broad objectives. The survey was also part of her capstone research project required to complete the KBOCC Environmental Science associate degree program. Survey questions were designed to gain insight on community perspectives on the importance of the streams that provide brook trout habitat. KBIC Tribal members and descendants age 18 and older were eligible to complete the survey, although we did not employ measures to verify that respondents met these requirements (as is the case with much research based on self-reporting). The survey was promoted on various KBIC social media outlets and was administered for two weeks in October 2019 using SurveyMonkey.

Results

We quantified extensive canopy differences between cedar plots (1 and 2) and balsam fir plots (3 and 4), as summarized in Table 1. Cedar was the dominant overstory species in plots 1 and 2 in terms of density, relative abundance, and size. Gaagaaimizh (eastern hemlock; *Tsuga Canadensis*) and wiinizik (yellow birch; *Betula Allegheniensis*) were the next-most abundant overstory species in these plots, with others in lesser abundance. Six species were present in the midstory, with zhaashaagobiimag (mountain maple; *Acer spicatum*) and zhingobiig (balsam fir; *Abies balsamea*) the most abundant. Measured from plot centers, canopy cover was 78% in plot 1 and 82% in plot 2. Photographic evidence supports our observations of generally sparse midstory layers, likely due to the influence of the large and abundant overstory cedars (Figure 2). We estimated a canopy height of 18-20 meters.

Plots 3 and 4 featured greater tree density and species diversity than plots 1 and 2 (Table 1). Overstories were dominated by balsam fir, with zhiishiigimiiwanzh (red maple; *Acer rubrum*), yellow birch, and other species in lesser abundance. Large cedars were present but less abundant than in plots 1 and 2. The most notable difference, however, was the comparatively greater density in the midstory layers. Plots 3 and 4 were dominated by dense clusters of small wadoop (tag alder; *Alnus rugosa*), with six additional species present in midstories (Figure 3). Canopy cover was 71% in plot 3 and 73% in plot 4. Canopy height, aside from the few large cedars, was estimated to be 12-14 meters, which is notably shorter than plots 1 and 2.

Table 1

Forest Canopy Data from Sampling Plots

Cedar plots (1 and 2)			
Overstory species	density (trees/acre)	relative abundance	average DBH (in.)
Giizhik (northern white cedar; *Thuja occidentalis*)	110	39%	13.6
Gaagaaimizh (eastern hemlock; *Tsuga Canadensis*)	60	21%	9.0
Wiinizik (yellow birch; *Betula Allegheniensis*)	60	21%	7.1
Zhingobiig (balsam fir; *Abies balsamea*)	25	9%	4.5
Zesegaandag (black spruce; *Picea mariana*)	25	9%	6.6
Zhingwaak (eastern white pine; *Pinus strobus*)	5	1%	6.2
Midstory species	density (trees/acre)	relative abundance	average DBH (in.)
Zhaashaagobiimag (mountain maple; *Acer spicatum*)	85	28%	1.6
Zhingobiig (balsam fir; *Abies balsamea*)	70	23%	1.8
Zesegaandag (black spruce; *Picea mariana*)	50	16%	1.5

Gaagaaimizh (eastern hemlock; *Tsuga Canadensis*)	45	15%	2.8
Wiinizik (yellow birch; *Betula Allegheniensis*)	45	15%	1.3
Zhiishiigimiiwanzh (red maple; *Acer rubrum*)	10	3%	1.5

Balsam fir plots (3 and 4)

Overstory species	density (trees/acre)	relative abundance	average DBH (in.)
Zhingobiig (balsam fir; *Abies balsamea*)	125	39%	6.5
Zhiishiigimiiwanzh (red maple; *Acer rubrum*)	75	23%	8.5
Wiinizik (yellow birch; *Betula Allegheniensis*)	35	11%	7.0
Giizhik (northern white cedar; *Thuja occidentalis*)	30	9%	15.6
Zesegaandag (black spruce; *Picea mariana*)	20	6%	5.7
Gaawaandag (white spruce; *Picea glauca*)	20	6%	7.3
Zhingwaak (eastern white pine; *Pinus strobus*)	10	3%	7.0
Baapaaggimaak (black ash; *Fraxinus nigra*)	5	2%	5.1
Wiisagi-mitigomizh (northern red oak; *Quercus rubra*)	5	2%	10.4
Midstory species	density (trees/acre)	relative abundance	average DBH (in.)
Wadoop (tag alder; *Alnus rugosa*)	440	61%	1.8
Zhingobiig (balsam fir; *Abies balsamea*)	95	13%	2.4
Zhaashaagobiimag (mountain maple; *Acer spicatum*)	55	8%	1.5
Wiinizik (yellow birch; *Betula Allegheniensis*)	40	6%	2.0
Gaawaandag (white spruce; *Picea glauca*)	25	3%	2.2
Zhiishiigimiiwanzh (red maple; *Acer rubrum*)	25	3%	2.5
Baapaaggimaak (black ash; *Fraxinus nigra*)	20	3%	1.3
Zesegaandag (black spruce; *Picea mariana*)	20	3%	1.8

Figure 2

Photograph of Plot 2 ('Cedar Plot').

Note. The large trees on the left of the image are northern white cedar (*Thuja occidentalis*).

Figure 3:

Photograph of Plot 3 ('Balsam Fir Plot'),

Note. Highlighting the dense midstory layer dominated by tag alder (*Alnus rugosa*).

To test hypothesis 1, we compared the mean daily stream temperature of cedar plots with that of balsam fir plots. A t-test showed that there was no significant difference in the mean daily stream temperatures between these groups. The hypothesis was not supported, indicating that species composition did not significantly affect stream temperature.

To test hypothesis 2, we conducted correlation analyses in Microsoft Excel to compare the relative influence of groundwater temperature and sub-canopy air temperature on stream temperature. We ran separate analyses for each of the four sample plots. For three of the plots (1, 2, and 4), air temperature was most closely correlated to stream temperature. For plot 3, groundwater temperature was most correlated. Therefore hypothesis 2 was supported for plot 3 but not for the others. See Table 2.

Table 2

Results of Correlation Analyses for Each Plot, with Menge Creek Stream Temperature as the Dependent Variable

Independent variable	Plot 1	Plot 2	Plot 3	Plot 4
Groundwater temp	0.558169868	0.532079163	0.940356816	0.685711999
Sub-canopy air temp	0.916676297	0.913995962	0.872534293	0.848355062

Note. In correlation analyses, the output value will range from 0 (no correlation) to 1 (100% correlation).

The community survey garnered 84 responses from KBIC members and descendants, with 75 from residents of Baraga County. Respondents listed several values of local streams (Table 3), with fishing as the most cited response (69%). Respondents were also asked about their reasons for stream fishing. Sustenance was by far the most cited response (60%), followed by sport (31%) and cultural enrichment (19%). Support for the KBIC's fish-stocking efforts was very high; 92% of respondents stated that stocking is either "very important" (75%) or "somewhat important" (17%). Using the same scale, 89% of respondents either "strongly agreed" or "somewhat agreed" that human behaviors may negatively impact fish habitat in streams. Seventy-three percent were concerned about the potential of rising stream temperatures impacting fish populations.

Table 3

Top Five Values Associated with Baraga County Streams

Reason	Number of respondents	Percent of respondents
Fishing	58	69%
Wildlife viewing	50	60%
Hiking	46	55%
Swimming	40	48%
Cultural enrichment	32	39%

Note. Respondents were allowed to select multiple answers.

Respondents also shared their observations of changes in local streams over time. Forty-five percent of respondents said they had noticed reduced stream depth and 36% reported reduced flow. Thirtyfive percent stated that the predictability of seasonal patterns in streams have changed over time. Changes in water temperature and clarity were noted by 20% of respondents. Regarding changes in brook trout, 30% of respondents have observed fewer fish and 20% observed smaller fish.

Discussion

This preliminary investigation produced intriguing findings that in some aspects confirm knowledge from the literature while in other aspects raises new questions. The following paragraphs elaborate on key findings and describe how they will be re-examined in follow-up work.

We found sample plots 1 and 2 to be very representative of cedar swamps as described in the literature (Kost, 2002; MSU, 2015). Cedar was unquestionably the dominant canopy tree species, and all other species in the overstory and midstory matched expectations. We also found plentiful accumulations of saturated peat and muck and a shallow water table. The presence of groundwater feeding the stream was the basis for our hypothesis that groundwater would be correlated to stream temperature (Kost, 2002).

By comparison, the collection of species in plots 3 and 4 reflected riparian wetland communities that did not quite match any simplified classifications in the literature. All species we found were typical of wetland habitats, although their relative abundance and structural arrangement (i.e., size class relationships) indicated a fairly recent disturbance such as logging. For example, balsam fir, the most abundant overstory species in these plots, typically plays a less-dominant role in its surroundings. A competitive advantage of balsam fir is that it is shade-tolerant and can thrive as an understory member below the upper canopy (Barnes & Wagner, 2004). While we found larger individuals of other species in plots 3 and 4, balsam fir was by far the most abundant overstory species. The presence of tag alder further suggested that a recent disturbance likely happened. Tag alder is not shade-tolerant; its requirement of abundant sunlight indicates that canopy openings must have existed at the time of its establishment. We found the differences between these plots and the cedar plots intriguing to investigate, although we did not find the differences in species composition significantly related to stream temperature. Although our research design was simple and preliminary, our findings suggest that the shade provided by any type of canopy cover aids in stream temperature regulation. We suspected that the dense foliage of cedar could provide greater micro-climatic properties compared to other species, but findings do not support this hypothesis.

The findings described above present ideal opportunities for further investigation. For example, we documented substantial differences in midstory density between cedar plots and balsam fir plots. In cedar plots, foliage was concentrated in the overstory trees and the midstory layer was relatively sparse. In balsam fir plots, the midstory layer was comparatively dense, especially in areas featuring clusters of small tag alder trees. Possible effects of these structural differences could be examined more closely by configuring air temperature dataloggers at varying heights, including above the canopy. Our use of one temperature logger below the canopy was simply to assess the effects of shade (i.e., percent canopy cover) and might not have been adequate to examine the influence of varying canopy features.

Based on the literature, we were surprised that sub-canopy air temperature was more closely correlated than groundwater to stream temperature in three of our four plots (Kost, 2002). A possible explanation is that our research occurred in September, when mean daily air temperatures in northern Michigan solidly reflect autumn conditions. We are planning to replicate this test during peak summer conditions, and we anticipate that different findings could result. Regardless of the outcomes from correlation analyses, however, a direct relationship did exist between groundwater temperature and stream temperature, as indicated by correlation coefficients greater than 0.5 in all plots.

A limitation in our research design could be the expectation that water temperatures could vary across such a short distance in the same stream. A previous KBOCC student documented significant stream temperature differences across a shorter distance, but his study sites were upstream and downstream of a golf course, where direct sunlight was presumably able to warm the stream (Rodriguez, 2017). Perhaps the absence of significant canopy openings between our sample plots precluded the possibility of significant temperature differences. For fully-wooded sites, expansions of our research to quantify relationships between canopy, groundwater, and stream temperature will involve study plots in multiple streams.

While cedar was present in all sample plot overstories, it was completely absent in the midstory layers. This indicates that deer browsing is likely preventing seedlings from reaching maturity, as has been noted in the literature (Barnes & Wagner, 2004; Chimner & Hart, 1996; Cornett et al., 2000; Kost, 2002; Rooney et al., 2002). If this trend continues, these valuable forest communities are likely to transition over time into communities dominated by other species such as spruces, balsam fir, or red maple (Cornett et al., 2000; Kost, 2002). This could already be happening in our plots 3 and 4, which were dominated by other species, although we suspect a human disturbance could have hastened this process. Based on our preliminary findings, ecological impacts to Menge Creek may not be as extreme as we suspected since the species in plots 3 and 4 appear similarly effective at maintaining cool stream temperatures. Losses of cedar would certainly impact future generations of Anishinaabe peoples, however, considering its immense cultural value.

Regardless of differences in species composition or other canopy characteristics, we found relationships between trees and brook trout habitat intact across all study plots. We documented stable and cool stream temperatures, abundant shade, and habitat-creating features such as cut banks and debris-induced pools, all of which are important to brook trout. In fact, we observed brook trout at various plots while wading in the stream. An important finding from our work is the confirmation that in riparian swamps, fisheries management and forest management are undoubtably linked, as others have noted (Kost, 2002; Johnson, 2004; VanDusen et al., 2005).

In addition to increasing our understanding of relationships between various non-human entities, through our survey we increased our understanding of relationships between the human community and mother earth. Respondents expressed a wide range of values associated with streams and noted plentiful concerns about potential negative impacts to them. We only included one question involving changes in local streams over time, with respondents observing changes to stream depth, flow, temperature, clarity, and the timing of seasonal patterns. These responses indicate that valuable insight could be gained by following up the survey research with open-ended interviews. This type of insight from community members, representing traditional ecological knowledge, could be very valuable to natural resource stewards such as those at the KBIC-NRD. Previous survey research in the community found similar sentiment regarding water and fishery resources broadly, but our findings expand this knowledge by specifically examining community perspectives on brook trout habitat.

Conclusion

In keeping with Indigenous research methodology, all persons involved in this project were from the local community and have vested interests in our study sites and our research findings (Wilson, 2008). Our research team included educators, students, natural resource stewards, and KBIC Tribal members. To each of us this research was sacred in our own respective ways, just as our research topic is sacred to the community. As this project continues and expands, we will continue seeking insight from and sharing findings with the community as we try to better understand complex riparian wetland ecosystems and the array of relationships that exist between non-human relatives that inhabit them.

Acknowledgements

We acknowledge that our study area lies within ancestral, traditional, and contemporary lands and waters of many Indigenous nations, including the Anishinaabeg. We also acknowledge our many more-than-human relatives who call this region home and have done so since time immemorial. As the original caretakers of these lands and waters, we are most grateful to all our relatives and we thank all who practice stewardship and care today in partnership with local, state, federal, tribal, and other governance entities throughout the Great Lakes region.

This research was funded by the U.S. Department of Agriculture National Institute of Food and Agriculture, Tribal Colleges Research Grants Program, USDA-NIFA-TCRGP006534. We thank Karen Colbert and Sophia Michels for valuable contributions. We also appreciate the guidance of the editorial staff of Tribal College and University Research Journal and the anonymous reviewers whose guidance helped improve the quality of this manuscript.

References

Anglin, Z. W. & Grossman, G. D. (2013). Microhabitat use by southern brook trout (*Salvelinus fontinalis*) in a headwater North Carolina stream. *Ecology of Freshwater Fish*. https://dx.doi.org/10.1111/eff.12059.

Barnes, B. V. & Wagner, W. H. (2004). *Michigan Trees: A Guide to the Trees of the Great Lakes Region.* Revised and updated. Ann Arbor, MI: University of Michigan Press.

Benton-Banai, E. (1988). *The Mishomis book: The voice of the Ojibway*. Minneapolis, MN: University of Minnesota Press.

Chimner, R. A. & Hart, J. B. (1996). Hydrology and microtopography effects on northern white-cedar regeneration in Michigan's Upper Peninsula. *Canadian Journal of Forestry Research, 26,* 389-393.

Comte, L., Buisson, L., Daufresne, M., & Grenouillet, G. (2012). Climate-induced changes in the distribution of freshwater fish: observed and predicted trends. *Freshwater Biology, 58(4),* 625–639. https://dx.doi.org/10.1111/fwb.12081.

Cornett, M. W., Frelich, L .E., Puettmann, K. L., & Reich, P. B. (2000). Conservation implications of browsing by *Odocoileus virginianus* in remnant *Thuja occidentalis* forests. *Biological Conservation, 90,* 359-369.

Danielson, K. C. (2002). *The Cultural Importance, Ecology, and Status of Giizhik (Northern White Cedar) in the Ceded Territories.* Great Lakes Indian Fish and Wildlife Commission Administrative report 02-06. Available at https://data.glifwc.org/archive.bio/Administrative%20Report%2002-06.pdf.

Dickman, D. I. & Leefers, L. A. (2016). *The Forests of Michigan.* Revised and updated. Ann Arbor, MI: University of Michigan Press.

Forester, J. D., Anderson, D. P., & Turner, M. G. (2009). Landscape and local factors affecting northern white cedar (*Thuja occidentalis*) recruitment in the Chequamegon-Nicolet National Forest, Wisconsin (U.S.A.). *American Midland Nationalist, 160,* 438-453.

Geniusz, W. D. (2009). *Our Knowledge is Not Primitive: Decolonizing Botanical Anishinaabe Teachings.* Syracuse, NY: Syracuse University Press.

Jobling, M. (1981). Temperature tolerance and the final preferendum – rapid methods for the assessment of optimum growth temperatures. *Journal of Fisheries Biology, 19*, 439-455.

Johnson, S. L. (2004). Factors influencing stream temperatures in small streams: Substrate effects and a shading experiment. *Canadian Journal of Fisheries and Aquatic Sciences 61,* 913-923.

Johnston, B. (1976). *Ojibway Heritage.* Lincoln, NE: University of Nebraska Press.

Jones, N. (2013). Trees. In St. Arnold, J. & Ballinger, W. (Eds.), *Dibaajimowinan: Anishinaabe Stories of Culture and Respect* (pp.110-116). Odanah, WI: Great Lakes Indian Fish and Wildlife Commission Press.

Kimmerer, R. W. (2015). *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants.* Minneapolis, MN: Milkweed Editions.

Kost, M. A. (2002). Natural community abstract for rich conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 10 pp. Available at: https://mnfi.anr.msu.edu/abstracts/ecology/Rich_conifer_swamp.pdf.

Kozich, A. T. (2016). Climate change and the sacredness of water in Native America: A case study in the Keweenaw Bay Indian Community, Michigan, USA. *Tribal College and University Research Journal, 1,* 20-37.

Kozich, A. T., Gagnon, V. S., Jondreau, G. P., Loonsfoot, T. A., & Rivas, M. L. (2019). Climate change perspectives and policy support in a Great Lakes Anishinaabe community. *Tribal College and University Research Journal, 4,* 5-20.

Kozich, A. T., Gagnon, V. S., Mensch, G., Michels, S., & Gehring, N. (2020). *Ogaawag* spearing in the Portage Waterway, Michigan: Integrating mixed methodology for insight on an important Tribal fishery. In press at *Journal of Contemporary Water Research & Education.*

Meeker, J. E., Elias, J. E., & Heim, J. A. (1993). *Plants used by the Great Lakes Ojibwa.* Odanah, WI: Great Lakes Indian Fish and Wildlife Commission Press.

Michigan State University Forestry Extension Team [MSU]. (2015). Forest Types of Michigan, Northern White-Cedar. E3202 Bulletin 7. 3 pp. Available at: https://www.canr.msu.edu/resources/forest_types_of_michigan_northern_white_cedar_e3202_7.

Nuhfer, A. J., Zorn, T. G., & Wills, T. C. (2015). Effects of reduced summer flows on the brook trout population and temperatures of a groundwater-influenced stream. *Ecology of Freshwater Fish.* https://dx.doi.org/10.1111/eff.12259

Pregitzer, K. S. (1990). The ecology of northern white-cedar. In *Northern white-cedar in Michigan, Workshop Proceedings. Agricultural Experiment Station Research Report* (Vol. 512, pp. 8-14).

Rodriguez, M. C. (2017). *Potential effects of a golf course on coldwater fish habitat* [Unpublished associate degree capstone]. Keweenaw Bay Ojibwa Community College.

Rooney, T. P., Solheim, S. L., & Waller, D. M. (2002). Factors affecting the regeneration of northern white cedar in lowland forests of the Upper Great Lakes region, USA. *Forest Ecology and management*, *163*(1-3), 119-130.

VanDusen, P. J., Huckins, C. J., & Flaspohler, D. J. (2005). Associations among selection logging history, brook trout, macroinvertebrates, and habitat in northern Michigan headwater streams. *Transactions of the American Fisheries Society*, *134,* 762-774.

Wilson, S. (2008). *Research is Ceremony: Indigenous Research Methods.* Black Point, Nova Scotia: Fernwood Publishing.

Author Biographies

Andrew Kozich has been the KBOCC Environmental Science Department Chair since 2011. While working on a Ph.D. in Forest Science from Michigan Technological University he also completed an Associate Degree in Anishinaabe Studies from KBOCC. He conducts community-based research most often related to the abundant and sacred water resources of northern Michigan. He typically mentors 20 or more Environmental Science majors per semester. He enjoys engaging students in hands-on scholarly research and helping guide their independent capstone research projects that are required for graduation. He also enjoys partnering with faculty from other Tribal Colleges and contributing to conferences and workshops relevant to indigenous communities worldwide.

Carisa LaFernier is a 2020 Environmental Science graduate from KBOCC who previously earned an Anishinaabe Studies degree in the same graduating class with Dr. Kozich. The research presented in this manuscript is largely based on the work she completed for her capstone research project. She is an enrolled member of the Keweenaw Bay Indian Community.

Sydni Voakes is a 2020 Environmental Science graduate from KBOCC who assisted with the collection of field data for this research. For her capstone research project, Sydni conducted an analysis of four years of stream temperature data from study sites across the L'Anse Indian Reservation. She is an enrolled member of the Keweenaw Bay Indian Community.

Patrick LaPointe is a Field Fisheries Technician for the Keweenaw Bay Indian Community Natural Resources Department. He frequently provides technical guidance for KBOCC research projects related to fisheries and water resources and served as a valuable mentor for the students who contributed to this work. Patrick is an enrolled member of the Keweenaw Bay Indian Community.

Gene Mensch is a Fisheries Biologist for the Keweenaw Bay Indian Community Natural Resources Department and an Adjunct Instructor at KBOCC, teaching courses in biology, ecology, and fisheries and wildlife biology. Together with Dr. Kozich, he plays a lead role in departmental research projects and works closely with students on their capstone research projects. Gene was recognized as KBOCC's 2020 Faculty Member of the Year, as determined by student testimonials.