Indigenous Phenology: An Interdisciplinary Case Study on Indigenous Phenological Knowledge on the Menominee Nation Forest

A Thesis
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF THE
UNIVERSITY OF MINNESOTA
BY

THOMAS RICHMOND KENOTE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

Advisor: DR. REBECCA MONTGOMERY

JUNE 2020

Acknowledgements

Posoh mawaw-new weyak. Waewaenon kaetaenon. Awaesahsaehsah newishwen. Netotem makana. Keshena ‘skew wekiyan. Omaeqnomenew mesek Anishinaabe netawem. Nahaw, eniq.

First and foremost, I would like to acknowledge that the University of Minnesota – Twin Cities occupies the ancestral, traditional, and contemporary lands of the Dakota Oyate or the Dakota Nation.

Hello and thank you for taking the time to read this. My name is Thomas R. Kenote and I am an Indigenous person who found myself in academia. I am an enrolled member of the Menominee Nation and I am also Lac Courte Oreilles Anishinaabe. I am turtle clan. I would like to acknowledge and honor those who have walked before us and those who will walk after us. I would like to give thanks for my partner, Sasha, and my family who have been my biggest supporters throughout this journey. Waewaenon!

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CMN = College of Menominee Nation

CMN SDI = College of Menominee Nation Sustainable Development Institute

MITW = Menominee Indian Tribe of Wisconsin

MSU NAI = Michigan State University Native American Institute

MTE = Menominee Tribal Enterprises

SI = Smithsonian Institute

UMN = University of Minnesota

USFS = United States Forest Service

Chapter 1: Introduction

Indigenous phenology or Indigenous phenological knowledge is a collaborative concept that builds partnerships through planning, Indigenous knowledge, and scientific understanding of the natural world. Phenology, the timing of annually recurrent lifecycle events (Fitchett et al. 2015), has its roots in western science beginning in the 19th century. Famous nature writers and conservationists like Aldo Leopold and Rachel Carson have long documented phenological observations in their personal journals. However, recordings of phenology date back to at least 5000 years in Asia and centuries in Europe (Cleland et al. 2007). Wisconsin also has a rich history of written western phenology records dating back to the early 20th century (Bradley et al. 1999). Phenology is both a western science and an Indigenous knowledge concept.

In Wisconsin, phenology has been practiced by tribal nations for centuries. Notably the Menominee, Ojibwe, Potawatomi, and Ho-Chunk practice and integrate phenology through tribal beliefs, activities, and ceremonies such as sugar bush in spring and wild rice in the fall. These tribal nations have a unique relationship with the plant and animal relatives in that they have based their lifeways off of the lifecycles of certain organisms.

Indigenous peoples and native communities have relied on phenological knowledge to inform harvesting and gathering. Phenology is also inherently within tribal nations knowledge and language systems. Tribes have used phenology for resource management, agriculture, hunting, fishing, and other ceremonial activities. In particular, I am interested in helping identify the consequences a changing climate has on the forest understory on the Menominee Indian Tribe of Wisconsin's reservation through study of the flowering and fruiting phenology of understory plants.

Phenology informs population abundance and distribution, trophic interactions, ecosystem services, and is also used to monitor the carbon and water cycles (Cleland et al. 2007). Phenology can be used to measure changes within the environment because it is altered by environmental changes such as temperature and precipitation (Cleland et al. 2007). Phenology can be affected in adverse ways by climate change (Kassam et al. 2018). Phenology is affected by climatic events such as extreme weather (i.e. drought and floods) through "inconsistency of seasonality of temperature and precipitation" (Kassam et al 2018, 249). Climate change also has positive implications for phenology such as an earlier spring and warmer temperatures that can lead to more degree-warming days that can create longer growing seasons. Climate change can be measured based on the phenological responses of species of interest.

Phenology has a deep connection to citizen science. Phenological data is often collected by amateur naturalists and citizen science volunteers (USA National Phenology Network, 2019). The field depends on volunteers to record and document phenological changes within their environments. For example, a 61-year long citizen science record from Wisconsin shows consequences of climate change on phenological events such as migratory bird arrival and flower bloom in the spring. The study suggests that organisms that have "phenological adaptability" are more likely to survive a shift in spring arrival than those organisms that may be more dependent on other signals such as photoperiod (Bradley et al. 1999).

Phenology has a wide variety of uses from agricultural recordings to documenting species biology for conservation purposes. Most importantly, it can help observe and document changes within the environment and identify potential impacts of climate change while also be used to prepare for and develop strategies to mitigate these impacts. Phenology is a tool to be used to document changes in ecosystems and allows for responses to these changes.

My thesis is an interdisciplinary two-part thesis. The first chapter is ecological while the second chapter is a blend of social science and Indigenous knowledge. The first chapter looks at the reproductive phenology of 11 forest understory species on the Menominee Indian Tribe of Wisconsin's reservation situated in northeastern Wisconsin. Specifically, I use the phenology of the forest understory plants to examine responses at the community level. The second chapter explores Indigenous phenology or Indigenous phenological knowledge as a process that brings together partnerships in order to combat climate change on the Menominee Indian reservation. Through a case study of an Indigenous phenological knowledge process at the Menominee Reservation, I examine what effects the partnerships had on tribal sovereignty, capacity of the institutions, and whether or not the research relationship was ethical. Ultimately, this thesis proposes a new theoretical framework for understanding Indigenous phenological knowledge as a complex process embedded in culture and spiritual contexts.

Chapter 2: Using Phenology as an Indicator Tool on the Menominee Nation Forest: A Forest Understory Species Study

Climate change has increased global temperatures by 0.9°C (1.62°F) since the 19th century (https://climate.nasa.gov/evidence/, 2019) and temperatures are expected to increase further. While there are perceived risks due to warming such as an increase in climatic events like severe storms, extreme flooding, and intense drought, some warming may be beneficial for forest understory plants. For example, climate change will lengthen the growing season in deciduous boreal forest ecotone in the western Great Lakes region (Duveneck et al. 2014), which may increase productivity and fitness of forest understory plants (Jacques et al. 2015).

Flowering phenology is important for a species' fitness (Forrest & Thompson 2010). The timing of flowering influences the environmental conditions experienced during pollen, ovule, and seed development (Rathcke & Lacey, 1985). Flowering time affects plant size, growth patterns, and architecture because energy is committed to reproductive growth rather than vegetative growth. Flower timing also influences the interactions with pollinators and predators. Co-flowering with others in the community may increase competition or facilitate access to pollinators and abiotic factors. Flowering phenology will determine if a species will reproduce successfully.

Recent studies show that spring is arriving earlier in the northern hemisphere (Schwartz et al. 2006), which has numerous consequences for plant phenology. For example, the timing of plant emergence may be advanced by an increase in temperature, which could increase spring high light periods for early and late spring plants (Roberts et al. 2015). This could increase productivity through increased assimilation but also alter timing of life history characteristics, like flowering phenology and seed production which are dependent on light availability. Understanding plant life history and how it is altered by climate change will help to predict impacts on forest functions (Kudo et al. 2008).

Climate change could affect plant life history in a variety of ways. Earlier onset of spring alters flowering phenology of plants as well as pollinator interactions (Gezon et al. 2016). Climatic warming leads to an earlier response in reproduction in some species (Post et al. 2008). An early spring can alter flowering phenology through earlier snow melt, which can increase flower abundance (Inouye 2008) and allows for more time for pollinator interactions with flowers (Gezon et al. 2016). More flowers pollinated means more fruit produced, which means more seeds created for reproduction. However, offspring production may also be limited by a number of other environmental factors such as competition, herbivory, density-dependent resources, and abiotic conditions unrelated to climate (Cole et al. 1954; Silvertown et al. 1997; Post et al. 2001; Post et al. 2008). Finally, climate change also affects plant phenology life history through increasing risk of frost damage due to early blooming (Inouye 2008).

Research projects that experimentally warm the environment have taught us much (Farnsworth et al. 1995; Jacques et al. 2015, Rice et al. 2018; Sherry et al. 2007). These studies aimed to simulate climate change and predict the responses of the different growth forms of forest plants. Warming experiments have found different responses in the tree, shrub, and herbaceous communities (Farnsworth et al. 1995; Jacques et al. 2015, Rice et al. 2018). The herbaceous community was particularly sensitive to warming with species such as Canada mayflower (*Maianthemum canadense*) increasing stem density in heated plots whereas other herbaceous species declined (Farnsworth et al. 1995).

The phenology of the herbaceous forest understory communities responded to experimental warming in many ways. The herbaceous communities changed through earlier emergence, longer growing season, increase in carbon uptake, changes in stem density, increase in reproductive output, and delayed leaf senescence (Farnsworth et al. 1995; Jacques et al. 2015, Rice et al. 2018). The reproductive output of Canada mayflower and other forest herbs increased under simulated warming conditions (Jacques et al. 2015). Earlier emergence of forest understory species led to an earlier leaf senescence while also increasing carbon uptake due to longer periods of time without a canopy (Jacques et al. 2015) although more studies are needed to support this. Climate change can increase the growing season by 11-30 days in some cases (Rice et al. 2018). This causes an increase in seasonal light availability (due to earlier spring) and leads to an increase in photosynthetic rates for herbaceous species. These increases in photosynthetic rates are also attributed to delayed leaf senescence in some herbaceous species (Rice et al. 2018). Experimental warming may not affect plant size but impact how many flowers and seeds are produced (Jacques et al. 2015; Rice et al. 2018). Experimental warming was found to advance flowering in most species but especially in late blooming species (Rice et al. 2018). These studies show that climate change will affect herbaceous phenology through earlier spring emergence, longer growing season, delayed leaf senescence, and increases in reproductive output and photosynthetic rates.

However, shifting herb phenology will also increase risks to forest understory communities. For instance, an earlier spring emergence could subject plants like Canada mayflower to increased risk of spring frost (Jacques et al. 2015). Earlier spring emergence, which in turn would advance leaf senescence, also risks altered phenology synchrony with the forest system (i.e. pollinators, herbivores, seed dispersers) as well as possibly create a niche for invasive species to occupy (Rice et al. 2018).

Given the sensitivity of herbaceous plant phenology to climate change, it could be an indicator tool in climate change adaptation planning. The Menominee Nation forest is a 235,000 acre forest with old growth characteristics. The Menominee Nation forest is managed through sustained-yield forestry practices (Mausel et al. 2017; Pecore 1992). In order to protect the forest from potential future changes, the tribe needs more tools to adapt to climate change. Phenology may offer such an indicator. To fully maximize the indicator, we need baseline data and also to better understand the connection between timing and reproductive output.

My overarching objective was to gain a better understanding of the life history characteristics of key species in the Menominee forest and whether species that shift phenology with shifting climate are more likely to be successful. The specific research questions for this study were two-fold. First, do species vary in the timing and duration of flowering and fruiting and is that variation related to life history and environment? I expected species would differ timing of flowering and fruit maturation and that within species they may differ among sites. Second, does annual fruit production vary with timing of flowering and fruiting maturation? I expected that early flowering plants would have more fruit-yield when compared to later flowering plants.

Methods

Study site and System

The project was conducted on the plots developed by the College of Menominee Nation's Sustainable Development Institute and Center for First Americans Forestlands (Caldwell, personal communication, 2017). The project was situated in northeastern Wisconsin, on the Menominee Indian Tribe of Wisconsin reservation. We studied plants that occurred in three 1-hectare forest monitoring plots. The three plots were located at different geographical locations on the reservation in mature, upland hardwood forests. Two plots were located on lands that are actively managed through the Menominee Nation's sustained yield timber management on the northern section of the reservation. One plot is located on the College of Menominee Nation (CMN) campus and was not actively managed for timber but rather used for research purposes. A walking trail winds through each plot that has plant relatives present. The trails are used to avoid trampling the plot and plant relatives.

Site differences

The plots are located in different parts of the reservation and have their own unique species makeup that create the unique conditions for each area. Plot A is located on the northern section of the reservation close to the Langlade county border in northeastern Menominee county. Plot A is categorized as a mesic and nutrient medium-rich site for vegetation or as AFTD (Kotar et al. 2002). This plot is dominated by sugar maple (*Acer saccharum*) and beech (*Fagus grandifolia*) trees that create a closed canopy in some parts of the plot. In 2016 a harvest was conducted that left some canopy area open for some of our plant relatives to regenerate on the phenology trail in plot A. This area's topography is flat and is marked by the recent logging road inlet to the harvest area. Plot A is the only plot that contains Indian cucumber (*Medeola virginiana*).

Plot B is located on the northwestern half of the reservation, closer to the central part of the reservation and about 6 miles from Plot A. This plot is classified as ADTH or a mesic and nutrient rich site for vegetation (Kotar et al. 2002). It is an older stand and the species makeup in plot A is dominated by sugar maple (*Acer saccharum*) and hemlock (*Tsuga canadensis*) species. Plot B's topography is hilly compared to plot A. It has a small elevation change between the southern section of the plot and the northern section of the plot.

The last plot, CMN, is located on the campus of the College of Menominee Nation. This plot is not actively managed for timber, rather it is utilized by the College for educational and research purposes in partnership with the Sustainable Development Institute. Plot CMN is an AVb habitat classification or a dry-mesic and nutrient medium-rich site (Kotar et al. 2002). Plot CMN's canopy is mostly dominated by white pine (*Pinus strobus*) and sugar maple (*Acer saccharum*) but towards the northern section, black ash (*Fraxinus nigra*) and green ash (*Fraxinus pennslyvanica*) are mixed in on the edge of plot which also is an indication of a small wetland.

Plant Relatives

We selected eleven species common in moist, woodlands (Table 1). The eleven study species do not occur on every plot but each plot has eight to ten of the species. For each species that occurs on a given plot, we selected up to 20 individuals that were marked for the duration of the study. The species selected were a mix of generalist and specialist species. All species occurred in at least two of the three plots with the exception of Indian cucumber (*Medeola virginiana*) which only occurred in plot A. Most species selected were spring plants with the exception of sweet cicely (*Myrhhis orodata*) and wood nettle (*Laportea canadensis*) which flowered in the summer.

For some species, due to wildlife impacts and dieback, more than 20 individuals were selected to ensure a sufficient sample size throughout the growing season. We tracked the following phenology stages: flower buds, open flowers, unripe fruit, and ripe fruit. These phenology stages are also known as phenophases. To the extent possible, the same individuals are followed from year to year.

The life history of our plant relatives are two-fold. They are semelparous species that reproduce each year but only once in their yearly life cycle. In reference to when phenophases will occur, some species are early spring plants whereas other species are later summer plants. Each species will either produce many offspring through low-energy seeds whereas other species will produce few offspring but energy-packed seeds that have a high-rate germination.

Table 1: Plant Relatives (Study species) of the Menominee Phenology Project.

Species Code	Species
BAN	Red Bane Berry, Actaea rubra
COH	Blue Cohosh, Caulophyllum thalictroides
GSB	Gooseberry, Ribes cynosbati
INC	Indian Cucumber, Medeola virginiana
JIP	Jack-in-the-Pulpit, Arisaema triphyllum
LEK	Wild Leek, Allium tricoccum
MIT	Two-leaf Miterwort, Mitella diphylla
MYF	Canada Mayflower, Maianthemum canadense
SGN	Wood Nettle, Laportea canadensis
STF	Star Flower, Trientalis borealis
SWC	Sweet Cicely, Myrhhis odorata

Table 2: Characteristics of plant relatives

Species	Family	Life history syndrome (sensu Kudo et al. 2008)	Pollination mode	# of fruits	Fruit type
Blue Cohosh	Berberidaceae	Early spring	Insect	Few	Simple
Gooseberry	Grossulariaceae	Early spring	Insect/Self	Many	Simple
Two-leaf miterwort	Saxifragaceae	Early spring	Insect	Few	Aggregate
Canada Mayflower	Ruscaceae	Spring	Insect	Few	Simple
Starflower	Myrsinaceae	Spring	Insect	Few	Simple
Red Baneberry	Ranunculaceae	Spring	Insect		Simple
Indian Cucumber	Liliaceae	Spring	Insect	Few	Simple
Jack-in-the-pulpit	Araceae	Spring	Insect	Many	Multiple
Wild Leek	Alliaceae	Spring	Insect/Self	Many	Aggregate
Sweet Cicely	Apiaceae	Summer	Insect/Self	Many	Simple
Wood nettle	Urticaceae	Summer	Wind/Self	Many	Simple

Data collection

Data collection and phenophase observation occurred throughout the growing season starting at the beginning of first growth in spring, which is generally around late April to early May and ending in early September or when the last species fully ripens fruit in early autumn. Data was collected 1-2 times per week throughout the growing season. Observers used status monitoring methods (USA National Phenology Network, https://www.usanpn.org/about/approach, 2019), observers assessed whether or not a phenophase was occurring. When a phenophase was occurring, observers also collected abundance data on each phenophase, for example, if a plant had flowers blooming, they recorded how many out of the total are blooming. When collecting phenophase data, observers utilized codes (Table 3) for gooseberry, jack-in-the-pulpit, wild leek, two-leaf miterwort, Canada mayflower, and wood nettle. Observers counted flowers and fruits for red bane berry, blue cohosh, Indian cucumber, and star flower. Once an individual has reached full ripening, observers no longer collect data because ripe fruit is the last phenophase of interest. Observers also take notes of any observations or notable information about the plot, individual, or trail. Protocols and phenophase definitions follow those developed by Nature's Notebook, the citizen science program of the USA-National Phenology Network (USA National Phenology Network, 2019). Given staffing constraints, the study was only able to collect data from early May onward, which led to missing data on some of the earliest phenophases for some plants such as Canada mayflower (*Maianthenum canadense*).

Table 3: Abundance and Open flowers/ripe fruits codes

Codes	Total # of Flowers/Fruits Abundance	Open Flowers/Ripe Fruits %
A	Less than 3	Less than 5%
B	4-10	5-25%
C	11-25	25-50%
D	26-100	50-75%
E	101-1000	75-95%
F	Greater than 1000	Greater than 95%

Data Analysis

From the raw data, we extracted a suite of response variables: date of first flower buds, flowers, and fruiting of each species, date of last flowering and fruiting of each species. The study also assessed peak flowering and peak fruiting using abundance data (via average high for flowering and fruiting data) as well as reproductive success as % of flowers that produced ripe fruit.

We used mixed effects analysis of variance (ANOVA) models to assess the responses of day of year (DOY) of the start of each of the following phenophases: flower buds, open flowers, fruit, and ripe fruits. We examined Tukey-HSD tests to evaluate significant differences among pairs ($P < 0.05$). In addition, we assessed fruiting success by comparing maximum ripe fruit abundance to the timing of flowering and fruiting through regression analysis. We used the statistical analysis software JMP 10 (SAS Institute, Cary, NC, USA) for the analysis.

Results

We followed a total of 278 individuals from ten species during the 2017 growing season from May to September. We started our phenological observation at different stages of phenophases for each species such as early spring plants that already produced flower buds compared to later summer plants that just had leaves and no evidence of flowers yet. There were clear differences among plots in the phenophases of flower buds, open flowers, fruits, and ripe fruits. The reproductive success of individuals varied by species and was related to timing of flowering and fruiting phenophases.

Species phenology

The species in the study differed in timing. Gooseberry was the first to flower and wood nettle the last to flower. Some species flowered for longer periods of time than others. For example, Indian cucumber had the shortest flowering time (about 35 days) whereas wood nettle had the longest period of flowering (203 days). The duration of phenophases varied widely among species. Species differed in fruiting and flowering time and did not enter phenophases at the same time within and among the three different plots.

Plot differences

The ANOVA results for flower buds varied by plot and species. During the phenophase of flower buds, the only species that showed significant differences among plots was wood nettle, ($F_{2,28} = 5.063$, $P < 0.0013$). Plot A's wood nettle was significantly later than the other plots (Tukey HSD, $P < 0.05$).

The ANOVA results for open flowers varied by plot and species. During the open flowers phenophase, Jack-in-the-pulpit and gooseberry showed significant differences among the plots (JIP $F_{2,40} = 5.364$, $P < 0.008$ and GSB $F_{2,16} = 6.962$, $P < 0.006$). The Jack-in-the-pulpit species in plot A were significantly later than plot B and CMN plot (Tukey HSD, $P < 0.05$). In the GSB species, plot B was significantly earlier than the other plots (Tukey HSD, $P < 0.05$).

The ANOVA results for fruit phenophase showed significant differences among plots in the species wild leek ($F_{2,18} = 21.276$, $P < 0.0001$), two-leaf miterwort($F_{2,44} = 9.6793$, $P < 0.0003$), and sweet cicely($F_{2,12} = 214.660$, $P < 0.0001$). For the wild leek, Plot B fruited significantly earlier than the other plots (Tukey HSD, $P < 0.05$). The two-leaf miterwort showed the CMN plot to fruit later than the other two plots (Tukey HSD, $P < 0.05$). Finally, the sweet cicely species group in CMN plot fruited significantly later as well in comparison to the plots A and B (Tukey HSD, $P < 0.05$).

The ripe fruit phenophase ANOVA results differ among plots for red baneberry, two-leaf miterwort, and wood nettle. These groups had significant differences among the plots. For red baneberry ($F_{2,13} = 15.972$, $P < 0.0003$), plot A was significantly later than plot B and CMN (Tukey HSD, $P < 0.05$). For the species group two-leaf miterwort ($F_{2,38} = 6.859$, $P < 0.002$), the CMN plot was later than plots A and B. Finally, the wood nettle group ($F_{2,20} = 5.953$, $P < 0.009$) showed plot B was earlier than plot A and CMN. Overall, our data suggests that plot B was significantly earlier than CMN and plot A as evidenced by the ANOVA results in the phenophases of open flowers, first fruits, and ripe fruits.

Plant Species Code	**Plot**	**First Flower DOY Avg ± Std Err**	**Open Flower DOY Avg ± Std Err**	**First Fruit DOY Avg ± Std Err**	**Ripe Fruit DOY Avg ± Std Err**
COH	Plot A	ND	144±1	147±1	160±2
COH	Plot B	132±3	144±0	146±1	187±18
GSB	CMN	141±0	142±1	145±3	222±3
GSB	Plot A	ND	145±0	145±0	ND
GSB	Plot B	134±0	137±2	148±4	211±9
MIT	CMN	141±0	144±3	183±14	186±14
MIT	Plot A	138±3	141±1	150±0	161±1
MIT	Plot B	139±3	141±1	151±1	158±1
MYF	CMN	142±1	149±0	157±1	192±10
MYF	Plot A	143±1	149±1	158±1	192±11
MYF	Plot B	139±3	150±0	155±5	ND
STF	CMN	149±0	148±1	159±2	195±11
STF	Plot A	140±2	145±0	161±4	ND
STF	Plot B	134±0	144±0	ND	ND
BAN	CMN	147±4	145±2	153±3	187±4
BAN	Plot A	138±0	ND	148±3	226±2
BAN	Plot B	142±2	150±3	154±2	185±2
INC	Plot A	146±1	153±1	168±1	243±0
JIP	CMN	146±1	149±0	170±2	233±2

JIP	Plot A	151±0	156±2	172±0	ND
JIP	Plot B	147±2	150±3	176±7	232±0
LEK	CMN	149±1	184±0	182±1	228±2
LEK	Plot A	151±0	191±0	200±0	ND
LEK	Plot B	146±1	184±3	193±1	ND
SWC	CMN	ND	ND	222±0	222±0
SWC	Plot A	154±1	158±2	167±2	218±3
SWC	Plot B	155±2	155±2	163±1	211±0
SGN	CMN	168±2	189±2	203±2	233±0
SGN	Plot A	181±6	189±5	192±6	234±2
SGN	Plot B	166±3	184±7	206±6	229±1

Table 4: Average Day of year start for phenophase (earliest flowering to latest flowering)

Individual reproductive successes

For individual reproductive successes, we compared the maximum fruit abundance of each species to the date of year of each respective phenophase (first flower buds, first open flowers, and first fruit appearance). We did not find a significant correlation between maximum fruit abundance and date of first flower buds in any species. We found a significant negative correlation between date of first open flowers and maximum fruit abundance in two species, wild leek (Figure 1) and Indian cucumber (Figure 2). We also found six of the eleven species (Figures 3-8) showed a negative relationship between the day of year of first fruit and maximum fruit abundance (wild leek, Jack-in-the-pulpit, Indian cucumber, Canada mayflower, wood nettle, and starflower).

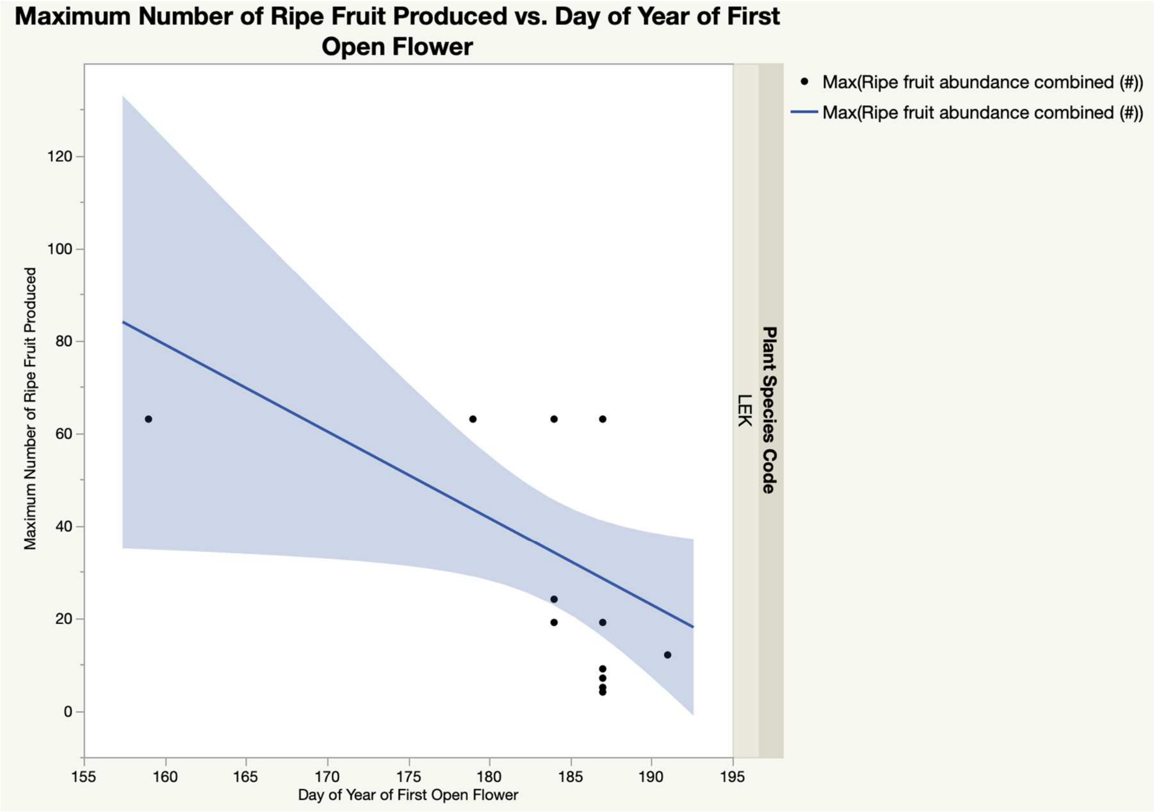

Figure 1: Maximum # of Ripe Fruit Produced vs. Day of Year of First Open Flower for Wild Leek

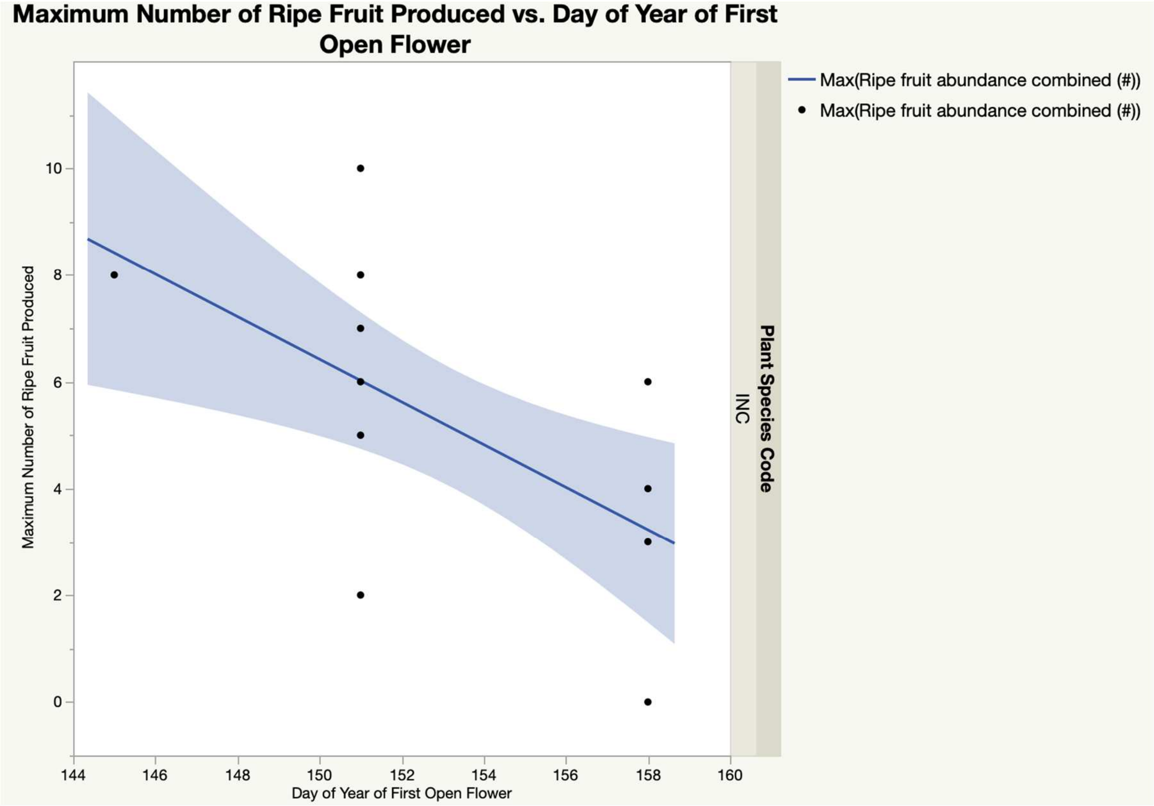

Figure 2: Maximum # of Ripe Fruit Produced vs. Day of Year of First Open Flower for Indian Cucumber

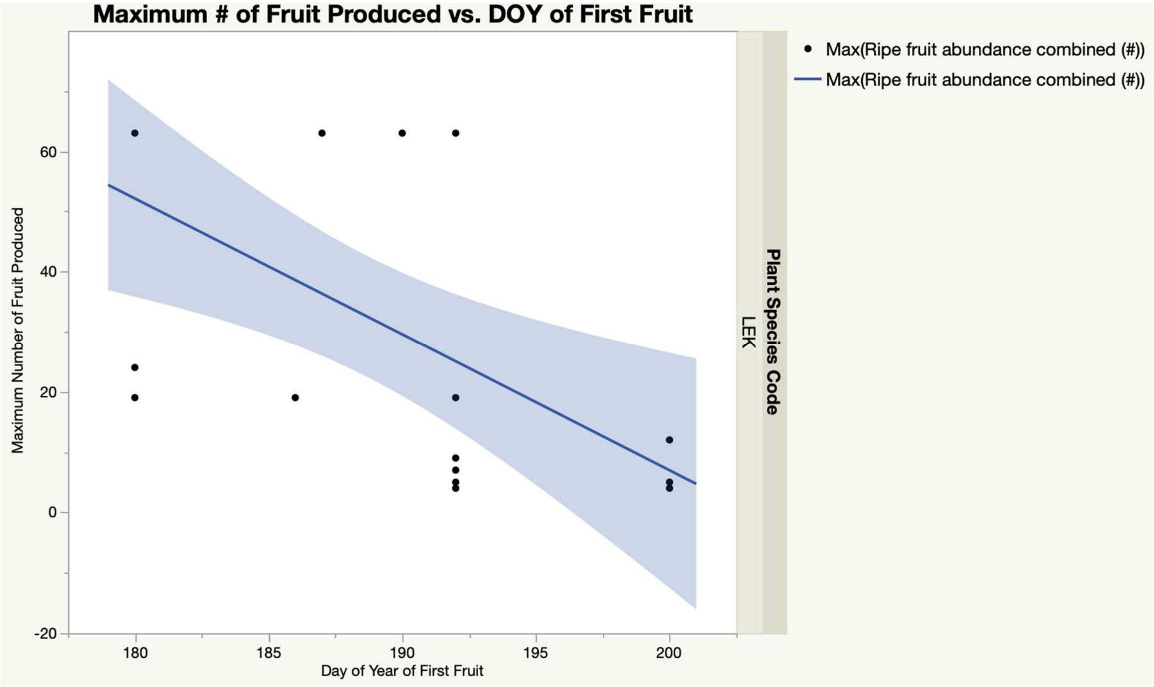

Figure 3: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Wild Leek

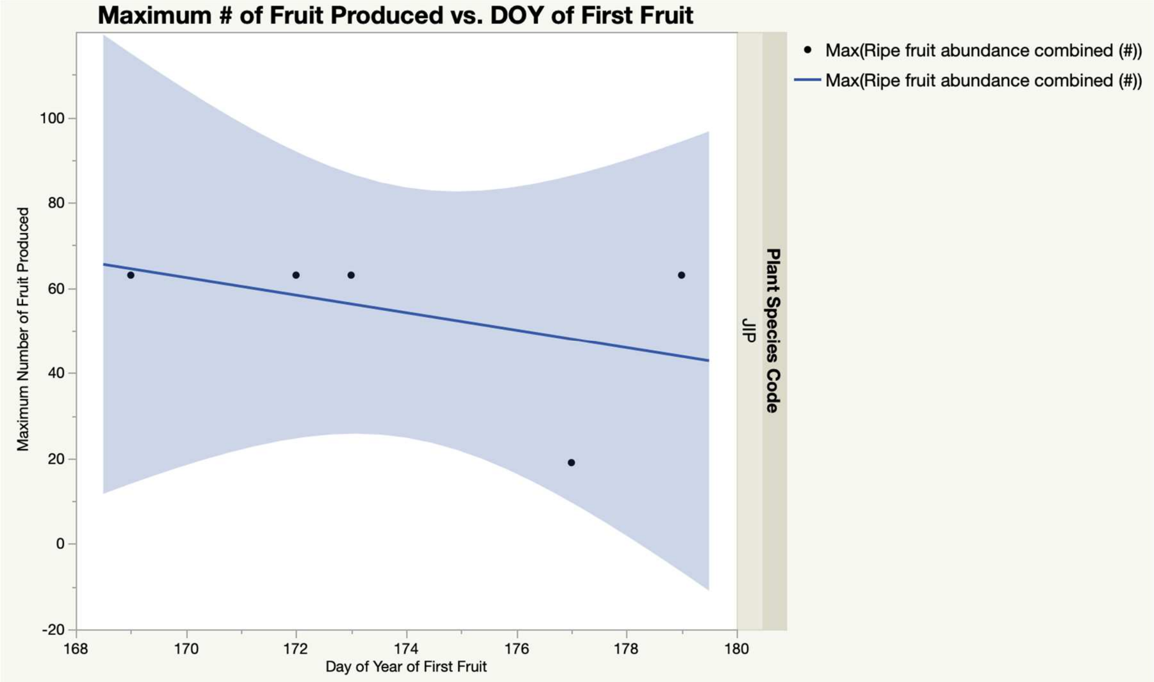

Figure 4: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Jack-in-the-Pulpit

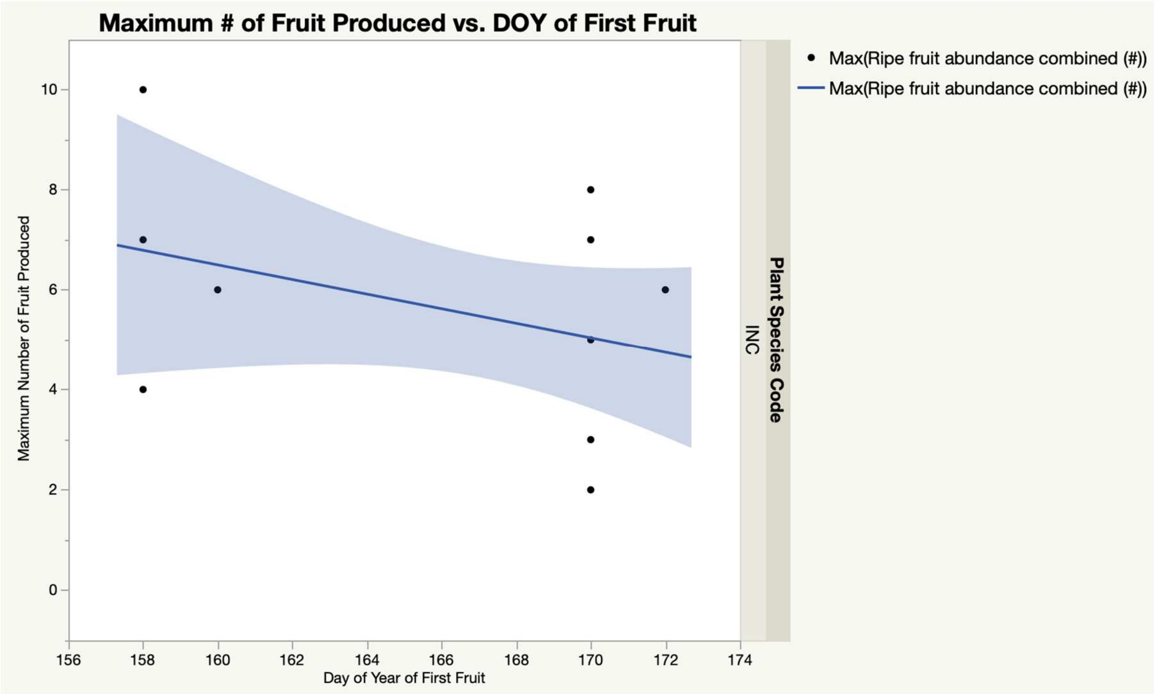

Figure 5: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Indian Cucumber

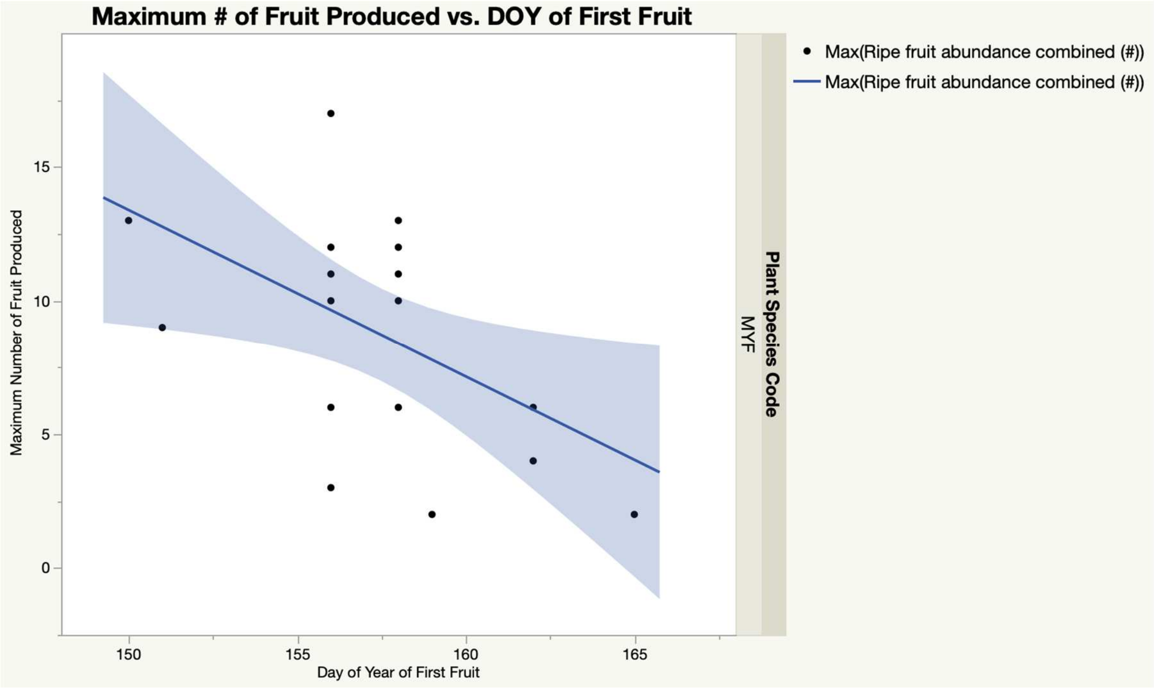

Figure 6: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Canada Mayflower

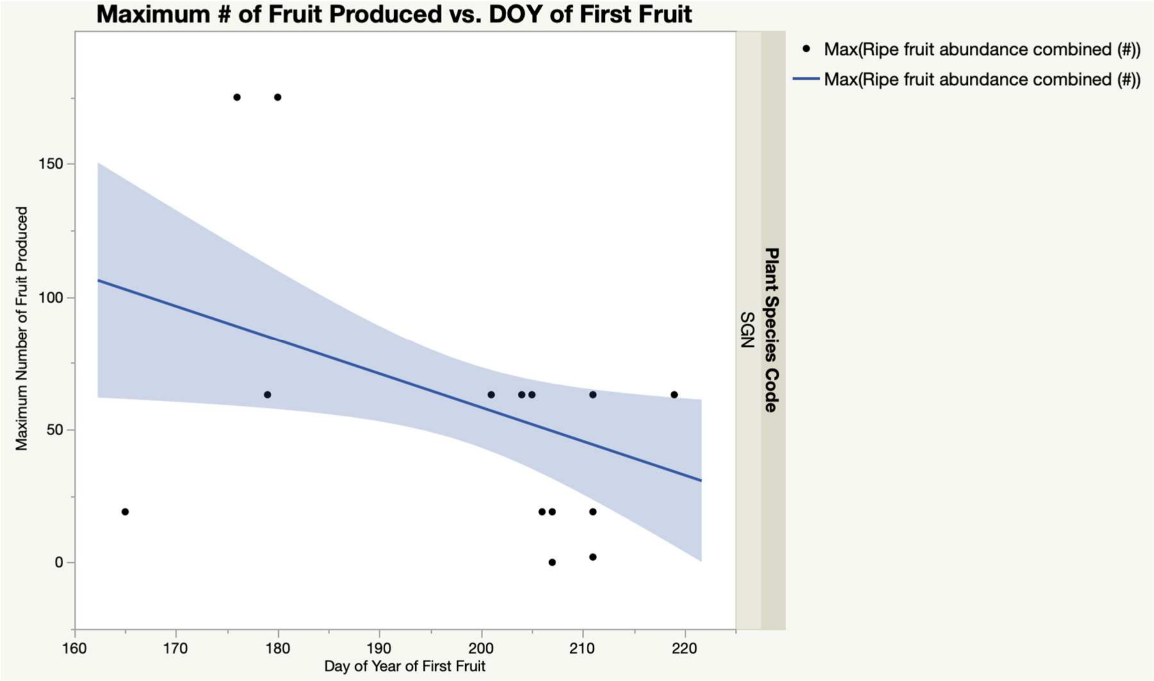

Figure 7: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Wood Nettle

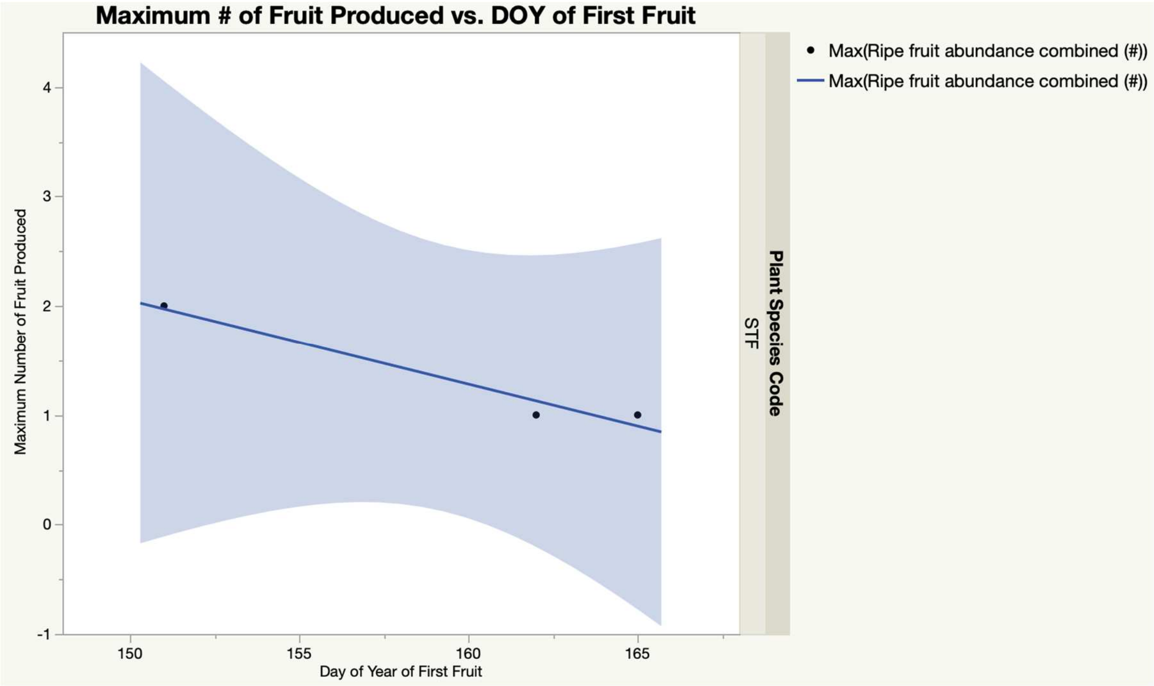

Figure 8: Maximum Fruit Produced vs. Day of Year of First Fruit Produced for Star Flower

Discussion

Climate change has increased global temperatures and is altering plant phenology. These changes have consequences for long-term dynamics and fitness of herbaceous species in the forests of the Menominee Nation. In particular, past research suggests that earlier flowering plants tend to have more reproductive success (Baeten et al. 2015). Our study supports this idea. We found two species, wild leek and Indian cucumber, that showed negative correlations between day of year of first open flower and maximum fruit abundance. In addition, we found that for seven of ten species, individuals that started fruiting earlier set more fruit. Our results have implications for understanding climate change response of these species. Climate change is expected to make more springs early. For those species that advance flowering and fruiting in response our results suggest that phenological shifts will benefit plant fitness by increasing reproductive output (Jacques et al. 2015; Rice et al. 2018).

Variation among sites

We found variation among sites (Table 4). These differences among sites may be due to a number of factors such as dominant canopy species, management history and topography. Canopy species varied widely among the three plots. In the CMN plot white pine (*Pinus strobus*) dominated the canopy. The CMN plot is drier than both Plot A and B via habitat type classification (Kotar et al. 2002). Plot B's canopy was mostly Eastern hemlock and sugar maple whereas Plot A was dominated by beech and hemlock. Dominant canopy species may have altered the microclimate such as the light environment due to different times of canopy closure and abundances of evergreens, which cast year-round shade. In terms of management history, plot A was harvested more recently than other plots. Harvest can alter microclimate by increased soil temperature in the warm months and decreased soil temperature in the cold months (Proe et al. 2001). Finally, Plot B, had considerable variation in elevation across the plot compared to other plots that could have affected local conditions.

Variation among species

One of our core questions was how species varied in timing or duration of flowering and fruiting and whether that variation was related to life history? We found differences among species in both timing and duration (Table 1 and 2) as well as order in which they reproduce. Species in the study have different life histories. While all of our study species were perennials, they differed in other aspects of life history such as number of fruits, fruit types, pollination mode, and life history syndromes. Kudo et al.

(2008) created three life history syndromes, also known as phenological types of forest understory species: early spring, spring, and summer. Early spring species are species that emerge before the forest canopy appears. Spring species emerge simultaneously with the forest canopy emergence. Summer species occur post-canopy closure. In our study, we have three early spring plants; blue cohosh, gooseberry, and two-leaf miterwort. In the spring syndrome there is Canada mayflower, starflower, red baneberry, Indian cucumber, wild leek, and Jack-in-the-pulpit. Sweet cicely and wood nettle are the only summer syndrome species in our study. Overall, we had at least one species from each aforementioned syndrome with complete phenophase data (flower buds, open flowers, fruit, and ripe fruit).

Studies suggest that earlier flowering species benefit most by warming (Cleland et al. 2007; Jacques et al. 2015; Rice et al. 2018). Earlier flowering species benefit most from warming through accelerated phenology due to snowmelt (Cleland et al. 2007), earlier emergence and modest carbon gain (Jacques et al. 2015), and extension of the growing season allowing for more successful reproduction (Rice et al. 2018).

Variation among individuals

We found that early flowering and early fruiting individuals had more ripe fruit-yield when compared to later flowering and fruiting individuals (Figures 3-8). Plants that tend to flower in the early spring benefit from an increase in light levels, increase in moisture, and lower levels of interspecific competition for pollinators (Forrest & Thomson 2010, Rice et al. 2018). This could result in higher reproductive success as energy is gained early allowing the plant to focus on reproduction at an earlier time. In other words, a plant is able to direct energy into producing flowers and fruits after having received enough photosynthate from producing leaves from early emergence.

Our overarching goal was to understand if species that shift phenology with a shifting climate will to be more successful. When individuals flowered earlier, we saw that fruit production was increased versus when flowering occurred later in the season, fruit production decreased (Table 1). Given the current climate predictions, the growing season has been observed to be increasing by about nine days throughout the Great Lakes region (Hibbard et al. 2017). This may be favorable for most forest understory species given our results: a longer growing season may mean that more plants have the opportunity to produce more fruits, increasing fitness.

However, an extended growing season also brings risks such as frost damage. It can change the phenology of biotic interactions such as pollination. For example, queen bees winter underground and their hibernation is broken by a soil temperature indicator. In contrast, spring emergence in plants is cued by both temperature and snowmelt (Kudo et al. 2008), so warm springs could disrupt the interaction of flowering and pollinators. A longer growing season also offers more opportunities for pathogens and invasive species to affect forest ecosystems (Hibbard et al. 2017). A longer growing season would create more opportunities for invasive species and pathogens to occupy niches traditionally held by native forest understory plants.

Caveats

Overall we had several caveats for the study. First, we only have one year of data. With more years of data we hope to see stronger patterns that link phenology to reproductive fitness. Secondly, for some species we missed the start of the phase (early spring syndrome species) reducing the amount of data in some of our analyses. It may be that more species would have shown a relationship between early flowering and fruit production but we only could assess seven species due to lack of data. We also had a small number of species compared to the total biodiversity of the herbaceous layer. Finally, our protocol didn't differentiate between different ripening styles and fruit types (e.g., simple, aggregate and multiple) adding variability to our dataset.

Conclusions and Future Research

Our work is important for several reasons. First, the baseline data on the phenology of these species that may be used by the Menominee tribe on phenological studies and climate change impacts on the forest understory community. In addition, we show that within species early flowering individuals have greater reproductive success. This means that individuals that flower early are more likely to have higher fitness. Overall, our results may be used for climate change adaptation and tribal forestry management goals specifically for the Menominee Indian Tribe of Wisconsin. The tribe has used a biodiversity management approach to their forestry management, meaning that the tribe actively manages the forest understory for a diversity of species that would help combat invasive and pathogen presence in the Menominee forest (Mausel et al. 2017; Pecore 1992; Waller & Reo, 2018). Tribal nations will have to assess whether or not their current systems of forest management will continue to achieve their goals, and if not must employ alternative strategies for forest management in a rapidly changing climate. Climate change will bring different pathogens and create niches for invasive species to occupy in the forest understory but an active biodiverse approach to the forest understory management can create a resilient community.

Our research suggests areas for further research to create a wholistic picture of forest phenology. First, a more long-term study is required in order to understand the impacts and risks of climate change and the tribe's forest climate change adaptation strategy. We also recommend research on the pollinator interactions with the forest understory plants. Questions might include: How does early flowering affect pollinator interactions compared to later flowering individuals? How might pollinator phenology be impacted by climate change and the changing phenology of forest understory plants? Since the pluses of early flowering may depend on pollinator interactions then researching pollination might be of interest. Finally, we suggest further research into areas such as canopy phenology, harvest impacts on phenology, and wildlife phenology.

Climate change will have both positive and negative effects on reproductive phenology. Climate change will bring an earlier spring which will create more degree-warming days for the forests of the Menominee nation which will present more opportunities for different types of species that require longer growing seasons as well as pests that benefit from longer growing seasons. Our research joins a growing body of literature that suggests an earlier spring onset can have positive repercussions for plant reproductive phenology through earlier flowering and longer growing season for reproduction (Rice et al. 2018). Climate change will also provide opportunities for the tribe to manage for different types of commercial species while also staying true to the tribal goal of biodiversity in their sustained-yield management style.

Overall, this study presented information for a baseline of phenology data of eleven forest understory species on the Menominee Indian Tribe's reservation in northeastern Wisconsin. This data presents suggestions for more research in the areas of how early flowering may affect pollinator phenology and interactions? How does an early spring affect the rest of the forest community rather than just the forest understory species we studied? How does an earlier spring affect the phenology of the tree species at our sites? How does a shifting phenology of the forest understory affect the wildlife interactions with our study species? These questions need to be explored in order to get a complete picture of how a changing climate may affect the phenology of the forest community.

Chapter 3: Indigenous Phenological Knowledge

Climate change will affect tribal nations' forests and tribal nations' peoples in adverse ways. Climate change has the potential to impact culturally important species (de Echeverria & Thornton, 2019), tribal food systems (LaDuke 2019; Voggesser et al. 2013), mental and physical health (Willox et al. 2013; Fond du Lac n.d.), tribal economies (Bennet et al. 2014), tribal natural resources, (Tribal Adaptation Menu Team 2019) and other aspects of life and culture (Voggesser et al. 2013; Mockta et al. 2018). Indigenous knowledge has been shown to be resilient (Berkes et al. 1994; Daigle et al. 2019; Kofinas et al. 2010; McMillen et al. 2017) and tribal nations will turn towards their vast knowledge systems to adapt to the impacts.

Indigenous phenology, also known as traditional phenological knowledge or ethnophenology, is central to how tribal nations and communities govern their lifeways, from ceremonial events to resource use and management (Armatas et al. 2016; Haines & S.R.F. Nation 2017, Hatfield et al. 2018). To date, however, there has been little research done on what Indigenous phenology is and how Indigenous communities/tribes are currently implementing Indigenous phenology today. This is true in regard to both climate change and natural resource management. Based on my lived experience as an Indigenous person, specifically an enrolled member of the Menominee Nation and also Anishinaabe, my participation in phenology projects with the College of Menominee, and the research for this thesis, I view Indigenous phenology as a collaborative process defined through partnerships. In this chapter, I argue that Indigenous phenology is a process similar to Kyle Whyte's definition of traditional ecological knowledge as a collaborative concept between two or more Indigenous and non-Indigenous institutions

(2013). Indigenous phenology is also a process that includes partnerships, co-built knowledge, and tribal self-determination by furthering tribe's goals. The process of Indigenous phenology on the Menominee Indian Tribe of Wisconsin's reservation can be viewed through the lens of the College of Menominee Nation Sustainable Development Institute's model of sustainability (Dockry et al. 2016). This model defines sustainable development as a process of balancing multiple dimensions and is centered on the Menominee tribe's deep relationship to place. In this light, Indigenous phenology for the Menominee people is a process that involves multiple parties, perspectives, is centered on Menominee relationship to place, and furthers the goals of the Menominee Nation.

Indigenous phenological knowledge is also a process that builds trust, capacity, and reinforces tribal sovereignty through partnership-building. I have seen this first-hand through my experience as an Indigenous (Menominee) graduate student working on a Menominee phenology project. Through my research and experience I have learned that Indigenous phenological knowledge is more complex than the current literature's conception of Indigenous phenological knowledge. To deepen the concept of Indigenous phenological knowledge as a process, I developed a model to better contextualize Indigenous phenological knowledge. Indigenous phenological knowledge has been and continues to be used as a tool by Indigenous peoples for timekeeping and survivance, (see Vizenor 2008). This chapter will define Indigenous phenological knowledge, outline my experiences working on an Indigenous phenological knowledge project from a tribal perspective (see chapter 1), and propose a complex Indigenous phenological knowledge model. Through the concept of a unique Indigenous knowledge process, Indigenous phenological knowledge, partnerships are built to find solutions towards adaptation in the face of climate change for the Menominee Indian Tribe of Wisconsin and the Menominee forest.

Research Questions

The overarching research question for this chapter is, how does Indigenous phenological knowledge as a process further the goals of the tribe and reinforce tribal sovereignty? To answer this, I have three guiding research questions; 1. In what ways does the Menominee phenology research strengthen or weaken the Menominee Indian Tribe of Wisconsin's tribal sovereignty? 2. What does an ethical research relationship between an educational institution and the tribe consist of? and 3. How does the Menominee Phenology project respect the data sovereignty and sensitive information of the Menominee community? In order to understand these research questions, it is important to define three concepts: tribal sovereignty, ethics, and prioritizing Indigenous knowledges on Indigenous lands.

Tribal Sovereignty

Tribal nations have inherent sovereignty and autonomy since their beginnings (Ishiyama 2003; Lomawaima et al. 2003; UNDRIP 2007). Tribal sovereignty is inherent and existed before there was the United States. Tribal sovereignty is affirmed by treaties, US constitution, case law, federal regulations, and tribal laws. Tribal sovereignty is defined as inherent rights of self-government of a tribal nation, in which the relationship between the United States protects, provides benefits to, and services for the tribal nation (BIA 2019). Generally, the sovereign nation has an attachment to a land base and a plethora of shared knowledge and experiences (Chief et al. 2016). Researchers must recognize that Indigenous communities have a unique and deep knowledge system that holds alternative ways of understanding the world which can help to view problems in a broader, holistic way than the mainstream western euro-centric lens.

Tribal nations have had negative experiences with western scientific research that has exploited land, peoples, and knowledge (Smith 2013). Kovach suggests the idea of science contradicted Indigenous knowledge (2008). While Deloria offers, "[t]he fundamental factor that keeps Indians and non-Indians from communicating is that they are speaking about two entirely different perceptions of the world" (1979, p.1). These authors illustrate the point that science and Indigenous knowledge are separate paradigms. All research conducted in partnership with tribal nations should be inherently a community-based participatory research process because community-based participatory research methods can bring the two aforementioned paradigms together (Burhansstipano et al. 2005, Smith 2013).

Ethical Research Relationships

While collaborations between Indigenous/tribal communities and scientists have been increasing recently, the benefits of these collaborations tend to be unequal. David-Chavez & Gavin note that "majority of climate studies (87%) practice an extractive model in which researchers use Indigenous knowledge systems with minimal participation or decision-making authority from communities who hold them" (2018, p. 1). This is concerning in that Indigenous communities are sovereign nations and hold agency much like the agencies that claim to collaborate with them. Through a collaborative partnership and an ethical research relationship, benefits would be equally distributed across parties.

Additionally, researchers must recognize that there are specific and unique ethics that tribal nations and Indigenous communities have that may be unfamiliar to researchers. For example, tribal members often perceive the natural world as relatives or relations (Pierotti & Wildcat 2000). To develop a healthy ethical relationship with tribes, research projects have to balance the values of both Indigenous knowledge and western science ethics.

Data Sovereignty & Sensitive information

Researchers should approach all relationships with the acknowledgement that tribal nations and Indigenous communities have autonomous sovereignty and have rights to research, data and dissemination of research results (Smith 2013). This is a fairly straightforward concept that arises out of the inherent sovereignty of tribal nations. Tribal nations also have shared sacred societies that maintain sensitive information that are not meant for outsiders and researchers to access or to collect. Tribal research projects need to recognize that tribal nations have rights with regards to research, data, and the dissemination of research results.

Defining Indigenous phenological knowledge within an Indigenous Context

Since time immemorial, Indigenous nations, tribal communities, and First Nations tribes have lived, played, worshiped, ate, died and survived in their respective environments. Through trial-and-error experiences over generations, Indigenous peoples have developed a deep and place-based knowledge system known as Indigenous knowledge or in some cases Traditional Ecological Knowledge (Berkes et al. 2000, Pierotti & Wildcat 2000, Kimmerer 2000). These trial-and-error experiences led to time-tested strategies that have been developed to form immaculate conceptual systems that helped Indigenous peoples thrive in their respective environments. Systems like tribal agriculture, traditional burning practices, tribal forestry, wildlife management, medicinal plants, and maricultures are all based on Indigenous knowledge that reside within Indigenous nations. Indigenous knowledge involves much more than the western understanding of ecological knowledge. Kimmerer (2000, 5) writes that Indigenous knowledge is "[u]nlike scientific knowledge, it [traditional ecological knowledge] is woven into and inseparable from the social and spiritual context of the culture." Kimmerer suggests that traditional ecological knowledge is not value-free because of its cultural and spiritual dimensions and this is beneficial in that one needs both the culture and knowledge in order to understand the holistic nature of traditional ecological knowledge. Traditional ecological knowledge houses many facets of Indigenous knowledges, one in particular is Indigenous phenological knowledge also known as traditional phenological knowledge or ethnophenology. Indigenous phenological knowledge is an ecological and seasonal subset of traditional ecological knowledge that tracks seasonal changes in plant, animal, and ecological systems (Lantz & Turner 2003; Armatas et al. 2016). Indigenous phenological knowledge supports tribal sovereignty by integrating management, adaptation, and culture.

Indigenous phenology, according to Lantz and Turner (2003, 265) is defined as "encompass[ing] all knowledge of biological seasonality, including the observation of life cycle changes in a specific plant or animal species to indicate the timing of the onset growth stages in other species, linguistic references to phenological events, traditional conceptions of time as they relate to seasonal change, and spiritual beliefs about cause and effect relationships of seasonal change." Although this definition is broad, Lantz and

Turner (2003) include the linguistic and spiritual dimensions of Indigenous phenological knowledge. Nabhan (2010, 3) attempts to include the ecological side of Indigenous phenological knowledge through his definition “norms and baselines for seasonal events and a range of variation in species abundance and productivity which may serve as a benchmark from which change in phenological events can be measured.” But these Indigenous phenological knowledge definitions fail to include specific governing values and principles that inform Indigenous lifeways and practices such as maple sugar camps and wild rice gathering. For instance, Indigenous phenological knowledge operates within maple sugar camps, and wild rice gatherings through the governing values and principles of a societal-familial structure with stewardship or a caretaking concept at the core (Whyte et al. 2015; Yerxa 2014). Amongst the Great Lakes woodland tribal nations, these resource gathering camps tended to have a leader, for example, a rice chief during the phenological event of harvesting wild rice. Rice chiefs tend lakes and do frequent checks on wild rice bearing lakes because they then have a responsibility to their tribal nations to designate when it is time to begin harvesting (Anishinaabe elder, personal communication, 2016). This unique governing value serves many purposes including ensuring a sustainable harvest of important cultural plants and resources. These institutions are focal points for tribal nations and Indigenous communities and Indigenous phenological knowledge helps form tribes’ societal structures that are adaptive, fluid, and depend on seasonal phenological cycles.

Indigenous phenology is a process similar to how Whyte describes traditional ecological knowledge as a process (2016). I argue that Indigenous phenological knowledge or Indigenous phenology as a process helps to build trust, capacity, and knowledge between partners involved in projects. Researching phenology on tribal lands is by definition Indigenous phenology—a process of observing, learning, and adapting over time. As stated previously, Indigenous phenology is a subset of Indigenous knowledge or Indigenous ways of knowing. The very act of Indigenous folks and allies researching together on Indigenous lands about Indigenous topics itself is an example of Indigenous phenology as a process.

Indigenous phenology is important for tribal nations and communities for a variety of reasons such as tribal natural resource management and tribal sovereignty. Tribal natural resource management is the management of ecosystems within tribal nations, tribal lands, and/or ceded lands within tribal ancestral lands. Indigenous phenology is a useful tool for tribal natural resource managers in that Indigenous phenological knowledge inherently exists within the tribal customs, values, and lands. Tribal natural resource management is one way tribal nations and Indigenous communities exert their sovereignty by “managing” their natural resources. Indigenous phenology and tribal natural resource management programs are intricately connected through Indigenous knowledges. For example, in the Seine River First Nation (S.R.F.), peak sturgeon spawning times have been explained through Indigenous phenological indicators such as presence of Tiger Swallowtail butterflies, *Papilio glaucus*, during the spring in southern Ontario (Haines & S.R.F. Nation 2017). Tribal nations have long used phenological indicators for resource harvesting (Hatfield et al. 2018). These results will help with climate change response and help to build solutions to climate change adaptation for tribal nations.

Indigenous phenology is important to tribal nations and communities because it is intergenerational and resilient. Intergenerational resiliency is also embedded within Indigenous knowledges. Indigenous knowledge systems have been maintained for thousands of years without western models of documentation. Indigenous phenology is inherent within Indigenous linguistics especially in place names. Through intergenerational communication and transmission Indigenous knowledge systems (including Indigenous phenology) pass along inherent values and ways of being that are encoded within Indigenous knowledge systems and languages.

Overall the Indigenous phenology literature does not include the inherent values Indigenous phenological knowledge is embedded within. To show the complexity of Indigenous phenological knowledge as a process embedded in an Indigenous worldview, I developed a model based on my thesis research, my research experience, and my own Indigenous knowledge. One of the more complete models of Indigenous phenology was created by Armatas and others (2016). This model was simple and included seasonal knowledge and ecological knowledge. However, this model did not include the spiritual and cultural knowledge aspects inherent to Indigenous knowledge systems. I argue that Indigenous phenological knowledge is more complicated than previous scholars have described (Armatas et al. 2016; Lantz & Turner 2003; Nabhan 2010). Indigenous phenological knowledge in my model is embedded within different levels of Indigenous knowledge (figure 1). The outside circle indicates the non-linear and cyclic conception of time in an Indigenous worldview. A common conception within Indigenous ceremonies and events is that time flows in a clockwise fashion. The second circle is Indigenous knowledge, and indicates that all other knowledges are embedded within an Indigenous knowledge system. The third circle is cultural knowledge. Cultural knowledge includes everything that may make up the specific cultural knowledge of a certain tribe or region. Cultural knowledge may include a tribe's language, societal structures, governing values and life way values, technology, and economic systems. These cultural knowledges uphold and also help to inform the spiritual knowledge of the tribe. The spiritual knowledge of a tribe is tied to the tribe's existence and is interwoven within most facets of the Indigenous knowledge system. The spiritual knowledge circle is held together by certain values and teachings that are encoded within intergenerational communication and oral traditions. Finally, the center of my model is adapted from Armatas and others (2016) in which they describe Indigenous phenological knowledge as a conjoining of the seasonal and ecological knowledge of an area for that respective tribe. My model shows how Indigenous phenological knowledge is much more complicated than previous definitions focused mostly on ecology and seasons.

This expanded model of Indigenous phenological knowledge is important because less complex models limit Indigenous phenological knowledge to only seasonal and ecological knowledge. These less complex models are damaging because they fail to include the broader cultural context and the inherent Indigenous values that reside within Indigenous phenological knowledge. For example, Indigenous phenological knowledge is tied to the teachings of a ceremonial events such as wild rice harvesting, or the values of when to plant certain crops like corn, or when to harvest maple sap for sugar bush. These are all important factors within Indigenous phenology that help to guide and indicate ceremonial events within tribes as well as values that are inherently tied to them that help with governance of lifeways for tribal nations and Indigenous communities.

Separating Indigenous phenological knowledge from values disregards Indigenous worldviews which can further marginalize and dispose of Indigenous peoples. Therefore it is important to consider these broader knowledge systems in relation to Indigenous phenological knowledge. I created this more complex Indigenous phenological knowledge model to illustrate the multiple knowledge systems and interactions of the knowledge systems within Indigenous phenological knowledge. My model acknowledges that Indigenous knowledge is vast and complex while also acknowledging that this model is not comprehensive in all of the interactions within the different knowledge systems of a specific tribal nation. Rather the model attempts to demonstrate the complex interactions in Indigenous phenological knowledge that go beyond seasons and ecology.

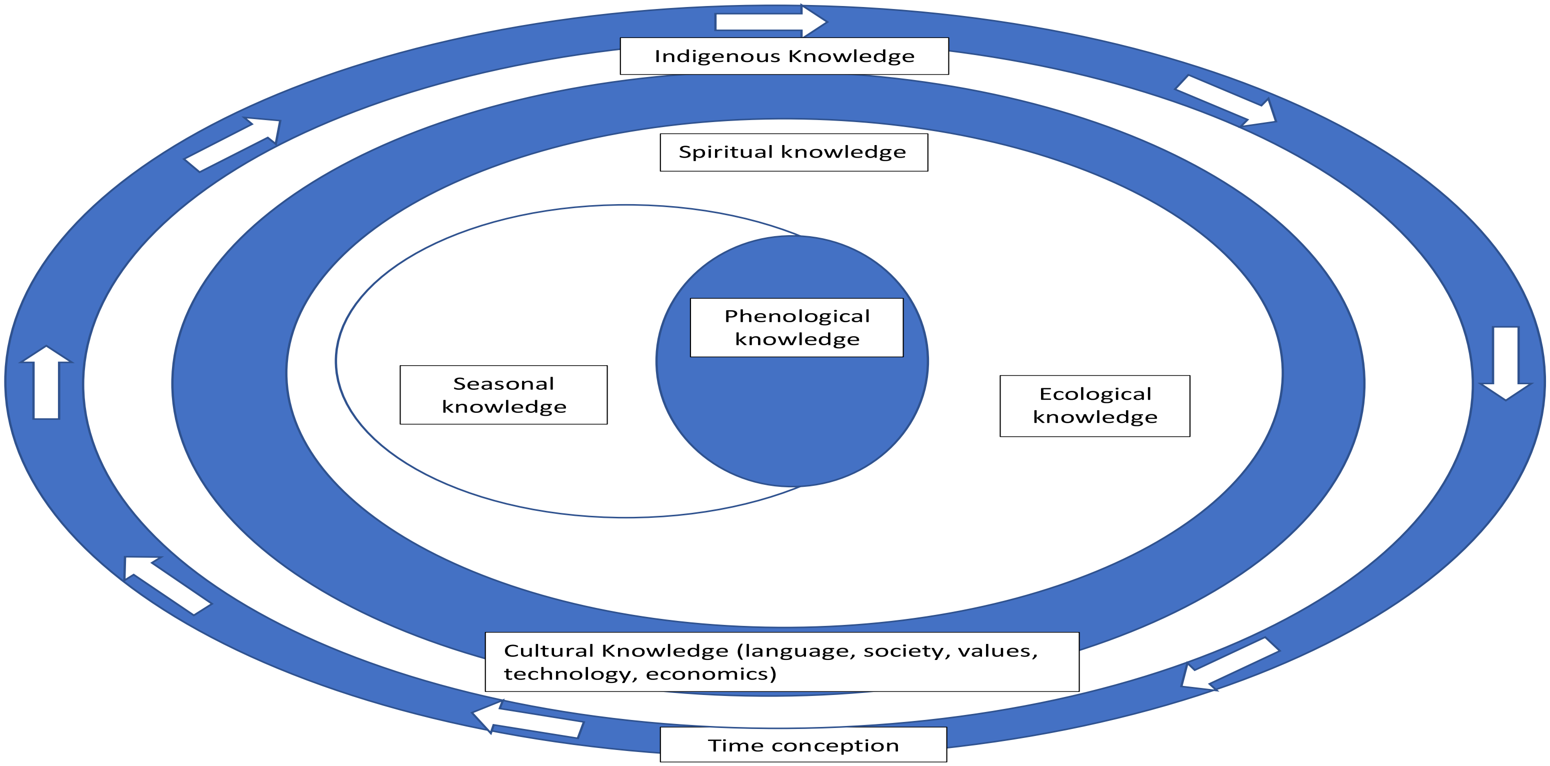

Figure 9: Indigenous Phenological Knowledge Model

A conceptual model of Indigenous phenological knowledge within the Indigenous knowledge system. The center of the model is adapted from Armatas et al. (2016) where phenological knowledge is framed by ecological and seasonal knowledge. The larger context of the model illustrates how seasonal and ecological knowledge reside within the inherent values of cultural and spiritual knowledges. This is part of a broader Indigenous knowledge system in which time conception is an ongoing cyclic process.

Building Tribal Partnerships

Tribal partnerships are built on the recognition that tribal nations are inherent sovereigns and have government-to-government relationships with the US (BIA 2016; Dockry et al. 2017). This recognition reaffirms the inherent sovereignty tribal communities have. Successful tribal partnerships start with tribal sovereignty but are also built on trust. Tribal partnerships require significant time to build the trust in part due to past tumultuous relationships with government and scientific entities (Montgomery 2013; Smith 2013; BIA 2016; Dockry et al. 2017).

The literature suggests multiple keys to keep in mind when building partnerships with tribal partners. Some studies show that upholding formal relationships, developing informal personal relationships, and collaborating in natural resource management are keys to building partnerships with tribes (Smith 2013; Dockry et al. 2017). Montgomery (2013) suggests engaging with Indigenous communities as partners, recognizing past injustices caused by irresponsible research practices, respecting traditional knowledge, allowing community values and perspectives to guide the partnership, fostering transparent and open communication, and becoming active and present within the community. Tribal partnerships require trust between the tribal and non-tribal partners. These are some suggestions and ideas to keep in mind when building partnerships with tribal partners.

There are various approaches to forming partnerships with Indigenous communities. A recent study conducted by Gittelsohn et al. (2018) mapped out suggestions for tribal partnerships for both non-tribal and tribal partners. For the non-tribal partners, suggestions include building institutional capacity to work with

Indigenous communities by identifying competencies needed. For tribal partners suggestions include building Indigenous community capacity to work with universities and conduct their own research. For both types of partners, a research partnership should employ formative research strategies to incorporate Indigenous community perspectives, utilize Indigenous research methods to build Indigenous community engagement, establish community advisory boards composed of people from the community, abide by tribal IRB regulations, and lastly, plan for dissemination, data ownership, and publication (Gittelsohn et al. 2018). Other suggestions for tribal partnership building include respect and listening, developing relationships outside of the conference room (informal and personal relationships), community inclusion, and resource investment (Dockry et al. 2017; Gittelsohn et al. 2018). Tribal partnerships require respect and the ability to listen (Montgomery 2013; Dockry et al. 2017). Tribal research partnerships require some form of community-based participation research model (Brockie et al. 2019; Kovach 2008; Smith 2013).

Most tribal nations have their own form of research protocols. These protocols can be anything from a tribal Institutional Review Board (IRB) to a document that outlines how research is to be conducted with the tribal nation. The literature on Indigenous research protocols suggests it is important to engage a tribe early in a research project (Chilisa 2011; Smith 2013; Lambert 2014; Dalbotten et al. 2017). These studies also show that a tribal partner should define what is being researched and how to go about the research in relation to tribal protocols. In most cases, tribal communities will have research topics they are interested in exploring and will have specific protocols on how to go about conducting the research. It is important to understand tribal research protocols and any tribal IRB processes that exist before forming a research partnership with a tribal community.

From the beginning of a project, non-tribal partners should follow the lead of tribal partners when it comes to research. This action creates an opportunity for the tribal and non-tribal partners to collaborate and the non-tribal partner to listen to what is best for the tribe. Dockry et al. suggest that “ [d]emonstrations of respect, support, honesty, integrity, trust building, and listening” will create a more trusting relationship among partners (2017, 126). This first and important step seems straightforward but will have a resounding impact on tribal communities.

Interpersonal relationships are also important for tribal partnership building in order to build community trust and strong relationships with tribal partners. Interpersonal relationships develop outside of the formal partnership with tribal partners at community events like powwows, community gatherings and feasts, at tribal college and university events, and break periods during more formal conferences (Dalbotten et al. 2017, Dockry et al. 2017). Investing in informal relationships and personal connections with tribal partners and community members, in some cases, are the keys to developing strong relationships with tribal partners (Dalbotten et al. 2017, 27). Interpersonal relationships help to develop community ties and acceptance for tribal partnerships.

Another important aspect of tribal partnership building is the inclusion of the tribal community. This resembles of community-based participatory research (Christopher et al. 2011, Chino & Debruyn 2011). It is important to include tribal community members when working with a tribal nation in the decision-making and active research aspects of the project, if possible, have a community member cited as principal investigator (Christopher et al. 2011). Incorporating a community member, such as an elder, when working with tribal nations can also help create a positive perception from the community in regard to the research project (Dalbotten et al. 2017). Non-tribal partners should invest time into personal relationships with tribal partners outside of the professional realm. This will help to create rapport with tribal partners and allow for more meaningful collaboration. Eventually, non-tribal members should strive to become community members of the tribal community to create a sustainable trustworthy relationship between partners. Once considered a community member, tribal partners and non-tribal partners will be able to collaborate on data, data analysis, results dissemination, and publishing.

Challenges to Tribal partnership building

There are also challenges in building partnerships such as bureaucratic structures, differences in natural resources perceptions, lack of resources for partnerships, and high turnover rate within all parties to name a few (Dockry et al. 2017). Also, tribal partnerships require resource investment. Time is the largest expense when it comes to working with tribal nations due to the amount of bureaucracy within the tribe as well as the non-tribal partners whether that is university, federal, state, or county agencies. Bureaucratic structures can slow processes down especially when working with two unique entities that may include the federal government and a tribal partner. Additionally, tribal communities often hold negative perceptions of research and scientists given the past experiences of Indigenous peoples. Authors cite these injustices by including them within their suggestions. For example, Montgomery's model recognizes and begins with the past injustices committed against Indigenous communities in research practices (2013). Another challenge to tribal partnership building is the dissemination of research findings that are understandable and useful to the tribal community. Tribal communities are increasingly demanding that research results be shared with them are free from jargon and relate to tribal community needs or goals (Gittelsohn et al. 2018). Tribal communities tend to not be directly involved with tribal research interests due to the separation of tribal professionals and the tribal public, hence easily-digestible research dissemination is a must for tribal communities.

Benefits to building tribal partnerships

Partnerships are important because they help tribal communities reach their respective goals while also serving to build trust with other non-tribal entities, or, essentially, build capacities of all parties involved. Partnerships for tribal and non-tribal partners can solidify sovereignty, increase trust, increase community capacity, and provide solutions for adaptation to climate change. Partnerships in tribal communities create opportunities for western science and Indigenous knowledge to work in conjunction to solve problems that pertain to tribal communities (Dalbotten et al. 2017).

Creating research partnerships in tribal communities allow the tribal community to view science and research in a different way if tribal community members have access to the research. Tribal research partnerships help to combat the negative research perception in tribal communities. Tribal youth involved in tribal research partnerships help to create a pathway to higher education and research institutions and allow opportunities for tribal youth to view Indigenous knowledge and western science as partners (Dalbotten et al. 2017).

Understanding Indigenous phenological knowledge and Partnerships through Menominee experiences

Indigenous phenological knowledge with a Menominee focus (Indigenous phenology on Menominee tribal lands) is a subset of the broader Indigenous knowledge system. Indigenous phenological knowledge with a Menominee focus is a tribally specific form of Indigenous phenological knowledge unique to the Menominee Indian Tribe of Wisconsin. Indigenous phenological knowledge works with ethical science to create sound solutions and adaptation strategies for Indigenous communities in the face of climate change. Indigenous phenological knowledge with a Menominee influence helps to form trust, capacity, and knowledge through partnerships between Menominee partners and non-Menominee partners (federal agencies and academic institutions).

The Menominee tribe is engaged in two Indigenous phenological knowledge projects designed to support sustainable management, understand climate change impacts, and build capacity/knowledge to adapt to climate change impacts on the Menominee Nation Reservation. My thesis research examines two Indigenous phenological knowledge projects (Measuring the pulse and the Menominee phenology project) situated on the Menominee reservation and in relationship to my experience as a Menominee graduate student.

Partnerships became a central focus of the Menominee response to climate change and the following two examples illustrate how Indigenous phenological knowledge projects support tribal sovereignty through partnerships. The Menominee tribal goals are to manage for biodiversity for survival as they have done for the past century and half (Beck 2005; Mausel et al. 2017; Menominee Tribal Enterprises 2012; Pecore 1992; Waller and Reo, 2018). The following two projects exemplify the process of Indigenous phenological knowledge with a Menominee focus through the partnerships the projects helped to build.

The Measuring the Pulse (MTP) project was a multi-year granted funded project through the USDA-NIFA-Tribal Colleges Research Grants Program (TCRGP)-003648 for the years of 2012-2015 (TCRGP) 2012-2015 developed in partnership by the College of Menominee Nation Sustainable Development Institute (CMN SDI), Michigan State University Native American Institute (MSU NAI), the Smithsonian Institute (SI), Menominee Tribal Enterprises (MTE), the Menominee Indian Tribe of Wisconsin (MITW), and the Menominee Indian community. According to the College of the Menominee Nation Sustainable Development Institute, the goal of the Measuring the Pulse project was to evaluate how sustainable forest management paradigms affect the resiliency of forests to anticipated variations and changes to climate (2014, 1). The project established three 1ha forest monitoring plots on the Menominee Nation's lands, one on the College of Menominee Nation campus and two in the actively managed sustain-yield forest (the three plots studied in Chapter 1 of this thesis). These plots were established for research purposes and knowledge exchange between tribal college students and scientists in relation to climate and environmental data. The project involved complete tree and plant inventories as well as the collection and analysis of information on "biological, physical, cultural, and social dynamics and relationships in forest systems" for each plot (Cook et al. 2015).

The Measuring the Pulse project aims to "evaluate how sustainable forest management paradigms affect resiliency of forests to anticipated variations and changes to climate" (Cook et al. 2015) because the very survival of Indigenous communities in the face of climate change depends on knowledge and technology exchange between scientists and Indigenous communities. The MTP project was developed out of the innate need for the Menominee community's survival. The Menominee Indian Tribe of Wisconsin is known for their sustainable forest management and it is one of the many ways the tribe derives capital by sale of timber and non-timber products from their forest. The increasing threat of climate change will affect the tribe in numerous ways especially in relation to their unique forest management style, sustained-yield management or sustainable forest management. The knowledge exchange involved in the project also serves as a capacity-building agent for the students and the Menominee Indian community in the context of research experience, methods, and analytics. This is creating the next generation of researchers and forest managers.

Menominee Phenology Project

The Menominee Phenology project grew out of the MTP and was a multi-year grant funded project through the USDA-NIFA tribal college research grants program developed in partnership by College of Menominee Nation's Sustainable Development Institute (CMN SDI), the Menominee community, Menominee Tribal Enterprises (MTE), Menominee Indian Tribe of Wisconsin (MITW), the United States Forest Service (USFS), and the University of Minnesota (UMN). I was a graduate student on the Menominee phenology project in which I spent 2 summers engaged with actively planning, conducting research, as well as analyzing data from the project (see chapter 1). I actively participated in the development of research protocols, the selection of plants, and supervised two teams of tribal college interns. According to grant documents, the goal of the Menominee phenology project was to "implement a research study that quantifies the timing, abundance and variability of key phenological phases (flowering, fruiting) for ten species in the forests of the Menominee Nation" while the secondary goal of the project was "create a phenology trail that engages the broader community in examining plant and animal response to climate" (Menominee Phenology Project proposal, 2016, p. 3,4). In 2014, a Menominee ethnobotanist completed an inventory of plant species in the forest monitoring plots for future educational and research efforts. The overall objective was to measure the variation of individual plants as a way to understand future climate change responses.

Methods

Our research design is an inductive mixed methods qualitative analysis. I analyzed grant proposals, grant reports, stakeholder agreements, partnership agreements, emails, team meeting notes, community engagement fliers, and internship reports from the Measuring the Pulse and the Menominee Phenology projects. In total I analyzed 30 pages of text from these documents. The document analysis used grounded theory analysis, and an iterative coding process (Corbin and Strauss, 2008). Themes emerged from the data and were tracked and structured using Nvivo 12 qualitative data analysis software. I then organized emergent themes into a structure that addressed our study questions and objectives.

I also incorporated my own participant observer story as a Menominee graduate student into the research design for clarity and insight into tribal dynamics. I led the field work for two summers on the Menominee phenology project in coordination with my advisor from the University of Minnesota. A participant observer story was incorporated because the method allows for an insider's perspective as a Menominee tribal member.

Research was conducted on Menominee tribal lands with Menominee tribal members at SDI and with the CMN interns, these are Indigenous methodologies (see Smith 2013). Participant observation helped to better understand the phenomenon of Indigenous phenology and Indigenous phenological knowledge. Participant observation in this project is part of the mixed methods approach in that it also allows for an Indigenous methodology, storytelling, and interpretation.

Discussion

Indigenous phenological knowledge

Indigenous phenological knowledge was the foundation of two Menominee projects. The Menominee project teams were made up of Menominee tribal members and descendants along with allies who researched and performed phenological observation and monitoring. The partners came together in an Indigenous phenological knowledge process to tackle the goal of how climate change will affect the forest understory plants in relation to the rest of the forest and the peoples that live within the forest.

Tribal partnership-building was a foundational pillar to both Menominee projects. Partnerships were formed between tribal and non-tribal partners within both Menominee projects. Partnerships helped shape the response for adaptation strategies to climate change and fostered tribal resilience. These responses are a collaboration of partners to create sustainable adaptation strategies in climate change. In the Measuring the Pulse project, a cultural knowledge inventory and forest climate data were completed and phenological monitoring protocols were developed in the Menominee Phenology project. The results of both these projects will help to guide tribal actions (responses) or inactions based on the data. The following subsections will describe how partnerships in these Indigenous phenological knowledge processes built trust, capacity, and knowledge.

Menominee Phenology Processes

A partnership formed between a University of Minnesota professor who specializes in forest ecology and phenology, myself, a Menominee master's student, and a Menominee ethnobotanist. We came together to develop a Menominee-centered phenology process. As partners we created a protocol for phenological monitoring on three 1-ha research plots that were established as part the MTP project. Our collaboration, the Menominee Phenology project, is an example of Indigenous phenology because it involved Menominee community members from the inception of the grant to the research. It is significant in that the Menominee Phenology project also included Menominee community members at CMN SDI and Menominee tribal college interns (both CMN and Menominee higher education students from other institutions). The research was conducted to benefit and further the goals of the Menominee Indian Tribe of Wisconsin and community on the tribal lands of the Menominee tribe. When Indigenous knowledge is involved from the beginning of the project, continues to be a part of the project until the end, and achieves tribal goals it is a process of Indigenous knowledge. Since it is a project focused on phenological phases of plants it is also uniquely a process of Indigenous phenology.

Trust

The partnerships within the Menominee Phenology project built trust through ethical relationships and a tribal partner-led research design. In early spring of 2017, personnel from CMN SDI, USFS, UMN, the Menominee ethnobotanist, and myself held planning meetings to develop a phenological sampling protocol. These meetings helped to establish the foundation for a trustful relationship. These meetings were important because the tribal partners led the research design with input from the university and federal partners. We borrowed sampling methods from the National Phenology Network and then developed phenological observation monitoring and data recording protocols and also created trails through the plot to avoid trampling plants (participant observation, 2017). This collaboration helped to establish positive rapport among partners in an effort to understand and respect everyone's goals within the grant parameters. This Indigenous phenology process created space for Indigenous peoples to research phenology on their own tribal lands and led to enhancement of tribal goals. Overall, the process of building a respectful partnership built trust that was maintained in each stage during the Menominee phenology project from planning to protocol development, and through implementation.

Capacity

There are several ways capacity was built through the Menominee Phenology project. First, capacity was built previously through the Measuring the Pulse project. The Sustainable Development Institute and the College of Menominee Nation built capacity in research and methods in the MTP forest census data but did not have phenology protocols and phenology research experience. The partnership with the University of Minnesota formed to develop this capacity. The University of Minnesota helped to build the capacity of CMN SDI and the Menominee community through plant phenology training on the College of Menominee Nation phenology plot. In my role as a participant observer I experienced the UMN phenology training the first year I was on the project. Based on the experiences I accrued during the first year's data collection and phenology monitoring, I helped lead the training and the project itself during the second year. In both years, the University of Minnesota helped to train tribal college students and interested Menominee community members in general phenology methods and how they were to be used in the Menominee Phenology project. In my experiences, people from the Menominee community would attend the phenology trainings to learn proper protocols for observing and collecting phenology data. They also learned what a phenophase was and what certain phenophases looked like in different plants. The Menominee ethnobotanist on the project also provided general botany trainings for tribal college student interns. This was especially important because some of the tribal college students did not have a background in biology or botany. Another part of the capacity building came from the Menominee ethnobotanist being with the interns every field day helping guide and collecting data on the forest monitoring plots. Another aspect of capacity building came when, at the end of their internships, the College of Menominee Nation students then gave community presentations with information and data about the Menominee phenology project and their experiences being involved in the research project. These are just some of the many ways in which capacity was built in the CMN SDI and the Menominee community—fulfilling a specific goal of the project.

Knowledge

As an Indigenous phenology process, the Menominee phenology project co-created knowledge. Most importantly, a phenology protocol was developed in collaboration among the partners; CMN SDI, USFS, UMN, and a Menominee ethnobotanist. This protocol was a hybrid between the National Phenology Network and specific adjustments to center Menominee knowledge and goals. The protocol was used by the team to monitor 200 individual plants of 11 different species. Each week, the team would go and visit the plant relatives and record what they saw for that week. Most importantly, they recorded if a certain phenophase was occurring, and if so, the number of flowers (buds or open flowers) or fruits (ripe or unripe) present. Based on Menominee community input and a concern for protecting Menominee knowledge, culturally sensitive plants were not monitored. This was a specific requirement that came directly from the Menominee Indian community. This hybrid monitoring protocol was an example of co-created knowledge through an Indigenous phenology process.

The importance of partnerships for Indigenous phenological knowledge

As part of my mixed-methods approach to understanding Indigenous phenology processes, I analyzed documents provided by the Sustainable Development Institute related to the Measuring the Pulse (MTP) project. Multiple themes to emerged from the documents that illustrate components of successful Indigenous phenological knowledge projects. One unifying theme that emerged across the documents was the importance of partnerships. Partnerships were used by the Menominee Nation in these projects to strengthen tribal sovereignty and build capacity. I define partnership as a mutual beneficial trust-based relationship between two or more parties in relation to a common goal. There are four kinds of partnerships that the College of Menominee Nation Sustainable Development Institute used to achieve their goals: tribal/non-tribal, tribal/non-tribal academic, and tribal/tribal partnerships. In the next subsections I will discuss each type of partnership in turn and show how they strengthen tribal sovereignty and build capacity.

Tribal / Non-Tribal Partnerships

Tribal and Non-Tribal partnerships are partnerships that recognize the inherent sovereignty of the tribal nation(s) or tribally-affiliated group that are involved in the partnership. This means recognizing that the tribal nation was and always will be an independent nation or is an agent of that tribal group with generations of traditional ecological knowledge and Indigenous phenological knowledge related to their territories. The partners recognize that the non-tribal partner is a much younger entity and has a different relationship to the land than the tribal partner(s) have but does have capability in their respective specialties and own experiences.

The Measuring the Pulse project involved many tribal and non-tribal partnerships. One document described this type of partnership and the responsibilities of the agreement between CMN SDI, the Smithsonian Institute (SI), and Michigan State's Native American Institute (MSU NAI). The agreement called for knowledge-sharing, knowledge-generation, and knowledge inventory for the project. The abstract states "[o]ur project forms a unique partnership between College of Menominee Nation, the Smithsonian Institution, and Michigan State University to bring together researchers and students from land grant institutions to work with Smithsonian scientists and scholars to collect and analyze climate and environmental data, generate new forest ecosystem climate information, and develop a community-driven inventory of Indigenous knowledge and understanding" (Measuring the Pulse Project summary/abstract, p.1). The partnership was a tribal and non-tribal partnership with CMN SDI being tribal and SI, MSU NAI being the non-tribal entities. This partnership was unique in that the it was composed of a non-academic public research institution (SI), an academic institution with individual Indigenous leaders (MSU NAI), and a boundary organization (CMN SDI). This unique partnership created pathways and solutions to building co-created knowledge while also reinforcing tribal sovereignty. In this instance, the non-tribal partners used western scientific methods to build capacity at the tribal level while also recognizing Indigenous knowledge as a rich valuable knowledge source for the tribal partners.

Tribal – non-tribal partnerships were also important in the Menominee Phenology project. The tribal partners were: CMN SDI, Menominee community members, Menominee Tribal Enterprises, and the Menominee Indian Tribe of Wisconsin. The non-tribal partners were: US Forest Service and the University of Minnesota. These partnerships were built on trust through planning and research. I was present in at least 3 preseason Menominee phenology project meetings and would travel with my professor to Menominee to meet with the CMN SDI partners and the USFS partners. We met at least 3 times before the growing season to plan and assess our methods for the Menominee Phenology project. Trust was built because tribal goals were put first and the non-tribal partners used their expertise to support those goals.

We adopted a "try it out" approach for our first couple of protocols before settling on the final one. We changed our methods a series of times based on feedback from our fieldwork crews (College of Menominee Nation interns, Menominee ethnobotanist, and myself). The tribal partners chose what topics to research and what pertained to the tribe. This led to the non-tribal partners supporting choices through capacity building. Specifically, the tribal partners built capacity through learning about different methods and approaches to botany and phenology protocols. While the non-tribal partners gained capacity through experience working with tribal members and tribal college students and learning about CMN SDI decision-making processes. These tribal and non-tribal partnerships built capacity within the Menominee Phenology project because they allowed for access, and knowledge and technology exchange between CMN SDI, Menominee community members, USFS, and the University of Minnesota. The tribal partners offered access to the forest, people, knowledge, and resources on the Menominee tribal land in exchange for the non-tribal partners' methodologies and ecological knowledge. The University of Minnesota partners, the forest ecologist in particular, conducted phenology training for the SDI staff and student interns. The ethnobotanist also gave refresher botany courses to the UMN graduate students and CMN student interns whom were the primary contact for the plant relatives in the forest monitoring stations (participant observer, 2017). The combined knowledge between the local and Menominee ecological knowledge of the ethnobotanist and the overall forest ecological knowledge from the university partners all came together to create a hybrid phenology observation protocol. This allowed for greater capacity-building on the tribal partner's side through co-production of climate and ecological data while also enhancing tribal sovereignty through co-creating knowledge in science and methodologies that support the goals of the Menominee and their tribal sustainable managed forestry goals.

There were also challenges with tribal – non-tribal partnerships. One challenge is related to data sovereignty or data ownership and rights. I examined the relationship between the Menominee Tribal Enterprises and the Smithsonian Institute and found that MTE did not want to hand over sensitive forest inventory data to the Smithsonian Institute. Menominee Tribal Enterprises' feared that the Smithsonian Institute would gain access to sensitive information that they strived to protect (Caldwell, 2018). This led to a rift in the relationship between MTE and the Smithsonian Institute which led to the breakdown of talks and eventually the removal of the Smithsonian Institute as a partner for the Measuring the Pulse project. This was due to lack of trust in the partnership between the two parties and MTE used the sovereignty of the tribe to protect sensitive tribal information by pushing SI out of the MTP project.

There are a variety of reasons why SI was ousted but Dockry et al. (2017) suggest that tribal partnerships require more than just a formal relationship. In other words, it could be suggested that the SI personnel did not develop informal and personal relationships with tribal partners. I also believe that SI did not invest the resources and time it takes to develop a strong partnership with the tribe and Menominee Tribal Enterprises. If the Smithsonian Institute would have invested more time and developed those critical informal and personal relationships with tribal and MTE employees along with “showing up and showing respect” (Dockry et al. 2017, p. 126) there might have been more willingness from MTE to collaborate. Additionally, SI would have learned how important it was and has been for MTE to protect their own data and how reluctant they would be to requests for sharing. Regardless, this outcome showed us that data sovereignty and sensitive tribal information ultimately both strengthened Menominee sovereignty through tribal control over the research process and weakened Menominee sovereignty and due to lost research potential with a national research institute.

In conclusion tribal and non-tribal partnerships were important to the Measuring the Pulse project because they built the foundation for the partnerships. These partnerships also built collaborative work between CMN SDI, MSU NAI and the Smithsonian Institute (although the latter was ousted). Lastly, tribal and non-tribal partnerships contributed to the capacity building and resilience of the Menominee Indian community.

Tribal – Non-Tribal Academic Partnerships

The tribal – Non-tribal academic partnership is a subtype of a tribal – non-tribal partnership. This partnership is defined as a relationship between a tribal-aligned entity and a non-tribal entity with capacity and methods in research and education. I observed these relationships in the MTP project via the partnership between CMN SDI and the Michigan State University Native American Institute (MSU NAI). I also observed a tribal – non-tribal academic partnership in the Menominee phenology project between CMN SDI and the University of Minnesota. Tribal -Non-tribal academic partnerships are important because through their agreements and collaboration, these partnerships foster trust and build capacity through research and information exchange. The partnerships in the Menominee phenology projects brought together academic and non-academic institutions in order to support and provide resources to further the aim of the Measuring the Pulse and the Menominee Phenology projects and ultimately, facilitate knowledge and technology exchange between scientists and students.

One document, titled "The 1994 and 1862 Cooperative Agreement" was a memorandum of understanding between the College of Menominee Nation and the Michigan State University that outlined the relationship between the tribal and non-academic partners. I found evidence of how these partnerships build capacity through sharing knowledges (methods and different ways of knowing) between entities and are ethical research relationships. The 1994 and 1862 Cooperative Agreement's main purpose was to "focus on efforts of building the capacity of College of Menominee Nation, its Sustainable Development Institute, and students to improve implementation of projects and strategies that address climate change and community-based participation"

(Henry et al. 2012). The objectives of the agreement were for College of Menominee Nation and Michigan State University to:

> Serve on the Project's Cultural Advisory Group, which will guide the development and provide evaluation of the methods and measures of projected impacts of climate change on the vulnerability and resilience of cultural services and relationships. Review interview questions, surveys, and focus groups protocols for preliminary inventory of forest cultural services. Participate in Cultural Advisory Group meetings and participate in on site meetings with project research team and cultural advisory group. Evaluate our methods for appropriate tribal community-driven and participatory approach to identify and quantify the depth and diversity of cultural services provided by forests and the impact cultural relationships have on biodiversity and the delivery of ecosystem services." (Henry et al. 2012).

The majority of the agreement was to oversee and develop coordinated measures to build tribal college capacity that extended beyond the Measuring the Pulse project. This is an example of how tribal – non-tribal academic partnerships further tribal and non-tribal institutional goals, and therefore tribal sovereignty, while also building capacity and creating ethical research relationships.

The Measuring the Pulse of the Forest project also demonstrates how tribal – nontribal academic partnerships can foster sovereignty and capacity building. The abstract for the project stated "[o]ur project forms a unique partnership between College of Menominee Nation, the Smithsonian Institution, and Michigan State University to … collect and analyze climate and environmental data, generate new forest ecosystem climate information, and develop community-driven inventory of Indigenous knowledge…" (Cook et al. 2012, 1). Knowledge sharing (collect and analyze climate and environmental data), knowledge generation (generate new forest ecosystem climate information), and knowledge inventory (develop community-driven inventory of Indigenous knowledge) are key components for the project and partnership.

The knowledge-sharing of the MTP project helped to build capacity and strengthen tribal sovereignty through research methods learned and the creation of forest plots. The knowledge-sharing component of the project was conducted by SDI, the Smithsonian Institute, and MSU NAI "[t]his project involves forming forest monitoring plots on the Menominee forest lands and establishing research teams from partnering institutions that include Smithsonian Institution, College of Menominee Nation, Menominee Tribal Enterprises, Menominee Community, and Michigan State University Native American Institute" (Cook et al. 2015, 1). These partnerships were formed to help develop the forest plots in which were used to generate climate knowledge and "cultural resiliency to climate change" (Henry et al. 2012). This in turn, is built capacity which expands the tribal capacity of CMN SDI and the Menominee Nation. This also strengthens tribal sovereignty through installing forest plots that can be used for tribally-conducted research to help the tribe prepare for climate change adaptation.

Two-way, knowledge-generation (tribal and non-tribal academic) was also an important aspect of the Measuring the Pulse project. Specifically, the grant report stated:

> [t]here was a need to build knowledge on both ends: educating the scientists on the decision-making capacity and concerns on the tribal side and providing more specific information for the tribal decision-makers based on the skills and experience from the scientists side. This brokering of knowledge was slow but necessary for the development of the current project and [sic] with an eye toward continued work with either the Menominee… (Sustainable Development Institute, 2014, 2).

In other words, the knowledge exchanged and gained from all partners in the project was an indirect result of the Measuring the Pulse project. I observed how the institutional knowledge (memory, methodologies, and analytical skills) of CMN SDI contributed to the development of the Menominee phenology project. This institutional knowledge builds upon the capacity of the CMN SDI while also creating a stronger sense of independence or sovereignty for the tribe in the form of social and ecological skills. The combination of knowledge-sharing and knowledge generation also strengthens tribal sovereignty, increases tribal capacity, and further builds trust through the co-production of knowledge.

Another aspect of the tribal non-tribal academic partnership was a knowledge inventory. Both the tribal and non-tribal institutions helped to develop the methods "…for assessing and monitoring the nature and meaning of cultural relationships between indigenous and local peoples and their forestlands" (College of Menominee Nation 2012, p. 1). This was important in that the Sustainable Development Institute, with the help of MSU NAI, was aiming to measure or conduct an inventory of Indigenous knowledge of the Menominee Nation while also being focused by the Menominee community. The expertise at MSU NAI assisted SDI with the inventory of Indigenous knowledge on the Menominee reservation which is part of the MSU NAI mission to enhance "tribal sovereignty." The IK inventory helped to create a tool/process to measure and inventory of IK using interviews and coding. This directly contributes to tribal sovereignty because it built capacity within the tribal institution.

Information dissemination was also important for tribal -- non-tribal academic partnerships because tribal partners strengthen their sovereignty through directing their information dissemination to their tribal members in order to create a sense of security while also building capacity by providing information to the tribal members and public. The Measuring the Pulse project grant proposal used community meetings for information dissemination. At these meetings, CMN SDI and MSU NAI partners would provide information about the project and provide updates as the project progressed. One document stated "…community information sessions will discuss the ecological and cultural components for the Measuring the Pulse of the Forest project" (Community Information Sessions: Measuring the Pulse of the Forest poster, 1). These meetings helped to create a more transparent and trustworthy process as both partners recognized the distrust of research amongst tribal communities. These meetings also allowed for Menominee tribal members and community members to ask questions and learn about the Measuring the pulse project. The tribal – non-tribal partnerships created space for community members thus building trust and creating a more ethical transparent research relationship.

These partnerships were important to give the non-tribal academic partner access to tribal lands, Indigenous knowledge, community relationships, and phenological knowledge. CMN SDI brought access to lands and relationships with community members on the tribal reservation along with the ability to teach about Indigenous phenological knowledge. I actively participated in the adjustment phase of our initial National Phenology Network protocol when we first started thinking of ways to visit the plant relatives on Menominee land without trampling the plants. This collaborative approach developed a solid protocol based on Menominee knowledge that allowed for the fieldwork team to respectfully visit each individual plant relative across the three plots weekly without disturbing the majority of the forest community.

I personally learned a lot from the Menominee knowledge and the plant knowledge after spending extensive time on the forest plots. I participated in the Indigenous phenological knowledge process by conducting research through partnership on tribal lands while also developing a relationship with each individual plant that I would see weekly, observing the plant grow and transition through each phenophase. This led to an intimate relationship with the plant relatives that allowed the fieldwork team and myself to understand the plants in ways such as where they like to grow, what each plant's phenophase looks like, and what communities these plant relatives liked to grow within (Kimmerer 2013). Tribal – non-tribal academic partnerships were rooted in and benefitted from both western scientific phenological knowledge (protocols and species classification) and Indigenous phenological knowledge (developing relationships with the plant communities and partnerships through IPK).

In summary, tribal – non-tribal academic partnerships are beneficial for both tribal and non-tribal academic partners. Non-tribal academic partners benefit from a variety of experiences; learning about Indigenous phenological knowledge, learning about tribal perspectives, how to build partnerships with tribes, experience working with a tribal community, and foster their own institutional goals and objectives. Tribal partners also benefit from tribal – non-tribal academic partnerships through offering tribal college students a research experience, access to a broader network of information including climate data, built capacity (forest plots), cultural inventory tools (methods and relationships) and experience working in a positive research relationship with a non-tribal academic partner. Tribal and non-tribal academic partners benefit from partnerships between the parties in their respective ways but most importantly, contribute to the capacity and foster institutional goals of the parties involved in the partnership

Table 5: Types of partnership that were formed in the Measuring the Pulse and Menominee Phenology projects

Type of Partnership	Definition
Tribal – Non-tribal	Partnerships that recognize the inherent sovereignty of the tribal nation(s) or tribally-affiliated group that are involved within the partnership. This means recognizing that the tribal nation was and always will be an independent nation or is an agent of that tribal group with generations of traditional ecological knowledge and Indigenous phenological knowledge related to their territories. The partners recognize that the non-tribal partner is a much younger entity and has a different relationship to the land than the tribal partner(s) have but does have capability in their respective specialties
Tribal – Non-tribal academic	A partnership that is defined as a relationship between a tribal-aligned entity and a non-tribal entity with capacity and methods in research and education

Tribal – Tribal	Partnerships that are collaborations between two or more tribal nations (federally recognized or otherwise) and/or agents affiliated within tribal groups such as schools, colleges, clinics, non-profit organizations and research institutions. These partnerships and collaborations are made among sovereign entities that have unique relationships to their respective lands and places. Generally, the entities of the partnerships have an attachment to a current or former land base and hold shared knowledge and experiences (partnerships can be formed within the same tribal nation or intertribally)

Tribal – Tribal Partnerships

Tribal-tribal partnerships are collaborations between two or more tribal nations (federally recognized or otherwise) and/or agents affiliated with tribal groups such as schools, colleges, clinics, non-profit organizations and research institutions. These partnerships and collaborations are made among and within sovereign tribes that have unique relationships to their respective lands and places. Generally, partners in this type of collaboration have attachments to a current or former land bases and hold shared knowledge, values and experiences. These partnerships can also be formed from within the same tribal nation or intertribally. Tribal - tribal partnerships generally strengthen tribal sovereignty and contribute to ethical research relationships between partners. Capacity building is important for tribal-tribal partnerships because these collaborations rely on built capacity and existing institutional knowledge from other intertribal entities. These partnerships are also beneficial to tribes because the data and research belong to the tribe and those involved. They also can shorten the turnaround for tribal IRB processes because there are often aligned interests between the tribe and tribal IRB board.

I found evidence of how tribal – tribal partnerships enhance tribal sovereignty, are important for an ethical research relationship, and create a safer sensitive information processes. In the contract that described the tribal-tribal partnership formed between CMN SDI and the Menominee ethnobotanist, the scope of work states the ethnobotanist will "1) serve as a technical resource for plant species identification on established climate change monitoring plots; 2) serve as a consultant and reviewer during the development of the forest relationship cultural assessment portion of the project; and 3) provide assistance in planning for an August workshop on the project" (Ethnobotanist

Contract Agreement, 2015). CMN SDI hired a Menominee tribal member as their ethnobotanist due to their expertise with plants on the Menominee Indian reservation. Through hiring a tribal member, CMN SDI reinvested in the community they serve and created a transparent planning and data-collection process. This enhanced tribal sovereignty by ensuring the funding stays in the tribal community while utilizing the skills readily available within the community, and also guaranteeing protection for any sensitive information related to the project. Overall, the relationship between CMN SDI and the tribal ethnobotanist enhanced tribal sovereignty while creating an ethical research relationship and creating a transparent, safer sensitive information process.

The tribal-tribal partnership focused on capacity building between partners. Specifically relying on the built capacity and institutional knowledge of CMN SDI and the ethnobotanist. The tribal-tribal partnership also established responsibilities for both parties involved. These responsibilities included the ethnobotanist's built capacity of science expertise, Indigenous knowledge cultural assessment, plant identification, and planning for the Measuring the Pulse and Menominee Phenology projects. The science expertise and plant identification aspect of the ethnobotany contract was to help with the initial setup of the projects as well as the training of the tribal college students from CMN. The students became adept in botany and plant identification which led to competent self-run fieldwork teams that were able to visit the plants weekly with or without the help of the ethnobotanist. The ethnobotanist also gave botany trainings to small groups of interested community members. This aspect helped to strengthen the capacity-building of the tribal partner, CMN SDI, and created a form of community-engagement from a local Menominee ethnobotanist.

The partnership between CMN SDI and the Menominee ethnobotanist help to ensure an ethical research relationship was established between the tribal institution and a member of the tribal community through the ethnobotany contract. The contract summarized the responsibilities of the ethnobotanist which included help to create a phenology plant list of the plots and also reviewing the Indigenous knowledge cultural assessment of the MTP project. This helped to create an ethical research relationship by utilizing the skills readily available within the community and also guaranteeing protection for any sensitive information related to the project. The ethnobotanist was added as an "…initial consultant, and a final reviewer" (College of Menominee Nation Sustainable Development Institute Contract Agreement, 2). This created a pathway for the Menominee tribal ethnobotanist to double-check and ensure information sought/obtained in the forest relationship cultural assessment (Measuring the pulse product) was appropriate and not culturally sensitive. The responsibility to review the Indigenous knowledge cultural assessment was critical to ensure an ethical research relationship with the Menominee community.

Working directly with a Menominee tribal member also provided a way to strengthen Menominee sovereignty through capacity-building and ensure protection of the Indigenous knowledge of the Menominee community. In the development of the Menominee Phenology project plant list, the Menominee community did not want "culturally sensitive" plants to be a part of the MTP and the Menominee ethnobotanist ensured that no sensitive plants were included. Through hiring a tribal member, CMN SDI reinvested in the community they serve. This enhanced tribal sovereignty by ensuring the funding stays in the tribal community while also utilizing the skills readily available within the community. This is significant due to the sensitive nature of tribal knowledge, resources, and customs of the Menominee Indian Tribe of Wisconsin and community hence creating a safer and culturally-respectful plant list intended for research. A non-Menominee person could not have ensured that culturally sensitive species were not included because they would not have had that cultural knowledge. This is one of the strengths of a tribal-tribal partnership—shared or similar cultural knowledge and understanding. These shared understandings within tribal-tribal partnerships ensure protection which strengthens tribal sovereignty by insulating sensitive cultural knowledge and values.

Tribal-tribal partnerships were also important for creating access to lands, relationships, and Indigenous knowledge. The Menominee tribal constitution establishes a three-pronged approach to tribal governance in which the Menominee Tribal Legislature manages the day-to-day affairs of tribal life and makes laws, the tribal courts are responsible for ruling on and upholding the laws, and Menominee Tribal Enterprises is responsible for managing the Menominee nation forest and forestry and sawmill businesses. The legislative arm of the tribe has strict policies in regard to their natural resources that limit who has access to the tribal forest. These limits could make partnerships with non-Menominee entities and non-Menominee people difficult. Tribal-tribal partnerships helped to ease the accessibility limits and create access to forest plots through an easement process based on education and research procedures. Creating a fieldwork team that included Menominee tribal members along with the non-tribal partners, MTE was more forgiving in allowing non-tribal members into the forest plots. Generally, Menominee tribal members share a Menominee land ethic in which they act with the forest's interests in mind. Menominee Tribal Enterprises was more accepting of tribal members and tribal descendants' access the phenology monitoring plots than with non-tribal members. In this case, the tribal-tribal partnership allowed for a smoother process for forest access permits and general acknowledgement of the Menominee Phenology project because Menominee tribal members were a part of the forest permitting process, were integral in the Menominee Phenology project development and application, and helped to create a sense of security through a shared Menominee land ethic.

The Measuring the Pulse and the Menominee Phenology projects brought together different tribal-tribal partnerships that were built on capacity-building, ethical research relationships, and tribal sovereignty. The College of Menominee Nation Sustainable Development Institute hired tribal college interns within the Menominee community which strengthened tribal sovereignty through protection of tribal resources and limiting non-community members into Menominee tribal forest. These tribal-tribal partnerships embodied the principals of Indigenous phenological knowledge as a process because Menominee tribal members and descendants actively engaged in the phenology monitoring and information exchange. Like traditional ecological knowledge or Indigenous knowledge, Indigenous phenology for the Measuring the pulse project and the Menominee phenology project was an ethical process that strengthened tribal sovereignty, built capacity, and achieved tribal goals.

Conclusion

This chapter shows that Indigenous phenological knowledge and partnership building are part of processes that build trust, capacity, ethics, and reinforces tribal sovereignty through partnership-building. Through my experience as an Indigenous (Menominee) graduate student on the Menominee Phenology project and my analysis of documents from the Measuring the Pulse project, directly supported the idea that partnerships are critical to develop Indigenous phenological knowledge that builds capacity, supports tribal sovereignty, and ethics. These partnerships can take several forms and involve tribal and non-tribal individuals and institutions. Additionally, this chapter shows how Indigenous phenological knowledge is more complex than the current literature describes. I developed a model to better illustrate Indigenous phenological knowledge as a process embedded within broad cultural and spiritual contexts. This model helps to better contextualize Indigenous phenological knowledge as more complex than seasonality and ecology. This is important because Indigenous phenological knowledge has been, and continues to be, used as a tool by Indigenous peoples for timekeeping and survivance. While this study takes a detailed look into a specific example of Indigenous phenology knowledge, there is a need for additional studies in different communities and regions to gain new and possibly corroborative insights. In the end, Indigenous phenological knowledge is a tool for the resiliency, survival and survivance of Indigenous communities as we face the myriad challenges of climate change and work together to develop solutions that will support our own values, goals, and world views now and for future generations.

Chapter 4: Conclusion

Indigenous phenological knowledge is a collaborative concept that builds tribal and non-tribal partnerships through planning, Indigenous knowledge, and scientific understandings of the natural world. The very act of researching phenology on Indigenous lands is Indigenous phenology. Specifically, Indigenous people and allies utilizing Indigenous knowledge and science to research through partnerships is Indigenous phenological knowledge. Tribal nations can use phenology as a indicator tool for climate change in order to further their respective goals and protect their livelihood and lands.

Climate change is altering plant phenology and will have consequences in the long-term and fitness of herbaceous species in the forests of the Menominee Nation. Climate change will also make more springs early. Climate change has shown to extend the growing season in the Great Lakes by about nine days (Hibbard et al. 2017). Although this may be favorable for the herbaceous species of the Menominee Nation, studies on trees and the rest of the forest community must be completed. A longer growing season also provides more risk for frost damage, changes in phenology of biotic interactions (pollination, wildlife, etc.), and risk of invasive species occupying niches. Our study supports the idea that earlier flowering plants tend to have more reproductive success (Beaten et al. 2015). Species that advance flowering and fruiting in response, as suggested through our results, show that phenological shifts will benefit plant fitness by increasing their reproductive output (Jacques et al. 2015; Rice et al. 2018).

In addition to the ecological results, Indigenous phenology as a process is a collaborative research concept. Indigenous phenology or Indigenous phenological knowledge as a process helped to create trust, capacity, and knowledge for the Menominee Nation. The Indigenous phenology process, thru various partnerships reinforced tribal sovereignty, enhanced capacity, and created an ethical research process. Tribal and non-tribal partnerships helped to build capacity and resilience of the Menominee Nation through collaborative work with non-tribal partners. Tribal and non-tribal academic partnerships contributed to capacity building of all parties involved through experience while also fostering institutional goals of those respective parties. Tribal and tribal partnerships created an ethical research process while also strengthening tribal sovereignty.

Finally, climate change will shape a different landscape in the future for the Menominee Nation and their forest. The Menominee Nation will require resilience and an adaptive capacity in order to respond and develop solutions to climate change. Through unique processes, like Indigenous phenological knowledge, the tribal nation will develop partnerships that will help to provide tools and solutions to climate change. Through using tools like phenology as an indicator of climate change through research on forest communities, like the herbaceous ones, the tribe can prepare solutions based on data received through the phenology study. Through Indigenous phenology and phenological research, tribes like the Menominee Nation can bolster their toolbox with cutting-edge solutions in the face of climate change.

Future research directions should include more research on phenology as a climate change indicator and research on Indigenous phenological knowledge through the lenses of tribal nations. Next steps could be in the areas of how early flowering may affect pollinator phenology and interactions, how early spring will affect the rest of the forest community including tree phenology, and how earlier springs could affect wildlife interactions with our study species. These questions need to be explored in order to provide a more complete picture of how a changing climate may affect the phenology of the forest community. Next steps for Indigenous phenology research would be for tribal nations to develop their own models of Indigenous phenological knowledge and how it informs their lifeways. Indigenous phenological knowledge should be developed by and through Indigenous communities to create a truly Indigenous model. Indigenous phenological knowledge needs to be studied in different communities and regions to gain new and possibly corroborative insights.

REFERENCES

Armatas, C. A., Venn, T. J., McBride, B. B., Watson, A. E., & Carver, S. J. (2016). Opportunities to utilize traditional phenological knowledge to support adaptive management of social-ecological systems vulnerable to changes in climate and fire regimes. *Ecology and Society*, *21*(1).

Austen, E.J., Rowe, L., Stinchcombe, J.R., & Forrest, J.R. (2017). Explaining the apparent paradox of persistent selection for early flowering. *New Phytologist, 215*, 929–934. doi: 10.1111/nph.14580

Baeten, L., Sercu, B., Bonte. D., Vanhellemont, M., & Verheyen, K. (2015). Intraspecific variation in flowering phenology affects seed germinability in the forest herb Primula elatior. *Plant Ecology and Evolution, 148*, 283–288. doi: 10.5091/plecevo.2015.1089

Beck, David. *The struggle for self-determination: history of the Menominee Indians since 1854*. U of Nebraska Press, 2005.

Bennett, T. M., Maynard, N. G., Cochran, P., Gough, R., Lynn, K., Maldonado, J., & Richmond, T. C. (2017). *Indigenous peoples, lands, and resources*.

Berkes, J., Colding, F., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*(5). 1251-1262.

Berkes, F., Folke, C., & Gadgil, M. (1994). Traditional ecological knowledge, biodiversity, resilience and sustainability. *Biodiversity conservation,* 269-287. Springer, Dordrecht.

Bradley, N. L., Leopold, A. C., Ross, J., & Huffaker, W. (1999). Phenological changes reflect climate change in Wisconsin. *Proceedings of the National Academy of Sciences*, *96*(17), 9701-9704.

Brockie, T., Azar, K., Wallen, G., Solis, M. O. H., Adams, K., & Kub, J. (2019). A conceptual model for establishing collaborative partnerships between universities and Native American communities. *Nurse researcher*, *27*(1).

Bureau of Indian Affairs (BIA). (2019). https://www.bia.gov/frequently-asked-questions.

Burhansstipano, L., Christopher, S., & Schumacher Sr, A. (2005). Lessons learned from community-based participatory research in Indian country. *Cancer Control*, *12*(4), 70-76.

Chief, K., Meadow, A., & Whyte, K. (2016). Enaging southwestern tribes in sustainable water resources topics and management. *Water (Switzerland). 8*(8). 1-21.

Chilisa, B. (2011). Indigenous research methodologies. Sage Publications.

Chino, M., & DeBruyn, L. (2006). Building true capacity: Indigenous models for indigenous communities. *American journal of public health*, *96*(4), 596-599.

Christopher, S., Saha, R., Lachapelle, P., Jennings, D., Colclough, Y., Cooper, C., & Kuntz, S. W. (2011). Applying indigenous community-based participatory research principles to partnership development in health disparities research. *Family & community health*, *34*(3), 246.

Chuine, I. (2010). Why does phenology drive species distribution?. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1555), 3149-3160.

Chuine, I., & Beaubien, E. G. (2001). Phenology is a major determinant of tree species range. *Ecology Letters*, *4*(5), 500-510.

Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. *Trends in ecology & evolution*, *22*(7), 357-365.

Cole, L. C. (1954). The population consequences of life history phenomena. *The Quarterly Review of Biology*, *29*(2), 103-137.

College of Menominee Nation Sustainable Development Institute, & Michigan State University. (2012). *1994 and 1862 Cooperative Agreement*. College of Menominee Nation.

College of Menominee Nation Sustainable Development Institute. (2014). Community Information Sessions: Measuring the Pulse of the Forest. Poster. Print.

College of Menominee Nation Sustainable Development Institute. (2014). Contract Agreement with R.A. Ecologial Data and Cultural Forest Relationships Consultant. Contract. 1-2.

College of Menominee Nation Sustainable Development Institute. (2014). Measuring the Pulse of the Forest: Assessing Adaptation and Mitigation of Tribal Sustainable Forestry and Communities to Climate Change. Grant Report. 1-5.

College of Menominee Nation Sustainable Development Institute. (2016). Using Plant Phenology as an Indicator of Forest Community Resilience and Adaptative Capacity. Grant proposal. 1-15.

Cook. M., Henry, G., Herman, D., McMahon, S., Parker, J., & Thompson, J. (2015). Measuring the Pulse of the Forest: Assessing Adaptation and Mitigation of Tribal Sustainable Forestry and Communities to Climate Change. Project Summary/Abstract. 1.

Corbin, J., & Strauss, A. (2008). Strategies for qualitative data analysis. *Basics of Qualitative Research. Techniques and procedures for developing grounded theory*, *3*.

Daigle, J. J., Michelle, N., Ranco, D. J., & Emery, M. R. (2019). Traditional Lifeways and Storytelling: Tools for Adaptation and Resilience to Ecosystem Change. *Human Ecology*, *47*(5), 777-784.

Dalbotten, D.M., Ito, E., Myrbo, A., Pellerin, H., Greensky, L., Howes, T, Wold, A., & McEathron, M. (2014). NSF-OEDG Manoomin Science Camp Project: A Model for Engaging American Indian Students in Science, Technology, Engineering, and Mathematics. *Journal of Geoscience Education, Special Issue on Place-Based Education 62*(2), 227-243.

David-Chavez, D. M., & Gavin, M. C. (2018). A global assessment of Indigenous community engagement in climate research. *Environmental Research Letters*, *13*(12), 123005.

de Echeverria, V. R. W., & Thornton, T. F. (2019). Using traditional ecological knowledge to understand and adapt to climate and biodiversity change on the Pacific coast of North America. *Ambio*, *48*(12), 1447-1469.

Deloria Jr, V., Wildcat, D., & Wilkins, D. (2012). *Metaphysics of modern existence*. Fulcrum Publishing.

Dockry, M.J., Gutterman S.A., & Davenport, M.A. (2017). Building Bridges: Perspectives on Partnership and Collaboration from the US Forest Service Tribal Relations Program. *Journal of Forestry 116*(2). 123-132

Dockry, M. J., Hall, K., Van Lopik, W., & Caldwell, C. M. (2016). Sustainable development education, practice, and research: an indigenous model of sustainable development at the College of Menominee Nation, Keshena, WI, USA. *Sustainability science*, *11*(1), 127-138.

Duveneck, M. J., Scheller, R. M., White, M. A., Handler, S. D., & Ravenscroft, C. (2014). Climate change effects on northern Great Lake (USA) forests: a case for preserving diversity. *Ecosphere*, *5*(2), 1-26.

Farnsworth, E. J., Nunez-Farfan, J., Careaga, S. A., & Bazzaz, F. A. (1995). Phenology and growth of three temperate forest life forms in response to artificial soil warming. *Journal of Ecology*, 967-977.

Fitchett, J. M., Grab, S. W., & Thompson, D. I. (2015). Plant phenology and climate change: Progress in methodological approaches and application. *Progress in Physical Geography*, *39*(4), 460-482.

Fond du Lac Band of Lake Superior Chippewa. n.d. Expanding the Narrative of Tribal Health: The Effects of Wild Rice Water Quality Rule Changes on Tribal Health. http://www.fdlrez.com/RM/downloads/WQSHIA.pdf accessed 4/27/2020.

Forrest J., & Thomson JD (2010) Consequences of variation in flowering time within and among individuals of Mertensia fusiformis (Boraginaceae), an early spring wildflower. *American Journal of Botany 97*,38–48. doi: 10.3732/ajb.0900083

Gezon, Z. J., Inouye, D. W., & Irwin, R. E. (2016). Phenological change in a spring ephemeral: Implications for pollination and plant reproduction. *Global Change Biology*, *22*(5), 1779–1793. http://doi.org/10.1111/gcb.13209

Gittelsohn, J., Belcourt, A., Magarati, M., Booth-LaForce, C., Duran, B., Mishra, S. I., & Jernigan, V. B. B. (2020). Building capacity for productive indigenous community-university partnerships. *Prevention Science*, *21*(1), 22-32.

Haines, R., & Nation, S. R. F. (2017). Use of Traditional Phenological Knowledge Indicators to Predict Lake Sturgeon Spawning Timing on the Seine River.

Hatfield, S.C., Marino, E., Whyte, K.P., Dello, K.D. and Mote, P.W., (2018). Indian time: time, seasonality, and culture in Traditional Ecological Knowledge of climate change. *Ecological Processes*, *7*(1), pp.1-11.

Hibbard, K.A., Hoffman, F.M., Huntzinger, D., & West, T.O., (2017). Changes in land cover and terrestrial biogeochemistry. *Climate Science Special Report: Fourth National Climate Assessment, I*, 277-302, doi: 10.7930/J0416V6X.

Inouye, D. W. (2008). Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers. *Ecology*, *89*(2), 353-362.

Ishiyama, N. (2003). Environmental justice and American Indian tribal sovereignty: Case study of a land–use conflict in Skull Valley, Utah. *Antipode*, *35*(1), 119-139.

Jackson, R. B., Lechowicz, M. J., Li, X., & Mooney, H. A. (2001). Phenology, growth, and allocation in global terrestrial productivity. *Terrestrial global productivity*, 61-82.

Jacques, M. H., Lapointe, L., Rice, K., Montgomery, R. A., Stefanski, A., & Reich, P. B. (2015). Responses of two understory herbs, Maianthemum canadense and Eurybia macrophylla, to experimental forest warming: Early emergence is the key to enhanced reproductive output. *American journal of botany*, *102*(10), 1610-1624.

JMP®, Version <*14.2.0*>. SAS Institute Inc., Cary, NC, 1989-2019.

Kassam, K. A. S., Ruelle, M. L., Samimi, C., Trabucco, A., & Xu, J. (2018). Anticipating Climatic Variability: The Potential of Ecological Calendars. *Human Ecology*, *46*(2), 249-257.

Kimmerer, R. W. (2000). Native knowledge for native ecosystems. *Journal of Forestry*, *98*(8), 4-9.

Kimmerer, R. W. (2002). Weaving traditional ecological knowledge into biological education: a call to action. *BioScience*, *52*(5), 432-438.

Kimmerer, R. W. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants*. Milkweed Editions.

Kofinas, G. P., Chapin, F. S., BurnSilver, S., Schmidt, J. I., Fresco, N. L., Kielland, K., ... & Rupp, T. S. (2010). Resilience of Athabascan subsistence systems to interior Alaska's changing climate. *Canadian Journal of Forest Research*, *40*(7), 1347-1359.

Kovach, M. (2010). *Indigenous methodologies: Characteristics, conversations, and contexts*. University of Toronto Press.

Kudo, G., Ida, T.Y., Tani, T., (2008). Linkages between phenology, pollination, photosynthesis, and reproduction in deciduous forest understory plants. *Ecology* *89*,321–331. doi: 10.1890/06-2131.1

Lambert, L. (2014). Research for Indigenous Survival. Omaha: University of Nebraska Press.

Lantz, T. C., & Turner, N. J. (2003). Traditional phenological knowledge of Aboriginal peoples in British Columbia. *Journal of Ethnobiology*, *23*(2), 263-286.

LaDuke, W. (2019). *Indigenous Food Sovereignty in the United States: Restoring Cultural Knowledge, Protecting Environments, and Regaining Health* (18), University of Oklahoma Press.

Lomawaima, K. T., & McCarty, T. L. (2002). When tribal sovereignty challenges democracy: American Indian education and the democratic ideal. *American Educational Research Journal*, *39*(2), 279-305.

Mausel, D.L., Waupochick Jr, A., & Pecore, M., (2017). Menominee forestry: past, present, future. *Journal of Forestry*, *115*(5), .366-369.

McMillen, H., Ticktin, T., & Springer, H. K. (2017). The future is behind us: traditional ecological knowledge and resilience over time on Hawai ʻi Island. *Regional Environmental Change*, *17*(2), 579-592.

Menominee Tribal Enterprises. (2012). Forest Management Plan. https://www.mtewood.com/SustainableForestry/ForestManagement.

Mockta, T. K., Fulé, P. Z., Meador, A. S., Padilla, T., & Kim, Y. S. (2018). Sustainability of culturally important teepee poles on Mescalero Apache Tribal Lands: Characteristics and climate change effects. *Forest Ecology and Management*, *430*, 250-258.

Montgomery, M. (2013). Fast facts about responsible research partnerships with Indigenous communities. University of Washington Center for Ecogenetics and Environmental Health. 1-2.

Nabhan, G. P. (2010). Perspectives in ethnobiology: ethnophenology and climate change. *Journal of Ethnobiology*, *30*(1), 1-4.

NASA. (2019). Climate Change Evidence: How Do We Know? Retrieved September 1, 2019, from https://climate.nasa.gov/evidence/

Norton-Smith, Kathryn; Lynn, Kathy; Chief, Karletta; Cozzetto, Karen; Donatuto, Jamie; Hiza Redsteer, Margaret; Kruger, Linda E.; Maldonado, Julie; Viles, Carson; Whyte, Kyle P. (2016). Climate change and indigenous peoples: a synthesis of current impacts and experiences. Gen. Tech. Rep. PNW-GTR-944. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 1-142.

Pecore, M., 1992. Menominee sustained-yield management. *Journal of Forestry*, *90*(7), 12-16.

Pierotti R, Wildcat D (2000) Traditional ecological knowledge: the third alternative. *Ecological Applications, 10*(5), 1333–1340

Post, E., Forchhammer, M. C., Stenseth, N. C., & Callaghan, T. V. (2001). The timing of life–history events in a changing climate. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*(1462), 15-23.

Post, E. S., Pedersen, C., Wilmers, C. C., & Forchhammer, M. C. (2008). Phenological sequences reveal aggregate life history response to climatic warming. *Ecology*, *89*(2), 363-370.

Proe, M. F., Griffiths, J. H., & McKay, H. M. (2001). Effect of whole-tree harvesting on microclimate during establishment of second rotation forestry. *Agricultural and Forest Meteorology*, *110*(2), 141-154.

Rathcke, B., & Lacey, E. P. (1985). Phenological patterns of terrestrial plants. *Annual review of ecology and systematics*, *16*(1), 179-214.

Rice, K. E., Montgomery, R. A., Stefanski, A., Rich, R. L., & Reich, P. B. (2018). Experimental warming advances phenology of groundlayer plants at the boreal□temperate forest ecotone. *American journal of botany*, *105*(5), 851-861.

Roberts, A. M. I., Tansey, C., Smithers, R. J., & Phillimore, A. B. (2015). Predicting a change in the order of spring phenology in temperate forests. *Global Change Biology*, *21*(7), 2603–2611. http://doi.org/10.1111/gcb.12896

Schwartz, M. D., Ahas, R., & Aasa, A. (2006). Onset of spring starting earlier across the Northern Hemisphere. *Global change biology*, *12*(2), 343-351.

Sherry, R. A., Zhou, X., Gu, S., Arnone, J. A., Schimel, D. S., Verburg, P. S., ... & Luo, Y. (2007). Divergence of reproductive phenology under climate warming. *Proceedings of the National Academy of Sciences*, *104*(1), 198-202.

Silvertown, J., Franco, M., Franco, F. B., & Harper, J. L. (Eds.). (1997). *Plant life histories: ecology, phylogeny and evolution*. Cambridge University Press.

Smith, L. T. (2013). *Decolonizing methodologies: Research and indigenous peoples*. Zed Books Ltd..

Tribal Adaptation Menu Team. (2019). Dibaginjigaadeg Anishinaabe Ezhitwaad: A Tribal Climate Adaptation Menu. Great Lakes Indian Fish and Wildlife Commission, Odanah, Wisconsin. 1-54.

United Nations General Assembly. (2007). " United Nations Declaration on the Rights of Indigenous Peoples." United Nations.

USA NPN National Phenology Network. (2019). Retrieved June 1, 2019, from https://www.usanpn.org/about/approach

Voggesser, G., Lynn, K., Daigle, J., Lake, F.K. and Ranco, D., 2013. Cultural impacts to tribes from climate change influences on forests. In *Climate change and indigenous peoples in the United States*, 107-118. Springer, Cham.

Vizenor, G. (Ed.). (2008). *Survivance: Narratives of native presence*. U of Nebraska Press.

Waller, D. M., and N. J. Reo. 2018. First stewards: ecological outcomes of forest and wildlife stewardship by indigenous peoples of Wisconsin, USA. *Ecology and Society* 23(1), 1-45.

Whyte, K. (2013). On the Role of traditional ecological knowledge as a collaborative concept: a philosophical study. *Ecological Processes 2*(1), 1-7.

Whyte, K.P., Brewer, J.P. & Johson, J.T. (2015). Weaving Indigenous science, protocols, and sustainability science. *Sustainability Science 11*(1). 25-32.

Willox, A. C., Harper, S. L., Edge, V. L., Landman, K., Houle, K., & Ford, J. D. (2013). The land enriches the soul: On climatic and environmental change, affect, and emotional health and well-being in Rigolet, Nunatsiavut, Canada. *Emotion, Space and Society*, *6*, 14-24.

Yerxa, J.-R. (2014). Gii-kaapizigemin manoomin Neyaashing: A resurgence of Anishinaabeg nationhood. *Decolonization: Indigeneity, Education & Society*, *3*(3), 159–166.