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EVALUATING ECOSYSTEM HEALTH OF THE SALT CREEK BASIN THROUGH TWO-EYED SEEING

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by

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Abstract

EVALUATING ECOSYSTEM HEALTH OF THE SALT CREEK BASIN THROUGH TWO-EYED SEEING

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Few instances of prior research into socio-ecological health have brought together both Indigenous Knowledge Systems and Western science, especially in Nebraska. This study attempts to fill this gap in Lancaster County, Nebraska by using "Two-Eyed Seeing". This equitably combines both Indigenous Knowledge Systems (qualitative data), obtained through oral interviews with Indigenous community members, and Western science (quantitative data), obtained through USGS, UNL, and U.S. Drought Monitor databases, to assess ecosystem health. Changes to the Salt Creek Basin were collected and analyzed through this Two-Eyed Seeing framework. Results found that there are high levels of consensus between both knowledge systems regarding decreases in water quality and increases in nutrient/pesticide levels in Salt Creek. Additionally, the two sets help to fill in the gaps of the other by providing information about indicators that the other cannot. Indigenous Knowledge alone provided information about the presence of native plants and wildlife, as well as the presence of Indigenous Peoples and their usage of the ecosystem for its pre-colonized purposes. Western science alone provided information about precipitation, discharge, and gage height amounts, as well as changes in the air and water temperatures. Overall, this Two-Eyed Seeing approach can lead to a more comprehensive and accurate environmental assessment of health and long-term change in the Salt Creek basin.

Preface

This study was made possible by faculty members and resources at the University of Nebraska-Lincoln. I would like to thank Lindsey Chizinski, the advisor for this project, who provided invaluable guidance and support throughout the entire process. I would also like to thank Ann Powers, a lecturer and graduate student at UNL, as well as the reader for this thesis, who was instrumental in the formatting and structure of this research and its presentation.

My endless gratitude is extended to Dr. Dave Gosselin, the director of Environmental Studies at UNL, for providing counsel and direction, not only for this project, but during my entire undergraduate career. Finally, thank you to all my family and friends for supporting me in pursuing my passions throughout college and life in general. You are my biggest advocates and help me every day.

Thank you!

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Introduction

Indigenous Knowledge Systems (IKS) are the "understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings," (*Local and Indigenous…,* 2017, p. 1). These systems are also known by other labels such as local and folk knowledge, traditional knowledge, Indigenous technical knowledge, environmental or ecological knowledge, and people's science (Tharakan, 2017, p. 4). Indigenous Peoples have used these knowledge systems for thousands of years. Each knowledge system is unique to the culture that it represents; just as Indigenous Peoples are not a monolith, their knowledges and perspectives are not monolithic either.

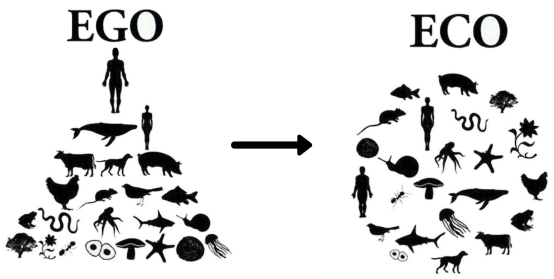


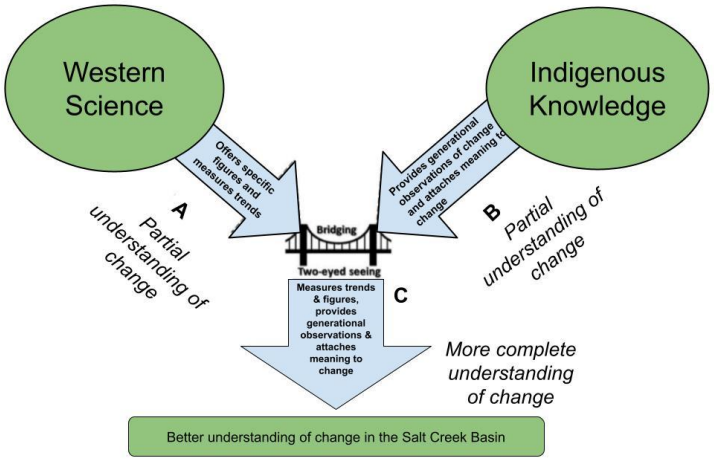
Figure 1. A representation of "ego" or "anthropocentrism" versus "ecocentrism", where humans are part of and equal to the environment, rather than separate and superior ("Ecocentric Leadership", 2020).

Indigenous Knowledge Systems are often founded on principles of sustainability and include complex systems thinking. They generally employ an "ecocentric" view of the environment, which states that humans are part of and equal to the environment, rather than separate and superior (Figure 1). In an ecocentric view, nature is deserving of moral consideration because it has intrinsic value, not merely because it has value to humans (Kortenkamp et al., 2001). Due to this reasoning, human action should be governed and regulated, not natural systems. This differs greatly from the Dominant Social Paradigm (DSP), or mainstream worldview in most Western societies, which favors an anthropocentric view ("Dominant Social Paradigm", 2022, pg. 1). In the DSP, humans are distinct from and dominant over the environment; nature is viewed as only having value when it has use to humans. Western knowledge/science is often based on this viewpoint, which adopts a

utilitarian and reductionist worldview that believes humans can and should conquer nature (Reid et al., 2021, p. 20).

The Dominant Social Paradigm currently heavily influences the Western scientific community and ecological management. Previous attempts at "bridging" IKS and Western knowledge have either integrated, incorporated, or assimilated IKS into Western science, insinuating that Western science is currently valued over forms of Indigenous Knowledge. Dr. Marie Battiste, an expert in decolonization, states, "Society under colonial influence has long perceived Indigenous knowledge as 'the other' and in binary opposition to Western scientific knowledge," (Battiste, 2005, p. 5). One way to equitably embrace both perspectives within the scientific community and world-at-large is by utilizing "Two-Eyed Seeing". Mi'kmaw Elder Albert Marshall defines Two-Eyed Seeing as "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all," (Bartlett et al., 2012, p. 18). This creates a system in which no viewpoint is valued over the other. Two-Eyed Seeing, or *Etuaptmumk* in Mi'kmaw, "offers a practical way to bridge Western science and Indigenous knowledge systems by providing strategies for checking the accuracy and filling in the gaps of each without one knowledge system subsuming the other," (Abu et al. 2019, p. 3). The Two-Eyed Seeing analogy describes a way in which two entities come together to form a stronger whole and can lead to more complete environmental assessments, as well as understandings of ecological change.

Figure 2. Using Two-Eyed Seeing by incorporating both Indigenous Knowledge Systems and Western science allows for a more complete understanding of change, both in the Saskatchewan River Delta and Salt Creek basin (Abu et. al, 2019).



The purpose of this project is to research how Indigenous Knowledge Systems and Western scientific knowledge can combine to form a strengthened assessment of environmental health by using both qualitative and quantitative indicators; the study also aims at further investigating if the qualitative data gathered from Indigenous Knowledge Systems and quantitative data obtained from Western science corroborate the other. The research questions ask, “How can Indigenous Knowledge Systems and Western Science be combined equitably to gain a more complete understanding of ecosystem health?” and “How do the two sets reinforce the other?”, specifically in regards to the Salt Creek basin in Lincoln and Lancaster County, Nebraska. IKS offers a more spatial understanding of environmental health and how it has changed over time, while Western science is often driven by objective measurements, allowing them to complement each other. This is especially important in the Midwest, and Nebraska specifically, as it is a state dominated by agriculture; ninety-two percent of the land area in Nebraska is agricultural land (“Nebraska Agriculture Fact Card”, 2022). In 2022, corn, wheat, and other crops, as well as meat, beef, and poultry accounted for over a quarter of the state’s total revenue, totalling around 34.1% of Nebraska’s Gross State Product (“Industry Market Research", 2022). Because of this, ecosystem quality and health is imperative to the livelihood of those living in the state, as well as to the natural resources and organisms in the region. Additionally, the Salt Creek basin, also

known as “Niskíthe”, or “salt water” in Omaha, is considered a sacred place to Indigenous Peoples; the land and waters in the area are recognized as the spiritual home and gathering grounds of the Lincoln Native Community. They are considered “life-sustaining” (“Niskíthe Prayer Camp”, n.d.). Therefore, it is also important to evaluate the health of the region due to the inherent value it holds to Indigenous Peoples in the area.

Furthermore, the Salt Creek basin is the home of many different wildlife species, including the Salt Creek Tiger Beetle, which is endemic to the saline marshes of Lancaster County. This beetle is considered an “indicator species”; the presence of the insect indicates a healthy ecosystem, or vice versa. However, in October of 2005, the Salt Creek Tiger Beetle was placed under the protection of the Endangered Species Act, as only a few hundred individuals currently remain. Since the late 1800s, 90% of the insect’s habitat has been destroyed, mostly by degradation due to development and pollution (“Salt Creek Tiger Beetle”, 2022). Therefore, this is another significant reason to obtain a more complete environmental health assessment in the area, as species that live exclusively in Lancaster County are already substantially threatened by ecological destruction. The presence, or lack of, the Salt Creek Tiger Beetle can also help assess the overall health of the region due to its status as an indicator species.

Currently, no research relating to Two-Eyed Seeing has been performed in Nebraska; the majority of the prior studies relating to this topic have taken place in Canada (Abu et al., 2019; Giles et al., 2016; Mantyka-Pringle et al., 2017). Since the environment is so important to the economy and lifestyles of those living in Nebraska, it is important to gain a deeper understanding of the health of the natural environment and how it has changed over time. As climate change becomes a more pressing issue, being able to reflect on how the area has changed over time and using this information to predict future changes will become a very valuable tool to those who

live here. Not only is this study important for assessing the health of various ecosystems in the region, as it will likely offer a more complete and holistic overview, but IKS can also help to remedy ecological degradation. Indigenous Peoples have existed in harmony with the land and ecosystems for thousands of years, and their knowledges reflect this.

While Indigenous Knowledge Systems have been in existence for thousands of years, research on the bridging of knowledge between IKS and Western science is relatively new. IKS has the potential to greatly decrease environmental degradation and increase sustainable farming/ecosystem management practices; therefore, this area of study can have valuable and long-lasting impacts on the health of the region. The research and connections forged during this study are also of interest to the University of Nebraska-Lincoln itself, as it is important to form deeper partnerships between the Indigenous Peoples in the area and the university. As a land-grant university, UNL received land from the Morrill Act, signed by President Abraham Lincoln in 1862. These “land-grab” universities were given land expropriated from different tribal nations (Fontana, 2022). Because of this, there is currently no strong bond between the university and Indigenous Peoples in Lancaster County, or across the state in general. This research will present a valuable opportunity and hopefully open the door for new, strengthened relationships.

The objective of this study is to utilize data points from Indigenous Knowledge Systems local to the Midwest and the Lancaster County, Nebraska area, along with indicators from Western science; however, potential limitations regarding IKS arise due to the limited number of Indigenous Peoples living in the area with historic ties to the region. Removal of Indigenous Peoples has forced many people to leave their ancestral homelands. The resulting small sample size is a constraint of this project. Regardless, both qualitative and quantitative data will be

included. This will offer more comprehensive results in regards to the health of the Salt Creek Basin. The usage of both knowledge sets can more accurately indicate the condition of the ecosystems being studied as compared to when they are studied exclusively from a Western scientific viewpoint.

Previous research on this topic has been performed in the Saskatchewan River Delta of Canada (Abu et al., 2019). In this study, a combination of Indigenous knowledge, archival records, and instrumental observations were used. Indigenous knowledge was obtained by interviewing 8 Elders and 34 fish harvesters of Indigenous ancestry. The qualitative indicators included data points such as “no occurrence of ice jams, less deep ice breaks” and “water is dirty, polluted, and unsafe for drinking”. Instrumental observations, acquired from the Western scientific field, provided quantitative data such as “nutrient and pesticide levels in the water” and “spring snowmelt peaks”. Supplemental archival records were also considered, with indicators such as “less spring flooding” (Abu et al., 2019). After the completion of the data collection, a comparison of the knowledge systems was initiated. A majority of the data points indicated consensus among the different sets of knowledges, meaning that Indigenous knowledge and Western science corroborated each other. There were very few instances in which they disagreed. IKS alone was able to provide information about some indicators, as was Western science, signifying that there are advantages to unifying Indigenous knowledges and Western science. The study states, “This two-eyed seeing approach can enhance environmental assessment and planning by providing a more accurate and coherent narrative of long-term social-ecological change,” (Abu et al., 2019, p. 1).

Another similar study performed in the Slave River Delta region of Canada yielded similar results. This study used a blend of Traditional (Indigenous) and Western knowledge to

assess ecosystem health in the delta and to gain a deeper understanding of ecosystem stressors and change (Mantyka-Pringle et al., 2017). This research used a similar design with both qualitative (IKS) and quantitative (Western science) data considered. A third study, which occurred in the Eskasoni First Nation of Canada, once again used both knowledge sets (qualitative and quantitative) to perform research into ecosystem health; this investigation also explored possible mechanisms for incorporating IKS into government policy decisions and the implementation of said policy. This example studied the health of an aquatic fishery ecosystem by using the Two-Eyed Seeing lens (Giles et al., 2016). Overall, Two-Eyed Seeing allows for a better understanding of ecosystem health and change by combining two different, yet equally valuable, sets of knowledges, as shown in multiple different studies in multiple locations across Canada. The next sections contain the methods, results, discussion, and conclusions utilized and obtained from implementing this Two-Eyed Seeing framework into the Salt Creek basin of Lancaster County, Nebraska.

Methods

Lancaster County, and therefore Lincoln, NE, is located on the Indigenous homelands of the Otoe-Missouria and Pawnee (Figure 2); however, Indigenous Peoples from numerous different nations have converged in this area for centuries. Historically, the Omaha people traveled to the region to collect salt from the Salt Creek basin. This salt, which the women collected using eagle feathers, was used to cure buffalo meat and other staples. To this day, the basin serves as an intertribal gathering zone, and is named “Niskíthe”, meaning “salt water” (“Niskíthe Prayer Camp”). The Salt Creek tributary itself served as the boundary between the Otoe tribe on the east and Pawnee in the west (“Lancaster County, NE”, n.d.).

Figure 3. Historic homelands of Indigenous Peoples in Nebraska ("Native American Tribes in Nebraska", 2023).

This study draws on Indigenous Knowledge from multiple Indigenous nations in the area, including the Omaha, Sicangu Lakota, and Rosebud Sioux People, as well as Western instrumental observations to measure change over time in the Salt Creek basin. This two-pronged approach is the basis of the Two-Eyed Seeing that this study is founded upon, and is found in the previous studies performed in Canada as well (Abu et al., 2019; Giles et al., 2016; Mantyka-Pringle et al., 2017).

The first prong of this study draws upon Indigenous Knowledge, which was gathered through oral history interviews with members of the Omaha, Sicangu Lakota, and Rosebud Sioux nations. The interviews each consisted of approximately 30-minute conversations with the 3 Indigenous community members living in the Salt Creek basin. A snowball sampling technique was implemented, and individuals chosen for interviews were recommended by UNL Extension members. The sample size itself is relatively small, but unfortunately, many of the Indigenous Peoples native to the area no longer live in the region or make the journey here, making it more difficult to interview those with ties to the Lincoln area and Niskíthe. Qualitative data points obtained from IKS interviews were analyzed and developed through thematic analysis, in which common patterns, themes, and changes were recorded and formed into qualitative indicators (Delve et al., 2020).

Open-ended interview questions focused on gathering first-hand, oral knowledge of changes in Salt Creek basin, and the impacts that these changes have had, both in the river itself and in the surrounding environments. Question topics included wildlife populations, water

appearance and health, and fluctuations in the surrounding environment, including the presence and functions of Indigenous Peoples in the area (table 1). Interviews were transcribed and placed into a Qualitative Indicator Coding chart; the answers were used to form qualitative data indicators to evaluate the health of the basin. Data points gathered from IKS are qualitative, as compared to the quantitative data that Western scientific instruments produce. The qualitative indicators are similar to those developed for the Saskatchewan River Delta in Canada (Abu et al., 2019), but customized to the Lincoln area and the Indigenous Peoples living there. The generated indicators were cross-validated by comparing interview responses. Any data point that was not verified by other interviewees was omitted, once again similar to the verification process used in the Saskatchewan River Delta of Canada (Abu et al., 2019). The names of the interviewees were omitted from the study in order to protect the participant's rights.

Table 1. Interview questions asked during the 30-minute conversations with participants.

Interview Questions
What changes have you seen throughout your life while living in the Lincoln area?
How has your way of life changed?
What has driven these changes?
How has the function of the Salt Creek basin changed throughout your life?
In what ways has the presence of wildlife and native plants changed?

The second prong of the study included quantitative instrumental-data indicators, guided by using the 2019 study "Using Two-Eyed Seeing to Bridge Western Science and Indigenous Knowledge Systems…" (Abu et al., 2019). Data points included discharge amount, precipitation, gage height, temperature change, and nutrient/pesticide levels. Data was obtained by utilizing multiple USGS monitoring locations, including station 06803080 at Pioneer's Boulevard (figure

4) and 06803500 (figure 5), located at 27th street in Lincoln, NE. All data used was obtained from the earliest date it was recorded until March 1, 2023. Precipitation amounts were obtained from the University of Nebraska-Lincoln's Weather and Climate Database, and information was drawn from the earliest available year (1887) until 2022, as 2023's annual records are not yet complete ("Monthly and Annual Precipitation Totals", n.d.). Historical and current drought conditions were drawn from the U.S. Drought Monitor and the National Integrated Drought Information System ("Lancaster County Conditions", n.d.; "U.S. Drought Monitor", n.d.) from 2000 until April 11, 2023. Western science data points were analyzed through quantitative analysis of the measurements taken at the various monitoring stations throughout the years based on the identified quantitative indicators.

Interviews were conducted with Indigenous community members who have lived in the Lincoln/Nebraska area for 30 or more years. Since most of the quantitative data was recorded starting in the late 1970's or early 1980's, this allows the timeframes of both the qualitative and quantitative data to come close to alignment. Since the majority of the participants have lived in the area for longer than 30 years, this brings the two time frames even closer, allowing for changes to be considered over relatively the same amounts of time, but through two different lenses.

Results were organized into four categories, which included *consistent*, where Indigenous knowledge and Western science corroborate each other about change in the area; *inconsistent*, where Indigenous knowledge and Western science differ or disagree; *no science*, where Indigenous knowledge alone provides information; and *no Indigenous knowledge*, where Western science alone provides information (Abu et al., 2019); the categories were utilized to verify corroboration between the Indigenous Knowledge and Western science, if any.

Table 2. Qualitative and quantitative indicators used to assess ecosystem health of the Salt Creek Basin based on Abu et al.'s 2019 research in the Saskatchewan River Delta (Abu et al., 2019).

Qualitative Indicators	**Quantitative Indicators**
Presence of Native Plants	Nutrient Levels
Water Quality	Discharge Amount
Biodiversity Levels	Precipitation
Usage of the Ecosystem for Native Purposes	Pesticide Levels
Presence of Indigenous Peoples	Temperature Change
Presence of Wildlife and Indicator species	Gage Height

Figure 4. Location of USGS monitoring station 06803080, Salt Creek at Pioneer's Boulevard ("Salt Creek at Pioneers Boulevard", n.d.).

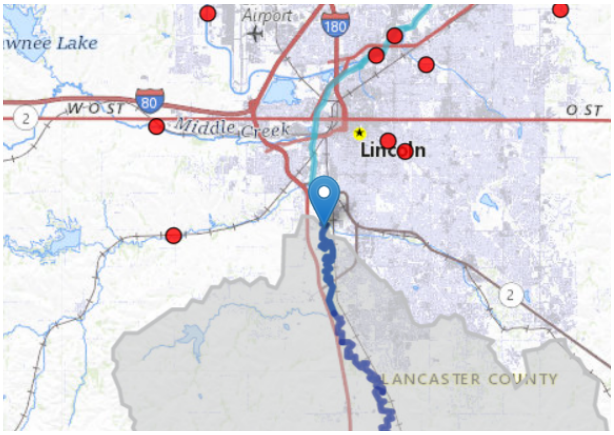
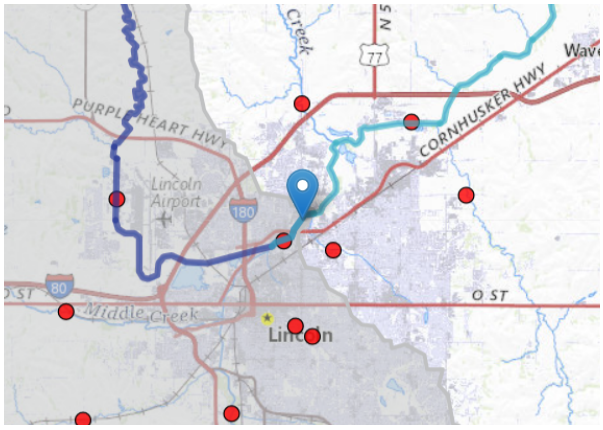


Figure 5. Location of USGS monitoring station 06803500, Salt Creek at 27th Street ("Salt Creek at 27th Street", n.d.)

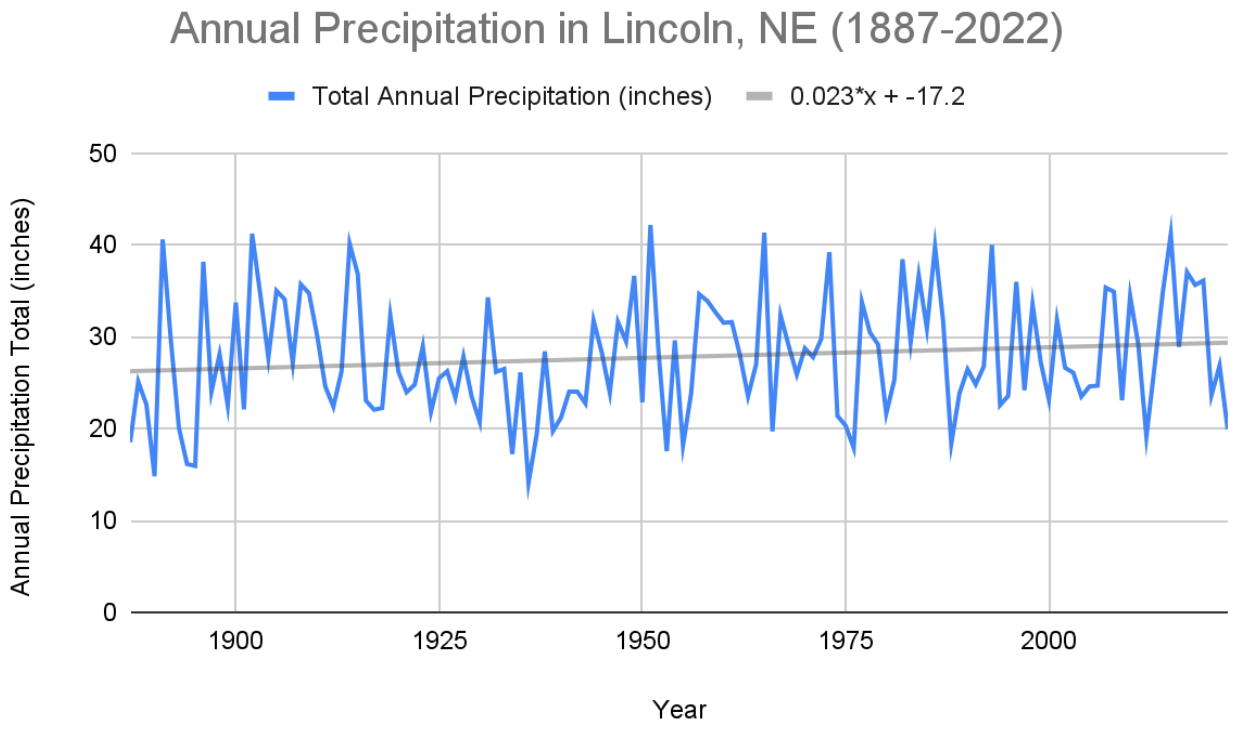


Results

Figure 6 shows the amounts of precipitation received in Lincoln, Nebraska from the years 1887 through 2022, as the annual precipitation record for 2023 is not yet complete. All data was taken directly from the University of Nebraska-Lincoln's Weather and Climate database. Figure 5 shows a slight increase in precipitation across the 135 years data was collected, with a general

increase of 0.023 inches per year. Recent years have seen near record highs and lows in precipitation, with 2015 being one of the wettest years on record, reaching a total of 41.16 total inches. Alternatively, 2012 and 2022 reached lows of 19.14 inches and 19.92 inches, respectively; since 2017, precipitation amounts have steadily declined.

Figure 6. Total annual precipitation in inches in Lincoln, NE from 1887 to 2022.



Figures 7 and 8 show the gage height, the depth of the water above the level of the gage, at the two Salt Creek USGS monitoring locations. Both Pioneer's Boulevard and 27th street have experienced a decrease in gage height, indicating that the level of water has declined. Similarly, streamflow, which is shown in figures 9 and 10, has experienced declines in recent years. While previously showing a cyclical pattern of highs and lows, both locations have shown decreasing amounts of streamflow since about 2020.

Figure 7. Gage height (ft.) Salt Creek at Pioneer's Boulevard.

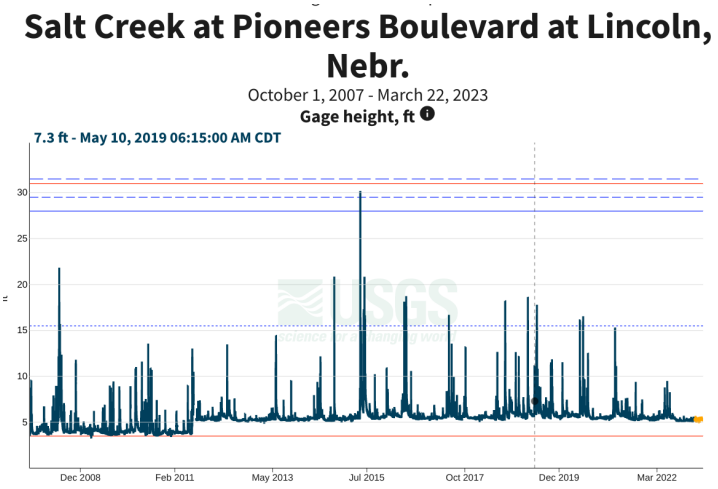


Figure 8. Gage height (ft.) Salt Creek at 27th Street.

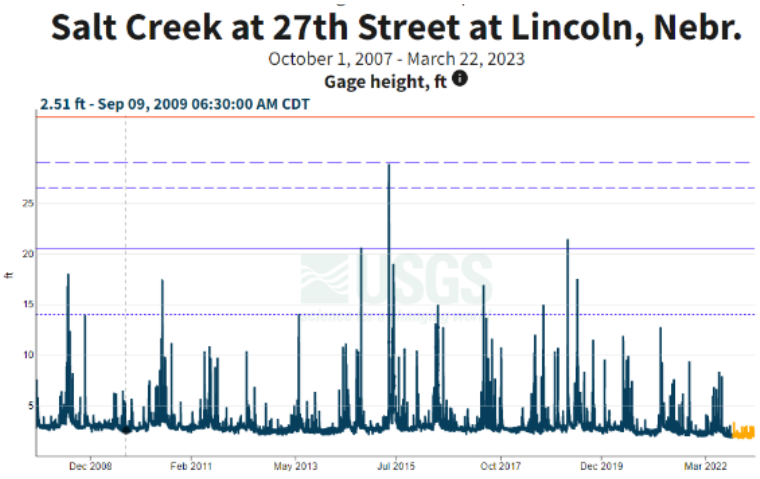


Figure 9. Streamflow (ft^3/s) Salt Creek at Pioneer's Boulevard.

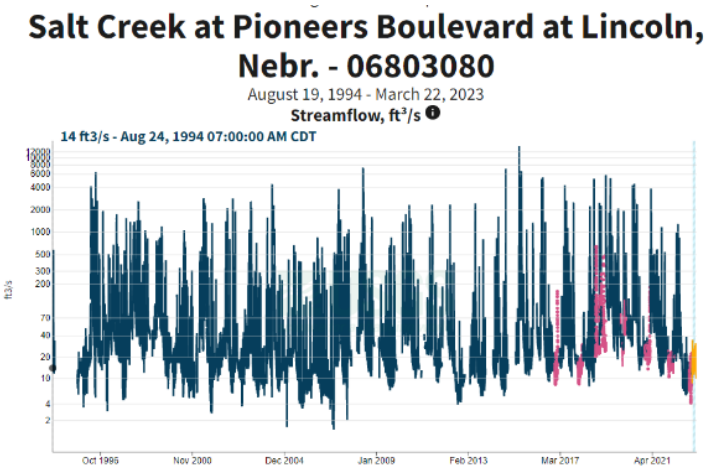


Figure 10. Streamflow (ft^3/s) Salt Creek at 27th Street.

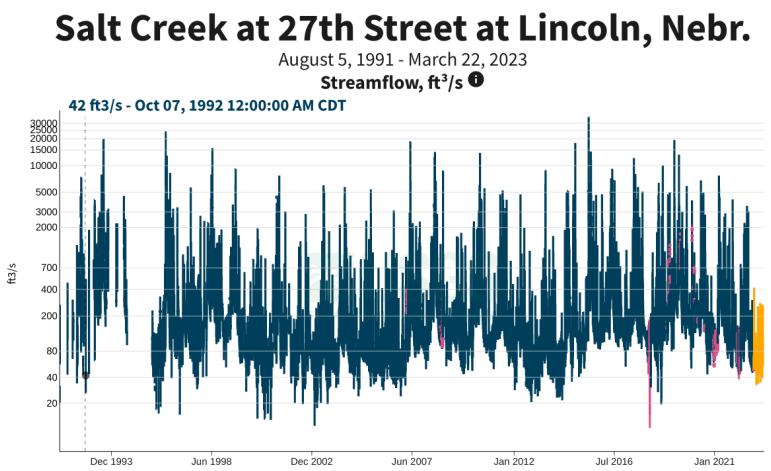


Figure 11 shows the U.S. Drought Monitor conditions in Nebraska, taken on April 11, 2023. As of this time, almost all of Nebraska (98.3%) is in drought, including Lancaster County, which is currently designated at a D2 level, meaning Severe drought ("Nebraska", n.d.). The majority of the state falls into this drought level, with some areas in the Northeast and Southwest even reaching Extreme or Exceptional Drought (figure 11). Figure 12 shows the historical

drought conditions in Lancaster County, Nebraska from 2000-present. The majority of this 23-year time period has been spent in drought, with 2012-2013 reaching Extreme levels. Currently, Lancaster County is in the middle of a Severe drought, which began in mid-2022.

Figure 11. The U.S. Drought Monitor for Nebraska shows high levels of drought across the state, including in Lancaster County, which is in Severe Drought ("U.S. Drought Monitor", n.d.).

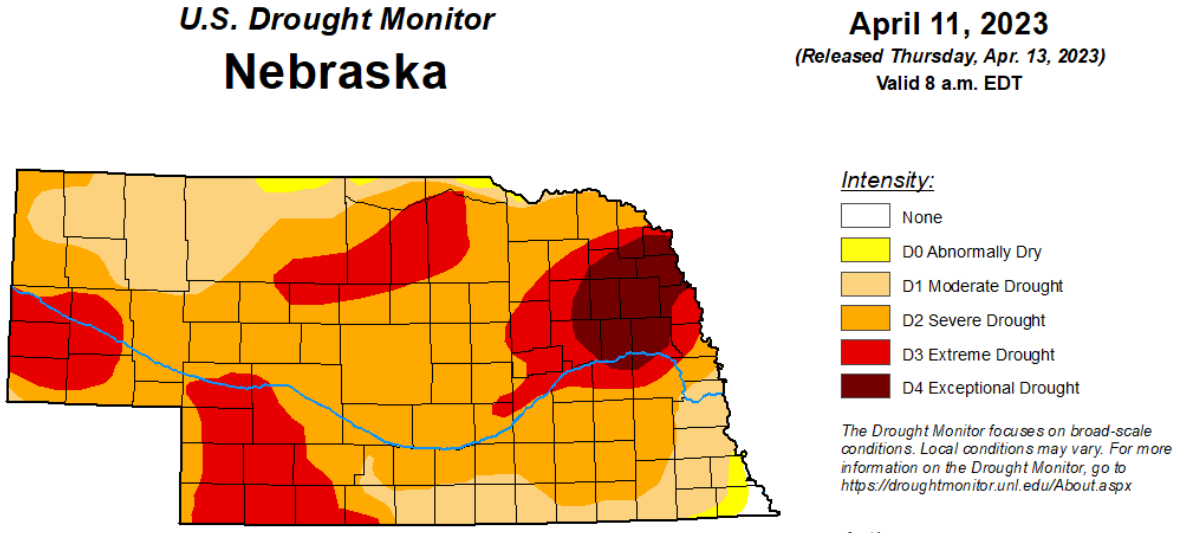
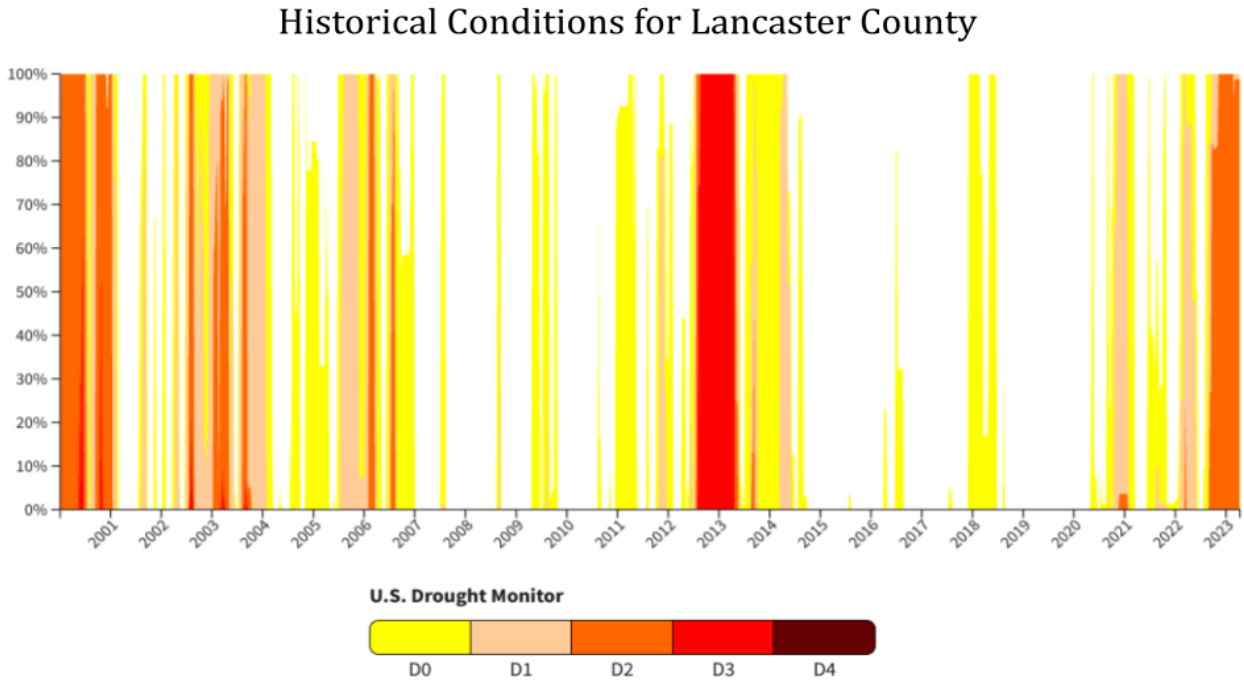


Figure 12. Historical drought conditions of Lancaster County, NE from 2000-2023 ("Lancaster County Conditions", n.d,). The scale ranges from D0 (Abnormally Dry) to D4 (Exceptional Drought).



Other quantitative indicators include Nitrogen (N) and Phosphorus (P) concentrations and air and water temperatures at both Pioneer's Boulevard and 27th Street Salt Creek locations. Total N concentration includes nitrates, nitrites, ammonia, and organic-N; at both locations, N concentrations have increased. Pioneer's Boulevard has seen an N increase of about 0.000159 mg/L per year (figure 13), and 27th street has seen about 0.000572 mg/L of increase per year (figure 14). The positive slope of the trend line indicates there is a positive relationship between N concentrations and time. Similarly, the Phosphorus concentrations at both locations have seen increases over the years, with a positive relationship between P concentrations and time as well. Pioneer's Boulevard's P concentrations have increased by 0.000012 mg/L per year (figure 15), and 27th Street has increased by 0.000199 mg/L per year (figure 16).

Figure 13. Nitrogen concentration (mg/L) Salt Creek at Pioneer's Boulevard.

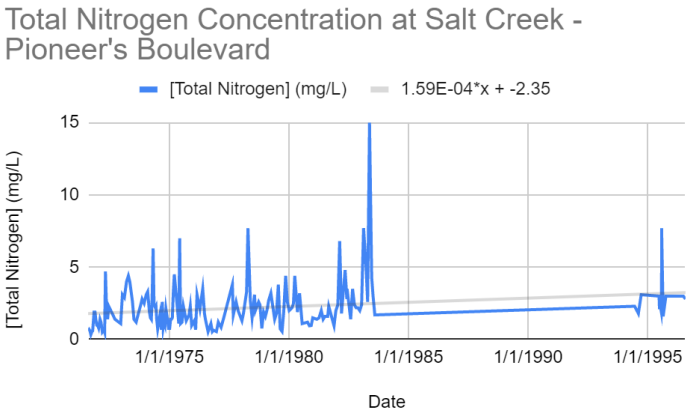


Figure 14. Nitrogen concentration (mg/L) Salt Creek at 27th Street.

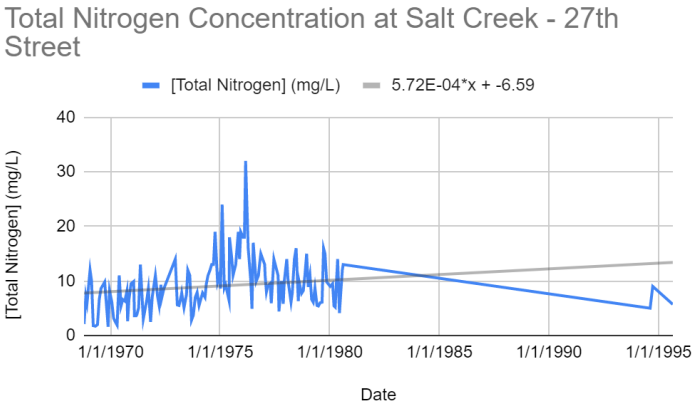


Figure 15. Phosphorus Concentration (mg/L) Salt Creek at Pioneer's Boulevard.

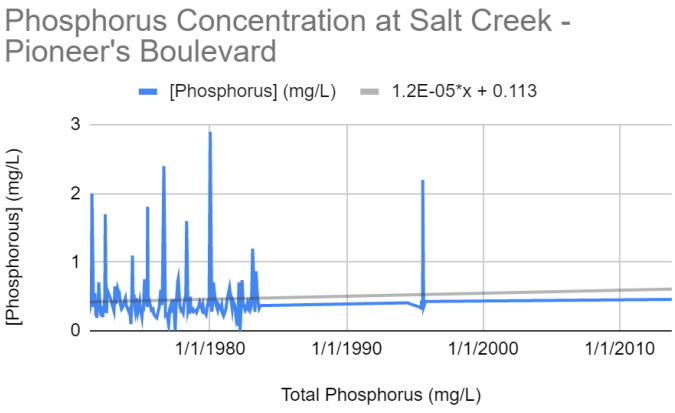
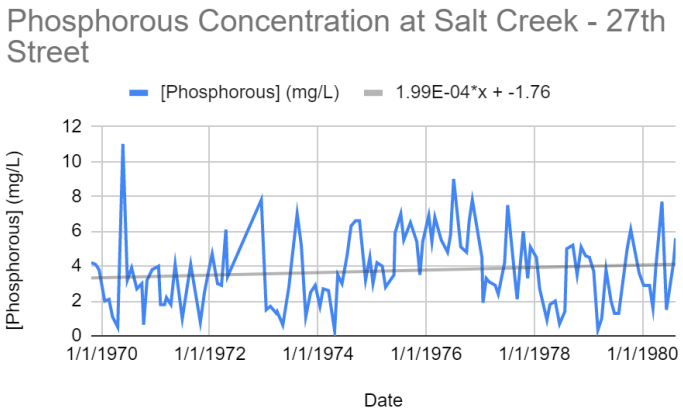


Figure 16. Phosphorus Concentration (mg/L) Salt Creek at 27th Street.



Air temperatures have increased as well at both locations; this increase amounts to about 0.00045 °C per year at Pioneer's Boulevard (figure 17) and 0.00113 °C per year at 27th Street (figure 18). Water temperatures have also increased at the rate of 0.000496 °C per year at Pioneer's Boulevard (figure 19) and 0.000174 °C at 27th Street (figure 20).

2,4-Dichlorophenoxyacetic Acid (2,4-D) concentrations were also recorded at the Pioneer's Boulevard monitoring station (figure 21). Since the 1970s, 2,4-D concentration has been increasing at a rate of about 0.00000443 mcg/L per year at this location. The amount of water in both locations has been decreasing, but the amount of pollutants and pesticides contained in the samples has grown. Additionally, both air and water temperatures have increased over the course of this timeframe.

Figure 17. Air Temperature (°C) Salt Creek at Pioneer's Boulevard.

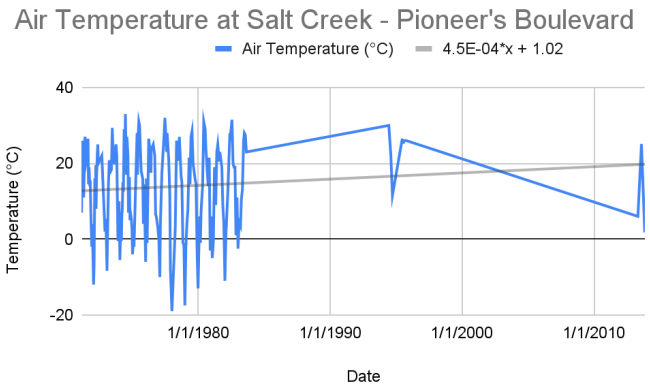


Figure 18. Air Temperature (°C) Salt Creek at 27th Street.

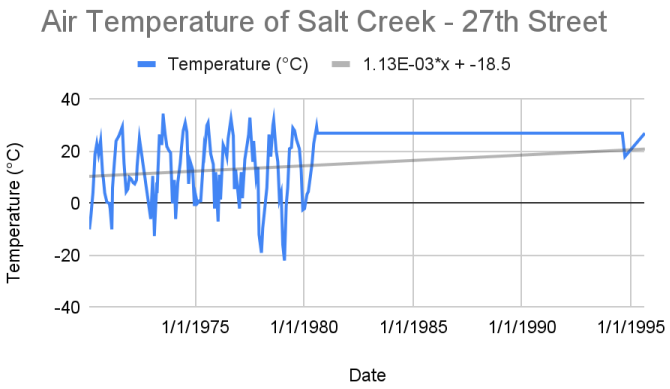


Figure 19. Water Temperature (°C) Salt Creek at Pioneer's Boulevard.

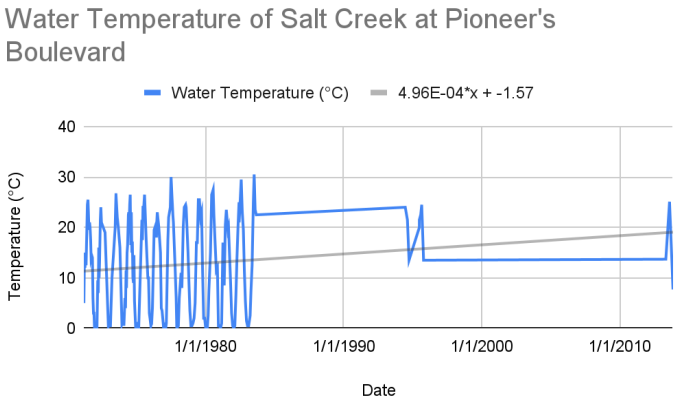


Figure 20. Water Temperature (°C) Salt Creek at 27th Street.

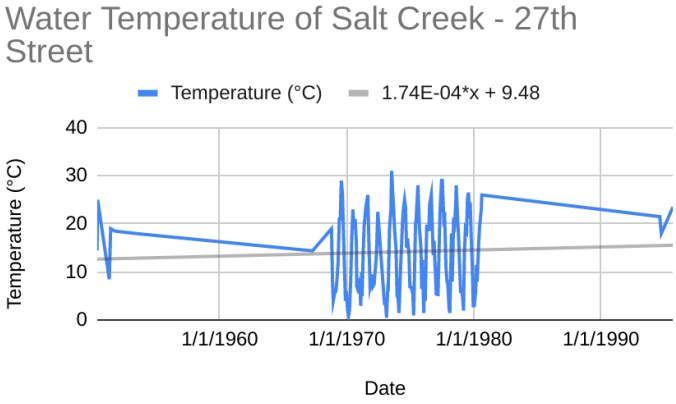


Figure 21. 2,4-D Concentration (mcg/L) of Salt Creek at Pioneer's Boulevard.

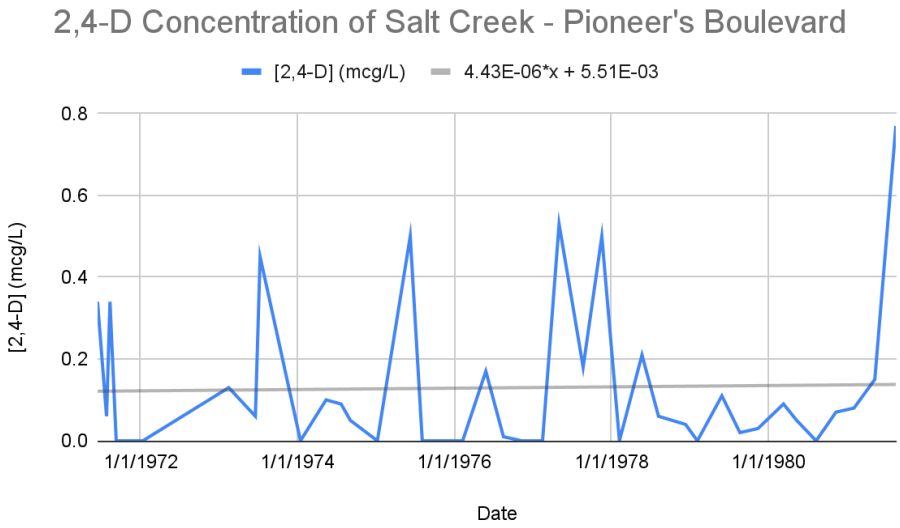


Table 3. Qualitative Indicator Coding based on interviews regarding Indigenous Knowledge Systems.

Qualitative Indicator Coding

Respondants	Qualitative Indicator Responses					
	Presence of Native Plants	Water Quality	Biodiversity Levels	Usage of the Ecosystem for Native Purposes	Presence of Indigenous Peoples	Departure of Wildlife and Indicator Species
Participant 1	Many native plants do not grow in the area anymore. Omaha people used to collect mushrooms, which was a large part of their livelihoods, but no longer do because they are not longer available. Also no longer able to gather natural foods that used to be incorporated into their diet.	Water contains high levels of pesticides and pollution from Western development. Water is polluted, dirty, unsafe to drink.	Significant decrease in biodiversity as compared with before western development. There is a lack of people, plants, animals, birds, etc.	Omaha people no longer collect salt from the river, which they did up until the 1960s. They also do not collect mushrooms or other native plants that were incorporated into their diets and livelihoods. River was used for bathing, drinking, and overall life for all. This no longer occurs. "Alter water, alter life".	Historic homelands of Missouria-Otoe, Ponca, and Pawnee. Missouria-Otoe were relocated to Kansas, Pawnee to Oklahoma, and Poncas to Northeast Nebraska.	No longer insects, buffalo, antelope, deer, coyotes, wolves, eagles, hawks, etc. in the area. Salt Creek Tiger Beetle is endangered and only has a few hundred individuals left.
Participant 2	Morel mushrooms are not growing as abundantly. The Omaha people had to stop their collection of this species, which used to be a main source of income and food for them.	The water is "poisoned" and filled with pollution. This cause caused many Indigenous Peoples to stop gathering and using the ecosystem how they used to.	Significant decrease in biodiversity. Lincoln has grown and taken over Native land. It used to be "green and pristine", but now is markedly less so. Reduction of biodiversity by agriculture and other ways of living by white people.	Omaha people stopped collecting salt, mushrooms, and other native plants because the water and land is poisoned. The salt was used to preserve food and for trade. Morel mushroom collection happened in May, as well as a collection of other main staples. This stopped because of pollution. There is no longer Indigenous stewardship, and the ways of life have changed. Omaha people specifically used to live in a natural state, but now "live like white people". They were forced to assimilate.	Lincoln was a "commons area", meaning that numerous different tribes gathered here. Salt Creek has a social and spiritual value. This is historically Otoe Lands, but is "currently occupied by Lincoln, Nebraska". Many people were forced to relocate.	Significant decrease in the amount of wildlife/biodiversity that the area historically contained. The land and water is poisoned, creating less habitat. There is also no longer Indigenous Stewardship of the land, in which people used to live in harmony with the land. Participant 2 wishes she could have seen the land the way in which it used to be.
Participant 3	The stewardship of native plants by Indigenous Peoples has changed. Used to preserve the prairie and reduce invasive species. Set intentional fires to keep the land healthy, and this can be seen in fire records found in the soil.	The amount of salt deposits in the water have been greatly reduced. There used to be pillars of salt in the water, but are no longer there. There is also a lack of water flow now.	Agreed with Particpants 1 and 2.	Corroborated what Participants 1 and 2 stated about Omaha people collecting salt. The Omaha people no longer do this due to pollution and lack of salt/water. Stewardship of the land, and especially prairie, no longer happens. Also stated that since moving here, he has seen a significant loss in the influence of environmental lobbyists. Development interests have gained lots of traction, and will win if challenged by environmental groups.	Used to be a sort of "DMZ" for groups in the area. Lincoln was a gathering zone, almost a "4 corners" area with a confluence of different tribes. This area still is important, but some tribes have been relocated to other areas of the state/country.	Agreed with Participants 1 and 2.

The results for qualitative indicators are shown in Table 3. For the first indicator, which questions whether native plants remain in the area, all interviewees state that there is a notable decrease in this category. They mention the Omaha people, who used to gather Morel mushrooms and other staple foods in the area; however, this practice has since been discontinued due to the pollution of the Salt Creek basin. According to their accounts, mushrooms and native plants used as dietary staples do not grow as well or as abundantly as in the past. Secondly, they addressed the water quality of the river. All participants agree that water quality has suffered a significant decline due to pollution or “poisoning” by pesticides and other forms of runoff. Indicators regarding biodiversity levels and the presence of wildlife/indicator species received similar answers. Individuals report that the basin has experienced mass departures of wildlife and indicator species, such as buffalo, deer, eagles, coyotes, and insects, especially the Salt Creek Tiger Beetle, an insect species endemic to the saltwater marshes of Lancaster County; the beetle is severely endangered (“Salt Creek Tiger Beetle”, 2022).

Finally, the interviewees addressed the indicators relating to the presence of Indigenous Peoples and their usage of the ecosystem for its pre-colonized purposes. Once again, all stated

that there has been a significant decrease in the number of Indigenous Peoples in the area, especially those whose historic homelands lie in Lancaster County. Use of the ecosystem for pre-colonized purposes is also reportedly lower. According to all respondents, Omaha women used to collect salt from the river, but stopped doing so in the 1960s due to pollution. Mushrooms are no longer collected as frequently, or at all. These staples were used to sustain Indigenous ways of life, but are reported to no longer be used in these ways due to the deterioration of the quality of the environment, especially due to pollution of the water and land.

Quality of the data collected was assured through cross-validation of the qualitative indicators by comparing interview responses. Any data point that was not verified by other interviewees was omitted, similar to the verification process used in the Abu et al. study in the Saskatchewan River Delta of Canada (Abu et al., 2019). Quantitative data quality was assured by utilizing verified and reliable resources, such as U.S. government and UNL databases, and cross-checking the data between them.

Discussion

The main research questions of this study inquire, “What can the combination of Western science and Indigenous Knowledge Systems reveal about the overall ecosystem health of the Salt Creek basin?” and “How do the two sets complement the other?”. In regard to the former, the utilization of both Western science and IKS has resulted in a more holistic understanding of the current conditions in the Salt Creek basin. Western science provided quantitative data, such as precipitation and streamflow amounts, nutrient concentrations, and air and water temperatures. Precipitation data, which includes 135 years of weather records, shows that there has been a slight overall increase in the amount of precipitation that has fallen in Lincoln, Nebraska since

1887 (figure 6). Precipitation has generally increased at an average rate of 0.023 inches per year; however, since 2017, there has been a steady decrease in the amount of precipitation in Lincoln, with 2022 being one of the driest years on record at only 19.92 total inches of precipitation. Similarly, the gage height (figures 7 and 8) and streamflow (figures 9 and 10) graphs show a decrease in water amounts, especially in recent years. Gage height begins decreasing around early 2020, and streamflow in late 2019.

The recent lack of precipitation has caused dramatic impacts in Lancaster County and across the state. Ninety-eight point three percent of Nebraska is in some level of drought, with Lancaster County falling into the Severe category (figures 11 and 12). Drought can be triggered by sustained periods of low precipitation, which has been the case in Lincoln since 2017. The impacts of drought are immense, especially in a state dependent upon agriculture. Lack of water can lead to decreased crop yields, as well as increases in food prices (Doney et al., 2014). Climate change also exacerbates the effects of drought by making them longer, frequent, and more severe ("Droughts and Climate Change", n.d.). The recent droughts are particularly severe, and they have been increasing in both strength and frequency in Nebraska since the late 1940s. Drought has also affected Indigenous Peoples living in the region. According to interviews with members of the Lincoln Indigenous community, the Omaha people stopped collecting salt and other staple ingredients around the 1960s due to decreases in water quality and amount, which was further exacerbated by drought. The Ponca, who, according to respondents, also used to live in the region, but were relocated to Northeast Nebraska, are currently facing extremely high levels of drought. Many counties in the Northeast are labeled as being in extreme or exceptional drought. The EPA states that "a lack of water impacts the survival of plants and animals, which hold additional cultural importance to tribal nations, as well as medicinal purposes," ("Tribal

Nations", n.d.). Increased drought frequency and severity has been intensifying the impacts of historical injustices already faced by Indigenous Peoples in the region

Other quantitative indicators, such as Nitrogen and Phosphorous concentrations, have shown increases at both Salt Creek monitoring locations sampled, located at Pioneer's Boulevard and 27th Street (figures 13 and 14, 15 and 16). 2,4-D concentrations, which is one of the oldest and most widely available herbicides in the world (US EPA, 2014), were also sampled from the Pioneer's Boulevard location (figure 21). 2,4-D has been available since the 1940s and is found in over 1,500 herbicide mixtures (US EPA, 2014). 2,4-D is becoming more widely used for both commercial and non-commercial applications. For example, between 2012 and 2020, 2,4-D application in agricultural sectors has increased almost 67% and over 240% between 1991 and 2020 (Freisthler, 2022); this trend is only expected to increase due to intensifying levels of weed resistance. Additionally, 2,4-D was the most widely used herbicide in non-commercial settings in 2012 (Freisthler, 2022). Therefore, it comes as no surprise that the concentration of this chemical has been increasing in Salt Creek. This illustrates an interesting relationship between water amounts and nutrient concentrations, as the quantity of water in both locations has decreased, yet the amounts of pollutants and pesticides have increased. This information, drawn from the Western scientific field, signifies that the water quality in the Salt Creek basin has declined, starting in the 1970's when data collection ensued and continuing until today. Indigenous Knowledge Systems agree and bolster this assessment, as community members report that the collection of salt from Salt Creek halted in the 1960's, and that Morel mushroom collection is becoming less frequent. This is due to the "poisoning" of the land and water, especially by Western development, as reported by interviewees. The pollution of the region has caused many

Indigenous Peoples to stop using the ecosystem for its pre-colonized purposes and altered the historic functions of the environment.

Similar to nutrient concentrations, air and water temperatures (figures 17 and 18, 19 and 20) have increased from the 1970's until today. Warming temperatures are one of the primary effects of climate change, which threatens the ways of life of all people in Nebraska. Once again, this has important implications for a state dependent upon agriculture; rising temperatures can have considerably detrimental effects on crop yields and other agricultural outputs. Additionally, Indigenous Peoples are especially vulnerable to the effects of climate change. The EPA states, "Many Indigenous peoples already have trauma from colonization, removal from their homelands, and loss of traditional cultural practices. Climate change impacts to the natural environment are worsening this trauma…Climate change threatens places and practices that are central to Indigenous peoples' identities and well-being," (US EPA, 2022, pg. 6). The combination of climate change and decreasing environmental quality in the Salt Creek Basin creates a toxic mixture for Indigenous Peoples and their ways of life, which have already suffered from historical injustices. Traditional practices and knowledges have been affected and even stopped, and this issue will only continue to grow worse if environmental degradation and climate change continues.

Interviews with Indigenous community members revealed illuminating insight into the qualitative indicators on which this study is based upon. In addition to coinciding with the information gleaned from Western science, IKS was able to provide information about the condition of the ecosystem that Western science was not. Conversations with Indigenous community members further revealed the extent of the environmental deterioration occurring in the Salt Creek basin. Those interviewed report a significant decline in the number of the native

plants and animals in the region, which are vital to Indigenous Peoples livelihoods. Additionally, respondents report a decline in the number of Indigenous Peoples themselves in the area, which is supported by historical records. Lincoln is the historic home of the Missouria-Otoe, who were relocated to Kansas; the Ponca, who were relocated to Northeast Nebraska; and the Pawnee, who were relocated to Oklahoma. This removal has only exacerbated the deterioration of the Salt Creek basin, as it also caused Indigenous Stewardship of the land to cease. The knowledges which allowed Native people to live in harmony with the environment for thousands of years are no longer practiced, and therefore, no longer benefit the environment.

Aligning Western science and IKS

The second research question asks how Western science and Indigenous Knowledge Systems align. Table 4 contains a consistency chart that explains how the two different fields corroborate each other; it also shows how the two are able to fill in the gaps on topics that the other cannot answer. Most of the indicators used during the course of this investigation received a designation of *consistent*, meaning that Western science and IKS agree. The remaining indicators fall into the categories of *no Western science* or *no Indigenous Knowledge*, where one domain is able to provide information about a topic that the other cannot. Most of the qualitative indicators rely solely on Indigenous Knowledges, and the majority of the quantitative indicators rely mainly on Western science. However, they corroborate each other whenever possible. The qualitative indicator relating to water quality shows that both sets of knowledge are in agreement. Western science shows this by illustrating the increasing amounts of nutrients and pesticides in the water, and IKS shows this by illustrating how Indigenous Peoples are no longer able to use the ecosystem in the same ways due to the environmental degradation and pollution

of the water. Similarly, the quantitative indicators regarding nutrient and pesticide levels are corroborated as well due to agreement on both sides about the increasing levels of pollution in the area.

Table 4. Consistency chart in which the categories are consistent (+), where Indigenous knowledge and science corroborate each other; inconsistent (–), where Indigenous knowledge and science disagree; no Western science (O), where Indigenous knowledge alone provides information; and no Indigenous Knowledge (*), where Western science alone provides information (Abu et al., 2019).

Qualitative Indicators	Information Sources
Presence of Native Plants	O
Water Quality	+
Biodiversity Levels	O
Usage of Ecosystem for Native Purposes	O
Presence of Indigenous Peoples	O
Presence of Wildlife and Indicator Species	O
Quantitative Indicators	
Nutrient Levels	+
Discharge Amounts	*
Precipitation Amounts	*
Pesticide Levels	+
Temperature Change	*
Gage Height	*

Key
Consistent (+)
Inconsistent (-)
No Western Science (O)
No Indigenous Knowledge (*)

Indigenous Knowledge and Western scientific knowledge are often viewed as binary opposites, with IKS being “the other” (Battiste, 2005), but table 4 shows that this is not the case. In fact, IKS and Western science often corroborate each other when possible, and when not possible, are able to fill in the gaps of the other. Instead of working against each other, both sets

of knowledge combine to provide a more complete and comprehensive overview of environmental conditions. In the Salt Creek basin, the blend of both sets of knowledges allows for a deeper understanding of environmental issues and deterioration, such as decreasing water quality due to heightened levels of nutrients and pesticides, even though water amounts have declined. Other issues include a lack of biodiversity, decreases in the numbers and pre-colonized functions of Indigenous Peoples, and increasing effects of climate change. When only looking at the Western scientific data points, one might assume that the increase in ecological degradation is not of much concern, as the concentrations, temperatures, and depths increase/decrease by very small amounts every year. However, when Indigenous Knowledge is factored in, the full breadth of the issue can be understood. The fundamental actions of the environment and those close to it have been substantially modified or even ceased to exist. The combination of these two realms through Two-Eyed Seeing reveals deeper and more complex issues and effects at hand. By themselves, each knowledge set is fragmented and partial, but together, they provide a more complete understanding of health and change.

This study has made a case for implementing Two-Eyed Seeing into the Salt Creek basin in order to better understand long-term change in the region. This recommendation is supported by previous work performed in the Saskatchewan River Delta of Canada (Abu et al., 2019). This research found similar results, in which each knowledge set by itself was incomplete, but together, formed a whole. However, the two studies diverged in some instances, as Abu et al. found that Indigenous Knowledge and Western science were not consistent regarding a few indicators, such as about Northern Pike population numbers. In this study performed in the Salt Creek basin, there was no divergence between the two knowledge sets. Overall, the majority of indicators and corresponding knowledge sets were in consensus in both studies. Abu et al. found

that Two-Eyed Seeing provides a more "accurate description of long-term change than any single knowledge system could do alone," (Abu et al., 2019, pg. 17), which is also the case in the Salt Creek basin. Implementing systems and policies which take both into account and value each equally are key for creating a more sustainable and equitable future.

Summary and Conclusions

The research in this study attempted to bridge the span between Western science and Indigenous Knowledge Systems using Two-Eyed Seeing in the Salt Creek basin. Prior to this study, no similar attempts had been made in the region; all of the previous work relating to this topic was performed primarily in Canada (Abu et al., 2019; Giles et al., 2016; Mantyka-Pringle et al., 2017). However, this left the information regarding the health of the Salt Creek basin ecosystem lacking. By using exclusively one knowledge system (primarily Western science), only partial understandings of change could be obtained. Therefore, this project questioned "What can the combination of Western science and Indigenous Knowledge Systems reveal about the overall ecosystem health of the Salt Creek basin?" and "How do the two sets complement the other?", as Indigenous Knowledge Systems are often viewed as "the other" in Western research. The results show that the combination of both Western science and IKS leads to a more accurate assessment of environmental health and change in the Salt Creek basin.

Western science data points revealed that recent precipitation levels have dropped (figure 6) and the amount of water in the Salt Creek has declined, shown through the diminished levels of streamflow and gage height (figures 7-10). This has served to increase drought frequency and intensity (figures 11 and 12), along with air and water temperatures (figures 17-20). Additionally, the concentration of nutrients such as Nitrogen and Phosphorus (figures 13-16), as well as herbicides including 2,4-D (figure 21), have intensified. However, when looking solely at the

trend lines associated with the graphs, one might not feel pressing levels of concern, as the increases seem minor year to year. The slight annual increase does not show the extent to which the environmental quality has declined in the region; a more complete understanding is only obtained once Western Science and Indigenous Knowledge Systems are combined. Respondents from the Lincoln Indigenous community report substantial changes to the Salt Creek basin environment and its uses (Table 3). These include a lack of native plants (and fungi), such as Morel mushrooms, diminishing numbers of wildlife and indicator species, and a decline in the number of Indigenous Peoples in the region, due to relocation and environmental degradation. Usage of the ecosystem for its pre-colonized purposes has almost ceased, including traditions such as the gathering of salt from the Salt Creek by Omaha women. The combination of both Western science and Indigenous Knowledge Systems allows for a more complete understanding of change, and in this case, decline, of the environmental conditions of the basin, especially over the past few decades. Each knowledge set works to overcome the limitations of the other.

These endeavors also exhibit how both sets of knowledge act to enhance and corroborate with the other whenever possible. Table 4 shows how Western science and IKS provide consistent information relating to topics like water quality and nutrient/pesticide levels. They also aid the other by filling in the gaps with information that the other cannot provide. The majority of the qualitative indicators rely on knowledge from IKS, and on Western science for the quantitative indicators. Instead of working against the other as “binary opposites” (Battiste, 2005), both knowledge sets reinforce the other and create a more comprehensive overview of ecological health in the Salt Creek basin.

Recommendations for further study include broadening the scope of the investigation, both in terms of land area and the number of respondents. This research in particular was limited

to the Salt Creek basin in Lancaster County, Nebraska. However, the rest of the state, and even Midwest, could benefit from a version of this comprehensive research into environmental health, as the Midwest is an important agricultural region with strong Indigenous roots. Additionally, increasing the number of respondents would be beneficial, as it would likely increase the accuracy and reliability of the information obtained from Indigenous Knowledge Systems; if this study were performed again, this could be done differently. It was difficult to find large numbers of members of Indigenous communities local to Lancaster County, as removal has forced many to different areas of the state or nation. Gathering more testimonies could provide more information regarding the changes occurring in the Salt Creek basin, or across the state/region if the scope were to be expanded.

Overall, the experience of completing this research project was very illuminating and informative (and even enjoyable). While I have always had an interest in Indigenous Knowledge Systems, I have never before had the opportunity to explore them in depth like I was able to during this study. I learned that I truly enjoy interacting with people from different backgrounds than I and that we can learn so much from those different from ourselves. This project also considerably enhanced my idea of sustainability, especially relating to the definition by UNL's Sustainability Initiative Team, which stresses the need to consider the long-term implications of today's choices on Earth's future and on all stakeholders involved. Indigenous Knowledge is often not incorporated into research in a society that relies mainly on Western science; however, doing so allows for the consideration of impacts on all shareholders, especially those who have strong connections with the planet and its life support systems. Taking more diverse perspectives and stakeholders into account can create a stronger understanding of both ecosystem health and

its impacts on those living there, especially when these viewpoints are equitably combined with others to form a stronger whole.

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