2015 Project Abstract
For the Period Ending June 30, 2019

PROJECT TITLE: Aquatic and Terrestrial Reptile Habitat
PROJECT MANAGER: Jennifer T. McGuire, Ph.D.
AFFILIATION: University of St. Thomas

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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03m

APPROPRIATION AMOUNT: $250,000
AMOUNT SPENT: $ 226,294
AMOUNT REMAINING: $13,706

Sound bite of Project Outcomes and Results

We collected and analyzed four years of water quality and habitat parameters in an urban lake. Conditional effects on turtle population dynamics were evaluated in three species using genetic and demographic data. Management and conservation recommendations were made to protect and enhance turtle populations and overall health of urban lakes.

Overall Project Outcome and Results

Turtles are among the most threatened organisms in the world, with approximately 61% of the 356 modern species of turtles and tortoises listed as threatened, endangered, or already extinct. Little is known about how human alteration of habitats, including water chemistry in urban lakes, affects turtle behaviors. Human activities can lead to the addition of chemicals such as road salt and excess nutrients, increased aquatic sediment, and altered water flow patterns. Understanding how these changes affect turtles is critical for appropriate planning to balance human and wildlife needs.

Beginning in the summer of 2015, our team of ecologists, water-quality specialists, wildlife managers and students, conducted research at an urban lake in Plymouth, MN (Medicine Lake) studying population dynamics of Painted Turtles (*Chrysemys picta*), Snapping Turtles (*Chelydra serpentina*), and Spiny Softshell Turtles (*Apalone spinifera*), three of the most widespread native turtle species in North America. We completed:

- Turtle trapping and telemetry of 314 turtles
- Genetic sampling to analyze population size and inbreeding
- Spatial and temporal analysis of lake sediment and water quality
- GIS analysis of turtle home range, habitat use, and water quality

These data were used to prepare recommendations (*see final management report for details*). Briefly, our data show it is important to protect and conserve diverse natural shorelines (with either sandy or vegetated habitat with locations for basking) to support diverse turtle communities. It is also important to balance human recreational needs with disturbance to basking or nesting sites, particularly for Spiny Softshell turtles that nested on the swimming beach. To maintain high genetic diversity and reduce inbreeding, aquatic connectivity between water bodies should be maintained and preserved. Finally, the impact of road salt should be limited via barriers, as our data show that these chemicals increased in the lake over the four year study, now reaching levels shown to produce aquatic toxicity and impaired food-web dynamics in other systems. Because dissolved salt is nearly impossible to remove from the water, limiting input BEFORE wildlife impacts are observed is critical.

Project Results Use and Dissemination

Although the work provided here was the subject of academic publications, student projects, and graduate theses *(see work plan for additional details)*, the main results use and dissemination was in providing specific recommendations for future management of Medicine Lake and communicating those to Three River's Park District, the organization managing the lake (*see final management plan*).

We considered public engagement to be a very important aspect of this project. For social media outreach we created a Facebook page, Turtles of Medicine Lake, with over 150 organic followers. This page was updated with fun facts about the three species of turtles included in this project, relevant new research, and any other project updates that were appropriate. Additionally, we had media coverage from local news channels and local papers throughout the duration of the study. Eric Nelson from Channel 12 Local News and CCX Media filmed and aired a segment in July, 2016. Jeff Edmondson from Kare 11 covered all three years of the project and filmed and aired segments in August of 2016, 2017, and 2018. Sonya Goins from Channel 12 Local News and CCX Media came to the lake to film a segment covering the winter ice dive in March, 2018. And Lastly, Kristen Miller published an article in the Sun Post, also covering the winter ice dive in March, 2018. Bridging the gap between scientific research and the public is one of the most important aspects of science and we were successfully able to this for the Medicine Lake Urban Turtle Study.

Environment and Natural Resources Trust Fund (ENRTF) M.L. 2015 Work Plan Final Report

Date of Report: August 16, 2019

Final Report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2019

PROJECT TITLE: Aquatic and Terrestrial Reptile Habitat

Project Manager: Jennifer T. McGuire, Ph.D.

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Location:

Medicine Lake, Hennepin County, MN

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$250,000**
	Amount Spent:	**$226,294**
	Balance:	**$13,706**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03m

Appropriation Language:
$250,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the University of St. Thomas in cooperation with the Three Rivers Park District to analyze the aquatic and terrestrial habitat parameters that affect the use of urban lakes by a three species turtle community and to make specific recommendations to protect and enhance their populations. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Aquatic and Terrestrial Reptile Habitat

II. PROJECT STATEMENT:

Habitat use of Spiny Softshell turtles is well known for riverine systems, but little is known is about their behavior in lake systems. Further, effects of microhabitat variation on turtle distribution is largely unstudied. Many significant human impacts, such as road salt or fertilizer inputs, perturb these systems. Softshells are found in all of the major drainages in Minnesota (Moriarty and Hall 2014) and in the larger lakes in the east central part of the state, especially in the Minneapolis – St. Paul Metropolitan area. Most of these lakes are highly developed with residential properties that extend to the shore line. Much of the shoreline has been hardened with retaining walls or rip-rap. Reports of large Softshells in the larger lakes, such as Minnetonka and White Bear, have been decreasing over the last 20 years.

Three Rivers Park District (TRPD) became aware of Spiny Softshells attempting to nest on the swimming beach in French Regional Park in 2005. TRPD began to monitor nesting Softshells at French Park in 2009. A fenced off sanctuary area was established that year and five nests were protected. The most recent (2014) nesting season had 43 nests in the sanctuary area. Prior to nesting, the female Softshells are observed in the "lagoon" area of the park, but there are not observations after nesting.

Medicine Lake also has populations of Painted Turtles and Snapping Turtles. These turtles are known to use the same basking habitat as the Softshells, but are more generalists for nesting. There is little information on interaction of the three species of turtles in Minnesota.

Similarly, there is little information on how human activities impact the distribution of nesting and other behaviors of Softshells which can be a challenge in generating and assessing management strategies. Human activities can lead to the addition of chemicals such as road salt and excess nutrients, increased aquatic sediment loads and altered groundwater flow patterns. These changes may or may not impact turtle population dynamics but knowing the extent to which they do is critical for appropriate future planning.

This projects seeks to conduct a study of the populations of Softshells, Painted, and Snapping Turtles in an urban lake environment, Medicine Lake, to discover the connections between water quality and turtle habitat use including nest site selection to inform management for this and similar lake systems. This will be accomplished by achieving the following:

- Turtle trapping and telemetry of 75 turtles (25 of each species)
- Genetic sampling and analysis of population size and inbreeding
- Water quality sampling that targets parameters as indicators of human activity as dictated by turtle dynamics
- GIS analysis of turtle home range, habitat use, and water quality parameters
- Preparing recommendations for turtle management in urban habitats

We expect this work will provide new knowledge of the linkages between aquatic characteristics, including water chemistry, and turtle population habitat usage. Surprisingly little is known about these connections in the environment and the need to understand is particularly acute in locations with a significant human impact such as urban lakes. These new data are critical to developing recommendations for urban lake management that responsibly balance human and wildlife needs.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of October 1, 2015: Work on the project began in July 2015 with the project managers working to recruit students, gather materials and begin testing best-practice methods to be used for the project. Project manager s have been working closely with the Three River's Park District, particularly John Moriarity, to develop agreements that maximize synergy of resources between the University of St. Thomas (UST) and Three River's Park District to ensure student safety and high-quality data collection. Students will be recruited from the University of St. Thomas undergraduate student population and supervised jointly between PIs McGuire and

Lewis and John Moriarity of the Three River's Park District. This project aims to produce new data on the relationship between water quality and three turtle populations at Medicine Lake that can be used to develop management plans for urban lakes, as well as to train the next generation of scientists in an interdisciplinary investigations. We have made good early progress on the goals.

Project Status as of April 1, 2016: PIs McGuire and Lewis have worked closely with John Moriarity over the past 6 months to prepare for our summer 2016 field season. Noteworthy preparations include the acquisition of all necessary animal permits from DNR, selection and hiring of student researchers from the University of St. Thomas and field interns at Three River's Park District to support extensive spring-summer field activities, the evaluation and acquisition of necessary equipment (new and existing), review of preliminary water chemistry data and maps, design of worker training materials, and development of timeline goals. Mr. Moriarity has also written and distributed informational materials about the project to Medicine Lake homeowners and various other interested parties (e.g., boaters and other recreational users of the lake).

Project Status as of October 1, 2016: Our team had a very successful summer 2016 data-collection campaign. PIs McGuire and Lewis worked together with John Moriarity to hire, train, and supervise a team of seven student and internship researchers in safety procedures, boat handling, radio telemetry, turtle trapping, water chemistry, data recording, intra-group communication, and public interactions. Our UST team worked closely with the Three Rivers Park staff and surrounding community to ensure high-quality data collection without disruptions to either group. Integrated data on turtle location and water chemistry have begun to be collected and analyzed.

Project Status as of April 1, 2017: Turtle tracking continued through the winter 2016-17 on Medicine Lake with UST undergraduate students and volunteers and Three Rivers staff and volunteers. Painted Turtles and Snapping Turtles were located regularly, but Spiny Softshells were not located despite repeated attempts including use of below-ice antenna, likely they were too deep to locate. Late winter tracking was ended early because of unsafe ice conditions caused by early melt. Turtle location points from 2016 have been entered into ArcGIS database and mapped for further analysis. Basic movement data has been reviewed allowing coordinated planning for spring and summer data collection on turtle locations and associated water chemistry. Water chemistry from last summer has been entered, plotted and basic statistics performed to identify areas of Medicine Lake where there are possible water-quality impairment(s) (e.g., high chloride concentrations). These areas will be targeted for further analysis including analyses to see if these areas are statistically avoided by any of the species of turtles. Hiring and training of student research support for spring/summer field season has begun.

Project Status as of October 1, 2017:

We completed a successful field season at Medicine Lake this summer engaging four undergraduates, one graduate student, and a Three Rivers technician. We trapped an additional 18 painted turtles, 12 snapping turtles, and 11 spiny soft shell turtles, collecting a DNA sample from each and equipping each with a pit-tag. In all, we have sampled and pit tagged 290 turtles. We maintained radio transmitters on 25 turtles of each of the three target species and focused this summer on location data, linking it to water quality sampling within the eight zones across the lake. Overall we recorded 1850 telemetry locations including 700 spiny soft shell locations, 650 snapping turtle locations, and 500 painted turtle locations for an average of 25 locations per turtle. Preliminary analysis shows painted and snapping turtles maintain small, localized home ranges near shore, but spiny soft shell turtles move throughout the lake. We also scored shoreline habitat using MN DNR Score the Shore protocols. Water chemistry and aquatic toxicology samples suggest that the greatest risk to turtle population health is elevated chloride concentrations at selected locations.

Project Status as of April 1, 2018:

During our winter season, data from the summer 2017 was analyzed, new data on water quality (including a focus on possible effects of chloride toxicity) and turtle location were collected, and plan made for our last summer of field work (2018), including hiring new students. Turtles were located by volunteers on several occasions through the winter. Softshell turtles were found to be concentrated on a sandy portion of the lake in 12 to 20 feet of water. Volunteer ice divers conducted a survey of the overwintering softshells.

Project Status as of October 1, 2018: Turtle trapping and tracking for the project was completed mid-August, 2018. Over the course of the field seasons, we trapped a total of 314 turtles in Medicine Lake, 192 Painted Turtles, 76 Snapping Turtles, and 46 Spiny Softshell Turtles. Telemetry during the 2018 field season focused on filling the gaps in the turtle location dataset at specific times during the day that were missing for individual turtles. We also conducted four "all-day-follows" in which a subset of six turtles were located once per hour for 24 hours. All turtle locations have been archived in the ArcGIS database. Habitat use and home range analysis is currently being carried out by a Central Michigan University masters student (Kirsten Deanna Frahm). Genetic analysis for all Medicine Lake samples was completed by another Central Michigan University masters student (Alaini Schneider Cossette) at the end of April, 2018. Nest site data has been compiled and analyzed and will be included in the final report along with the home range and habitat use data. Water chemistry has been collected to evaluate spatial and temporal variability for water quality parameters as they may impact turtle movements. In summer 2018, the water sampling goals were 1) to improve spatial resolution in a zone (south lobe-zone2) where turtle populations may be exposed to high (potentially toxic) concentrations of chloride, 2) to collect water samples from all zones across the lake to evaluate temporal variably across the 4 years of the study, and 3) to collect high-resolution water quality data in concert with the "all-day-follows" of turtles to identify any direct linkages between turtle summer movement and water quality.

Project Status as of April 1, 2019:
Over the last 6 months, our research group has been working on two main goals 1) Analysis and interpretation of dataset as a whole (turtle population data and water chemistry data for more than 3 years), and 2) development of some new water chemistry techniques to further understand the threats to water quality for food web dynamics. These activities have provided us the foundation for a draft management plan recommendations for Medicine Lake. We have been in close communication with The Three Rivers Park District and it is our hope that these data will be an excellent resource to mitigate key threats to the aquatic food webs at Medicine Lake.

Overall Project Outcomes and Results:

Turtles are among the most threatened organisms in the world, with approximately 61% of the 356 modern species of turtles and tortoises listed as threatened, endangered, or already extinct. Turtle populations are in decline and threatened by many factors, however, many altered (e.g., urban) lakes and rivers have robust turtle populations and little is known about the specific effects of human alteration of habitats, including water chemistry, on turtle basking, nesting and other behaviors. Human activities can lead to the addition of chemicals such as road salt and excess nutrients, increased aquatic sediment loads and altered water flow patterns. Understanding the effects of these changes, if any, is critical for appropriate planning to balance human and wildlife needs.

Beginning in the summer of 2015, our team of ecologists, water-quality specialists, wildlife managers and students, conducted research at an urban lake in Plymouth, MN (Medicine Lake) studying population dynamics of Painted Turtles (*Chrysemys picta*), Snapping Turtles (*Chelydra serpentina*), and Spiny Softshell Turtles (*Apalone spinifera*), three of the most widespread native turtle species in North America. We completed:

- Turtle trapping and telemetry of 314 turtles: 192 Painted Turtles, 76 Snapping Turtles, and 46 Spiny Softshell Turtles.
- Genetic sampling to analyze population size and inbreeding

- Spatial and temporal analysis of lake sediment and water quality (8 unique zones within the lake over 4 years)
- GIS analysis of turtle home range, habitat use, and water quality

These data were used to prepare recommendations (*see final management report for details*). Briefly, our data show it is important to protect and conserve diverse natural shorelines (with either sandy or vegetated habitat with locations for basking) to support a diverse turtle community. It is also important to balance limiting disturbance to basking or nesting turtles with human recreational needs, particularly for Spiny Softshell turtles that nested on the swimming beach. To maintain high genetic diversity and reduce inbreeding in urban turtle populations, we recommend that aquatic connectivity between water bodies be maintained and preserved. Finally, influx of waters impacted by road salt (i.e. during snowmelt) should be limited via barriers as our data show that these chemicals continued to increase in the lake water over the four years study and are now reaching levels that have been shown to produce aquatic toxicity and impaired food-web dynamics in other systems. This is a critical finding, as salt is nearly impossible to remove from the water once it is dissolved, so limiting input BEFORE impacts are observed in the wildlife is critical.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Turtle Trapping and Telemetry
Description:

Following specific turtles relative to microhabitats and estimating population size and inbreeding requires capture and processing of live specimens. We will capture 25 turtles each of three species using hoop nets and basking traps. We will focus most of our efforts on adult females as the breeding population is biologically most important, especially nesting and nesting movements, with 5 males and 20 females per species marked. Each captured turtle will be sexed, weighed, measured, and PIT (passive integrated transponder) tagged. These tags allow unique and permanent identification of each turtle. Turtles will each receive a radio transmitter to allow year-round locating and allow us to tie turtle locations to water quality sampling. All turtles will also have a small tissue sample removed for DNA analysis. For soft shells the tissue comes from a hole punched in the shell needed to affix the radio transmitter. For painted and snapping turtles this will be several scale clippings. DNA analysis provides a population size estimate independent of one derived from the mark and recapture data trapping affords. It will also allow linking turtles to nests if DNA can be obtained from egg shells. Population parameters will be analyzed using MARK software for live captures and BLAST or a similar program for DNA modeling.

Turtles will be radio located daily during the nesting season (June 1 – August 1), weekly during the rest of the active season, and monthly in the winter, unless movements require more frequent visits. All locations will be entered into GIS and home range and habitat use will be determined using ArcGIS.

All nests located within the French Park sanctuary will be located and protected. Nests outside the sanctuary will be protected with wire cages when found. Hatchlings will be captured and PIT tagged.

Summary Budget Information for Activity 1:

ENRTF Budget:	**$ 127,705**
Amount Spent:	**$ 122,085**
Balance:	**$ 5,620**

Outcome	Completion Date
1. Habitat use by turtles using telemetry	June 30, 2019
2. Nest site ecology and success	June 30, 2019
3. Habitat and home range analysis	June 30, 2019
4. Genetic sampling and Analysis	June 30, 2019

Activity Status as of October 1, 2015: PI Lewis and Moriarity have investigated equipment for telemetry investigations. Because of the lead times for telemetry equipment, and the unique challenges of attaching transmitters to softshell turtles, Lewis and Moriarity met with several venders about required equipment and costs of options. They held a meeting with area DNR and university herpetologists to discuss experimental design and methods for this project. They field tested several components at the study site including water attenuation of signal studies. They acquired 100 traps for use, modified a storage shed at the study site to hold the growing supplies, and began training students in boat use and radio telemetry.

Activity Status as of April 1, 2016: PI Lewis and Moriarity have completed their assessment of appropriate equipment for telemetry investigations and initiated purchase. Initial procedures to address the unique challenges of attaching transmitters to softshell turtles have been developed based on best-practices research among colleagues in the field as well as published work. Mockups of required attachments have been delivered to the transmitter manufacturer. Permits have been requested for proposed activities from DNR. University of St. Thomas IACUC (Institutional Animal Care and Use Committee) approval has been secured under protocol #85. Initial personnel commitments have been made to selected student researchers from the University of St. Thomas and interns from Three River's Park District. Necessary equipment (new and existing) is being evaluated and obtained. Field training materials for personnel are being created. Detailed timeline goals for data acquisition and quality control are being created. Work planned has been communicated in writing to Medicine Lake homeowners and other interested parties.

Activity Status as of October 1, 2016:
This field season was incredibly successful. PIs hired a team of five UST undergraduate students and two Three Rivers interns. Three Rivers provided a stand-alone garage, shed, and boat for daily use. UST supplied a truck and boat for daily use. We trained the team in safety, boat handling, radio telemetry, turtle trapping, instrumentation for water chemistry, data recording, intra group communication, and public interactions. We met weekly through the summer allowing us to deal with issues as they arose. We successfully trapped 225 turtles of the 3 target species, putting radio transmitters on 72 individuals (5 male and 20 female painted turtles, 5 male and 20 female snapping turtles, and 2 male and 20 female soft shell turtles). We were careful to make sure we trapped individuals from all around Medicine Lake. The team regularly monitored turtle locations using radio telemetry and began initial spatial analysis. We sampled water from across Medicine Lake and used data from analysis to refine study design. In addition, we placed informational signage around the lake directing questions, and crediting UST, Three Rivers, and LCCMR.

Activity Status as of April 1, 2017: Turtle tracking continued through the winter 2016-17 on Medicine Lake with UST undergraduate students and volunteers and Three Rivers staff and volunteers. Painted Turtles and Snapping Turtles were located regularly, but Spiny Softshells were not located despite repeated attempts including use of below-ice antenna, likely they were too deep to locate. Late winter tracking was ended early because of unsafe ice conditions caused by early melt. Turtle location points from 2016 have been entered into ArcGIS database and mapped for further analysis. Basic movement data has been reviewed allowing coordinated planning for spring and summer data collection on turtle locations and associated water chemistry.

Activity Status as of October 1, 2017:

We completed an extremely successful field season at Medicine Lake this summer engaging four undergraduates, one graduate student, and a Three Rivers technician. We trapped an additional 18 painted turtles, 12 snapping turtles, and 11 spiny soft shell turtles, collecting a DNA sample from each and equipping each with a pit-tag. In all, we have sampled and pit tagged 290 turtles. We maintained radio transmitters on 25 turtles of each of the three target species and focused this summer on location data, linking it to water quality. Overall we recorded 1850 telemetry locations including 700 spiny soft shell locations, 650 snapping turtle locations, and 500 painted turtle locations for an average of 25 locations per turtle. Preliminary analysis shows painted and snapping turtles maintain small, localized home ranges near shore, but spiny soft shell turtles move throughout the lake. We also scored shoreline habitat using MN DNR Score the Shore protocols.

Activity Status as of April 1, 2018:

Turtles were located by volunteers on several occasions through the winter. Softshell turtles were found to be concentrated on a sandy portion of the lake in 12 to 20 feet of water. Volunteer ice divers conducted a survey of the overwintering softshells.

Students, volunteers and interns have been hired and trained and have begun tracking turtles. As an interesting note, at 1200 hr on 14 May 2018, we observed C. picta basking on dead Castor canadensis (American Beaver) and Cyprinus carpio (Common Carp) at Medicine Lake in Hennepin County, Minnesota, USA. To our knowledge, this is the first report of C. picta basking on animal carcasses.

Project Status as of October 1, 2018: Turtle trapping and tracking for the project was completed mid-August, 2018 with the help of returning field students Lily Effertz, Megan Schwartz, Tom Shogren, and Evan Host. Over the course of the field seasons, we trapped a total of 314 turtles in Medicine Lake, 192 Painted Turtles, 76 Snapping Turtles, and 46 Spiny Softshell Turtles. Telemetry during the 2018 field season focused on filling the gaps in the turtle location dataset at specific times during the day that were missing for individual turtles. We also conducted four "all-day-follows" in which a subset of six turtles were located once per hour for 24 hours. All turtle locations have been archived in an ArcGIS database. Habitat use and home range analysis is currently being carried out by a Central Michigan University masters student (Kirsten Deanna Frahm) who has worked on the project, employed by Three Rivers Park District. In April 2018, genetic analysis for all Medicine Lake samples was completed by another Central Michigan University masters student (Alaini Schneider Cossette, who worked on this project while earning her BS at the University of St. Thomas). Nest site data has been compiled and analyzed and will be included in the final report along with the home range and habitat use data.

Project Status as of April 1, 2019: Excellent progress has been made on the analysis of nest site data and turtle movements and will be included in the final report along with home range and habitat use data. We expect these data to be valuable to ecologists and urban lake managers.

Final Report Summary: All turtle population data have been graphed, mapped and analyzed spatially. These data were then summarized into management recommendations for Medicine Lake. We included sufficient support to allow managers of other, similar, lake systems to consider if these recommendations would be appropriate in their systems as well.

ACTIVITY 2: Water Sampling and mapping
Description:
A critical component of the habitat survey will be the seasonal description of key water quality parameters as indicators of human activities that may impact turtle population dynamics. In late summer and fall 2015 as well as the early spring, late spring, summer, and fall of 2016, surveys of field water quality parameters (including

dissolved oxygen, temperature, ORP (oxidation /reduction potential), and salinity will be assessed across the lake to map the distribution of water types within the lake for comparison with habitat maps. To accomplish this, teams of students from the University of St. Thomas will be trained in field and laboratory water chemistry techniques. Selected sites will also be targeted for nutrients, chloride and trace metals based on a review of the existing historical data, areas of human impact, and/or major water inputs. These maps will be used to generate a refined sampling strategy that targets the areas of the lake where turtle communities are most impacted by human activities. Beginning spring 2017, higher-resolution water chemistry measurements will be conducted in these target areas and may include description of chemical gradients at the highly active sediment-water interface, major water recharge or discharge areas, or surface water interfaces such as those that may exist between the slough/lagoon area and the major waterway within the lake. The data would allow us to make recommendations regarding the impacts of activities such as road salt, nutrient loading, and physical shore design strategies.

Methods and Procedures:

Field Chemistry: A multi-parameter sonde (Yellow Springs Instruments) will be used to characterize lake and wetland water samples for temperature, pH, dissolved oxygen, Eh, and specific conductance. Dissolved iron (Fe^{2+}) will be determined in the field photometrically (phenanthroline method) using a Spectronic20D+ spectrophotometer (Thermo Spectronic, Rochester, NY). Alkalinity will be determined by potentiometric titration (Gran method).

Laboratory Methods and Procedures: Water samples collected for anions (including tracer (Cl^- or Br^-) and electron acceptors (SO_4^{2-} and NO_3^-)) and NH_4^+ will be syringe-filtered using Millex-HA 0.45 µm filters (Millipore, Bedford, MA). Anion samples will be preserved with formaldehyde and NH_4^+ samples will be preserved by flash freezing. Analyses will be conducted in UST geochemistry labs using a capillary electrophoresis system (Agilent Technologies, Wilmington, DE). Major cation and trace metal samples will be syringe-filtered using Millex-HA 0.45 µm filters (Millipore, Bedford, MA), acidified to less than pH2 and analyzed on an Inductively Coupled Plasma-Mass Spec (ICP-MS).

Summary Budget Information for Activity 2:

ENRTF Budget: $ 97,295
Amount Spent: $ 89,209
Balance: $ 8,086

Outcome	**Completion Date**
1. Whole-lake water chemistry and quality parameters	December 30, 2016
2. Targeted high-resolution water chemistry and quality mapping and analysis	June 30, 2019

Activity Status as of October 1, 2015: In late summer/early fall 2015, initial water chemistry surveys for major water quality parameters were made across the lake system to identify major trends in parameters to serve as baseline data and to identify locations where we might expect to see significant differences to better target future work. We have also purchased materials for the lab and field work and begun investigating the best methods to ensure high quality, low cost analyses. New technologies may allow for additional data to be collected without additional cost to the project. Students at UST, under the supervision of PI McGuire, have begun to evaluate these water and sediment chemistry methods.

Activity Status as of April 1, 2016: PI McGuire has reviewed preliminary water chemistry data/watershed maps and selected high-priority locations around the lake for further investigation. In Fall 2015, an initial analysis of the chemistry of the sediments in areas of major inflow and outflow to the lake was conducted using X-Ray Fluorescence technology (Thermo Scientific) on shallow sediment cores. These data are being statistically evaluated for planning purposes. Initial personnel commitments have been made to selected student researchers from the University of St. Thomas and interns from Three River's Park District. Necessary equipment (new and existing) is being evaluated and obtained. Field training materials for personnel are being created. Detailed timeline goals for data acquisition and quality control are being created. Work planned has been communicated in writing to Medicine Lake homeowners and other interested parties.

Activity Status as of October 1, 2016: This field season has yielded much high-quality water chemistry data across the Medicine Lake system. PIs hired, trained and supervised a team of five UST undergraduate students and two Three Rivers interns as described in Activity 1 status update. In addition to our weekly whole-group meetings, two students received additional training on laboratory safety and analytical chemistry methods and met, at least weekly, with PI McGuire to discuss status. Our team sampled water from across Medicine Lake and used these data to refine study design, dividing the lake into 8 different "zones" based on habitat, hydrological, and geochemical characteristics. More than 113 water samples were collected within the 8 different "zones" across Medicine Lake and analyzed for temperature, pH, dissolved oxygen, ORP (Eh), specific conductance, nitrate, ammonia, and chloride. In addition to data collection, quality assurance/quality control verification of our methods was completed and we are satisfied with our data collection protocols. Preliminary statistical and geospatial analysis of these data have begun and will guide our spring/summer field season data collection, in connection with the data described in Activity #1.

Activity Status as of April 1, 2017: Water chemistry from last summer has been entered, plotted and basic statistics performed to identify areas of Medicine Lake of possible water-quality impairment (e.g., high chloride concentrations) with respect to healthy turtle populations, and their aquatic food support. These areas will be targeted for further analysis, including analyses to see if these areas are statistically avoided by any of the species of turtles. Promising University of St. Thomas students have been hired (Carolyn Lussenhop and Hannah Link, along with Zach Mader) and have begun training on laboratory safety and analytical methods. Caroyln and Hannah have also recently attended a training on R (funded by the University of St. Thomas) to assist in these analyses. Reagents have been ordered and trials initiated to evaluate methods we may use to assess acute aquatic toxicity of these waters to aquatic organisms.

Activity Status as of October 1, 2017:

Freshwater systems contain ions and nutrients that have the potential to improve or diminish species habitats. In urban lakes, elevated nutrient levels are often the most prominent water quality impairment. However, excess nutrients are not always the most problematic pollutants; in particular, high levels of chloride (Cl-) can alter food web dynamics and are especially challenging to remove from lake basins. Previous studies indicate Cl- can have a negative impact on aquatic species. According to the Minnesota Pollution Control Agency, chronic (four days) and acute exposure (one day) to Cl- concentrations of 230 and 860 mg/L, respectively, is toxic to aquatic life. A major source of Cl- is road salt runoff, which warrants attention as its continued application in urban areas leads to increasing Cl- in urban lake systems. Thus, we analyzed how parameters including temperature (T), pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), Cl-, nitrate (NO3-), ammonium (NH4+), and specific conductance (SC) affect the use of an urban lake by three species of turtles: Chrysemys picta bellii, Chelydra serpentina, and Apalone spinifera. We trapped and radio-located 25 individuals of each species. Eight different habitats of the lake were identified and differentiated by hydrological factors and observed turtle locations. Preliminary data suggest no adverse correlations between pH, DO, ORP, NO3-, or NH4+ and turtle locations. However, Cl- ranged from 28 to 694 mg/L and these concentrations may have negative implications for aquatic food web dynamics and utilization of lake habitats by turtles. Shallow surface water samples were collected and analyzed for acute aquatic toxicity (Delta Tox II Analyzer). Preliminary data show limited evidence of acute toxicity, but deeper waters may exhibit greater toxicity, as a positive correlation between Cl- and water depth in half of the habitats was observed. In addition, in deeper areas of the basin, the water remains stratified into two distinct layers all year with recognizable differences in pH, T, SC, and Cl-.

Further analysis of the relationship between water quality parameters and aquatic species ecology (including toxicity to the aquatic organisms on which turtles feed) needs to be explored. In the next phase, we intend to focus on the temporal variability of water chemistry and toxicology to make recommendations to best manage and preserve turtle populations in Medicine Lake and similar urban lake systems.

Activity Status as of April 1, 2018:

During the winter season, we had several water-quality goals: 1) to collect water samples from beneath the ice to measure concentrations of dissolved oxygen, pH, temperature, specific conductance, chloride and oxidation/reduction potential (Eh); 2) to analyze summer/winter/whole datasets for correlations and data "populations" to identify water masses that may affect turtle population dynamics; 3) explore the effects of chloride ion (in particular) on aquatic toxicity. Our lab made good progress on all of these goals. We now have winter water quality data to be combined with and/or compared to summer data to better understand both spatial and temporal water chemistry controls on where each of the three species of turtles are primarily located. Analyses continue to support, though do not definitively conclude, that elevated chloride ion concentrations from road salt pose a serious threat to aquatic food web dynamics. Sample of lake water collected this winter show some low levels of aquatic toxicity (baseline, acute using Delta Tox II Analyzer). To evaluate our hypothesis that the source of the toxicity in the lake samples was chloride ion, we conducted a laboratory study using controlled waters containing only chloride and saw equivalent results. This summer, new students will be trained to collect water quality samples at the lake properly and safely as well as to analyze these waters in the lab for chemistry and toxicity.

Project Status as of October 1, 2018: During the summer 2018, our main research goals were 1) collect water-quality data to determining depth profiles of chloride, pH, dissolved oxygen, temperature, oxidation/reduction potential, and specific conductance in waters in the deepest portion of the south lobe of Medicine Lake (Zone 2), and 2) collect water-quality data (same parameters as listed in goal 1) across the lake to evaluate temporal variations in zones where greater spatial data was collected in the past. Within these goals, particular attention was given to chloride concentrations, as water run-off in winter and spring brings dissolved road salt into the lake. Because chloride ions are "conservative" (i.e., they stay dissolved in the water and are not precipitated out or otherwise removed under these water conditions) they easily build up year after year and chloride can reach toxic concentrations in the lake. This has potential to effect food web dynamics. We hope to use these data to compare to observations of the turtles in lake and their life travel patterns. In addition to these two main goals, we tested water quality during two of the 24 hour "all-day-follows" conducted by the Three Rivers Park District (see activity 1) to determine if water quality at turtle resting sites was playing any role in turtle population dynamics. Our depth profile shows that the lake has a definitive chemocline and thermocline, which begins at approximately 6 meters below the surface and often contained high chloride concentration and specific conductance for a Minnesota lake. Water samples were also take back to the lab to be analyzed by means of spectrophotometry to validate field techniques.

Project Status as of April 1, 2019: Winter season 2018-2019, has been devoted to carefully evaluating (spatially and temporally) various aspects of the water chemistry data to quantify variability in each parameter, determine degree and timing of lake mixing, and prioritize chemicals that may be the largest threat to aquatic food web dynamics and ultimately turtle population dynamics. We also statistically evaluated the 24 hour "all day follows" data to see if, on a daily timescale, the turtles would avoid/prefer water with some unique chemical characteristics. We found no significant relationships at that timescale. However, it is possible that the water quality threats that exist for turtle populations have the most impact during certain critical stages of life cycle. Our preliminary chemistry analysis suggests these water quality parameters are chloride concentrations (which appear to be increasing rapidly in some portions of the lake (deep pockets) due to road salt activities and are approaching levels seen as toxic in other toxicology studies) and metals in the water. Early on in the project, our team analyzed lake sediments for metal composition, but lacked the ability to look at water samples with our budget. Dr. McGuire's lab has recently obtained a water chemistry analyzer that makes use of voltammetry to provide low per-sample costs; we are currently developing this and hope to put to use in late spring/early summer to begin to address some of these questions. It is our hope to obtain one more round of water and toxicity samples just after snow melt to be able to evaluate the sources of this toxicity as well and improve management suggestions. These data will be included in our final report.

Final Report Summary: All water chemistry, sediment chemistry and aquatic toxicity data have been graphed, mapped and analyzed spatially. These data were then summarized into management recommendations for Medicine Lake. We included sufficient support to allow managers of other, similar, lake systems to consider if these recommendations would be appropriate in their systems as well.

ACTIVITY 3: Habitat, water chemistry effects, management guidelines
Description:

ArcGIS analysis of turtle habitat use in relation to physical and water quality variables. Development of urban lake turtle guidelines that will maintain healthy turtle populations for use by land and water management agencies.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 25,000
Amount Spent: $ 25,000
Balance: $ 0

Outcome	Completion Date
1. GIS Developed maps for physical and water quality parameters	December 30, 2018
2. Lake guidelines for turtle management in Urban habitats	June 30, 2019

Activity Status as of October 1, 2015: Work on this activity has not yet begun.

Activity Status as of April 1, 2016: Work on this activity has not yet begun.

Activity Status as of October 1, 2016: We initiated construction of the geodatabase for turtle and water sample locations. We entered summer data and used ArcGIS for initial analysis and to work on output designs. We also sent one Three Rivers intern to a one-day training session on the new radio telemetry receiver, which incorporates real-time GPS locations with telemetry data acquisition.

Activity Status as of April 1, 2017: We have refined construction of the geodatabase for turtle and water sample locations. We also sent two University of St. Thomas researchers to training for R to further analyze our data, funded by the University of St. Thomas.

Activity Status as of October 1, 2017:
Using ArcGIS, we have created a geospatial database to allow us to spatially evaluate turtle location data as well as water chemistry and aquatic toxicity data. These preliminary maps will be use to refine our sampling strategy for 2018 and identify areas of greatest potential concern. These maps were included in the 2 data dissemination activities listed below.

Activity Status as of April 1, 2018:

Analysis of turtle locations and home range calculations are being made and disseminated (see below).

Project Status as of October 1, 2018: ArcGIS map development of both aquatic and terrestrial parameters as it pertains to turtle habitat use as well as lake guidelines for turtle management in urban lakes has been underway and is nearing completion. This information will be included in the final report.

Project Status as of April 1, 2019: Various statistical and plotting analyses have been added to our ArcGIS map development of both aquatic and terrestrial parameters as it pertains to turtle habitat use as well as lake guidelines for turtle management in urban lakes. This information will be included in the final report.

Final Report Summary: All turtle population dynamics, water chemistry, sediment chemistry and aquatic toxicity data have been graphed, mapped and analyzed spatially. These data were then summarized into management recommendations for Medicine Lake. We included sufficient support to allow managers of other, similar, lake systems to consider if these recommendations would be appropriate in their systems as well.

V. DISSEMINATION:

Description:

The results of this study will be used to develop shoreline restorations and habitat management plans for urbanizing lakes in Minnesota. The water sampling results will be used to propose new pollution guidelines for contaminants as they relate to turtles in urban lake environments. The findings will be disseminated to the MNDNR, MN PCA, watershed agencies and other organizations interested in urban lake management. Further, we will present the findings of our work at regional, national, and international scientific conferences as appropriate opportunities allow. This will benefit the scientific community as we explore the relationship between turtle population dynamics and environmental factors such as shoreline habitat, aquatic vegetation, and water chemistry, and it will benefit the project as we gain valuable insight from recognized experts in the field.

Status as of October 1, 2015: Dissemination of work has not yet begun.

Status as of April 1, 2016: Dissemination of project plan has been accomplished via letter mailed to Medicine Lake homeowners and flyers to the attention of interested parties (e.g., boaters).

Status as of October 1, 2016: Dissemination of project activities has been accomplished via letters and enhanced signage within the Medicine Lake community.

Status as of April 1, 2017: No further dissemination to the public occurred over this time window.

Status as of October 1, 2017:

The results of this work were included in abstracts submitted to two professional conferences (* denotes student author).

1) The Annual Meeting of the Geological Society of America in Seattle, WA in October 2017

   Zach Mader*, Carolyn Lussenhop*, Timothy L. Lewis, John J. Moriarty, and Jennifer T. McGuire (2017) Assessment of the Potential Impact of Water Quality on Turtle Habitat Selection in an Urban Lake in Plymouth, MN, USA. The Annual Meeting of the Geological Society of America in Seattle, WA in October 2017

2) The Midwest Fish and Wildlife conference in January 2018

Hunt, KirstenD.*, Schneider, Alaini C.*, Moriarty, John J., Lewis, Timothy L, McGuire, Jennifer T., and Swanson, Bradley J. (2018) "Home range and movements of spiny softshell turtles (Apalone spinifera), painted turtles (Chrysemys picta), and snapping turtles (Chelydra serpentine) in an urban Minnesota Lake. The Midwest Fish and Wildlife conference in January 2018

Status as of April 1, 2018:

Submitted to *Herpetological Review* as a Natural History note:

CHRYSEMYS PICTA (Painted Turtle). BASKING BEHAVIOR.

KIRSTEN D. HUNT (e-mail: kirsten.d.hunt@gmail.com) and BRADLEY J. SWANSON, Central Michigan University, Department of Biology, Mount Pleasant, Michigan 48859, USA; JOHN J. MORIARTY, Three Rivers Park District, Plymouth, Minnesota 56601, USA; TIMOTHY L. LEWIS and JENNIFER T. MCGUIRE, University of St. Thomas, St. Paul, MN 55105, USA.

Submitted and accepted abstract:
Hunt, KirstenD.*, Schneider, Alaini C.*, Moriarty, John J., Lewis, Timothy L, McGuire, Jennifer T., and Swanson, Bradley J. (2018) "Factors influencing home range and movements of spiny softshell turtles (Apalone spinifera), painted turtles (Chrysemys picta), and snapping turtles (Chelydra serpentine) in an urban lake. Wildlife Society conference, October 7-11, 2018 in Cleveland, OH

Project Status as of October 1, 2018: Genetic analysis was completed as part of a master's thesis at Central Michigan University, and a subsequent journal article from the genetic analysis has been submitted for review in the Journal of Urban Ecology. Home range analysis data was presented at the 2018 Midwest Fish and Wildlife Conference in Milwaukee, WI.

Project Status as of April 1, 2019: Results of the water chemistry work is being prepared and will be included in abstracts at professional meetings in Fall 2019, the venues of which are still being determined.

Final Report Summary:

A final summary management plan (*see attached full version*) was completed and provided to the Three River's Park district office for consideration of future activities. It provides four clear recommendations (*see page 18 of 26 for summary*) based on all of the data collected.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 136,825	**University of Saint Thomas Personnel**: Note: Drs. McGuire and Lewis are on normal academic 9 month (Sept.-May) salaried contracts and request 1 month of summer salary each to complete this work. Personnel Costs based on current wages and assumed increases: *Jennifer McGuire*, Principal Investigator (PI), 1 month summer salary (8.33% FTE) per year (totaling $28,374 for 3 yrs) plus 7.65% fringe ($ 2170.61) for 3 years). *Tim Lewis*, Principal Investigator (PI), 1 month summer salary (8.33% FTE) per year (totaling $34,936 for 3 yrs) plus 7.65% fringe ($ 2672.60) for 3 years). *Undergraduate*

		Research Assistants (individuals to be determined), Assist with field sampling and lab analyses. Two students during the academic year for a total of 1,700 hrs @ $10/hr, totaling $17,000 for three years, no fringe (0%). 4 students during each summer, 40 hrs/week for 10 weeks @ $10/hour totaling $48,000 plus 7.65% fringe ($3,672) for 3 years.
Professional/Technical/Service Contracts:	$41,000	$13,000 for DNA analyses (DNA primer sequence $4000each * 3 species) plus 75 turtles *$14 per turtle analysis); $28,000 for internships at Three Rivers Park District
Equipment/Tools/Supplies:	$68,975	Nets and trapping supplies ($4675), telemetry equipment including radios and receivers ($25,300), Field supplies for water sampling ($18,500), Laboratory supplies for water analyses ($19,000), general field supplies including gasoline, repair kits ($1500)
Travel Expenses in MN:	$3200	Mileage to travel to Medicine Lake for PIs and Students from UST St. Paul Campus (19 miles one way). Note, this will provide support for 168 vehicle trips or roughly 60 per year.
TOTAL ENRTF BUDGET:	**$250,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 4.44 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 1.43 FTE (Three Rivers Park District Internships)

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Three Rivers Park District	$42,000	$42000	In-kind salary support for Madeleine Linck and John Moriarity
Three Rivers Park District	$3000	$3000	In-kind storage space, boats and miscellaneous supplies
University of St. Thomas	$20,000	$20000	In-kind support including field and lab equipment, boats and miscellaneous supplies
State			
	$0	$	
TOTAL OTHER FUNDS:	**$65,000**	**$0**	

VII. PROJECT STRATEGY:

A. Project Partners:

University of St.Thomas, ENRTF funds $222,000

Jennifer McGuire, Ph.D, . Role: Water Sampling and analysis,
Tim Lewis, Ph.D., Role: Genetic anaylsis, GIS analysis of Turtle habitat use, Telemetry
Three Rivers Park District, ENRTF funds $28,000
John Moriarty, M.S. Role: Turtle telemetry and nesting.
Madeleine Linck, M.S. Role: Turtle Nesting

B. Project Impact and Long-term Strategy:

Management Implications
The results of this study will be used to develop shoreline restorations and habitat management plans for urbanizing lakes in Minnesota. The water sampling results will be used to propose new pollution guidelines for contaminants as they relate to turtles. The findings will be disseminated to the MNDNR, MN PCA, watershed agencies and other organizations interested in urban lake management.

C. Funding History: N/A

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:
N/A

IX. VISUAL COMPONENT or MAP(S):
Maps obtained from Minnesota Pollution Control Agency TMDL project web page:
http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/upper-mississippi-river-basin-tmdl/project-medicine-lake-excessive-nutrients.html

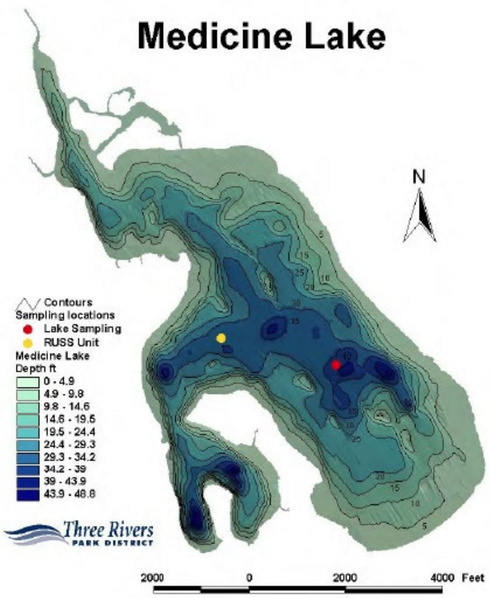


Figure 1-2. Medicine Lake Bathymetry.

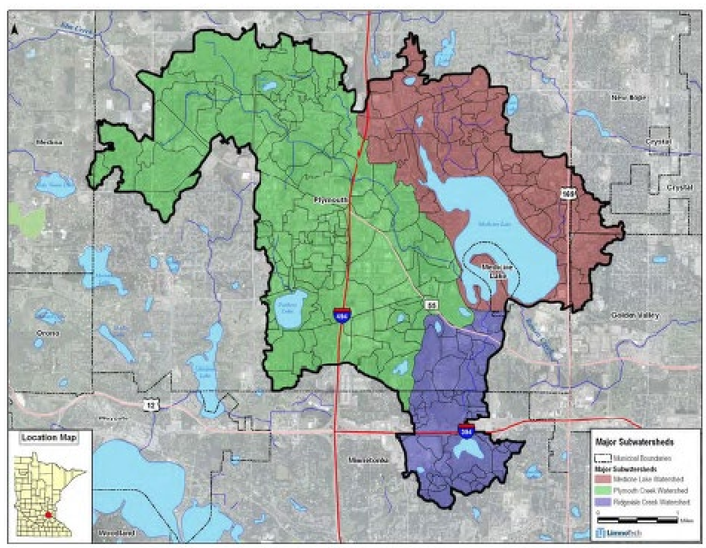
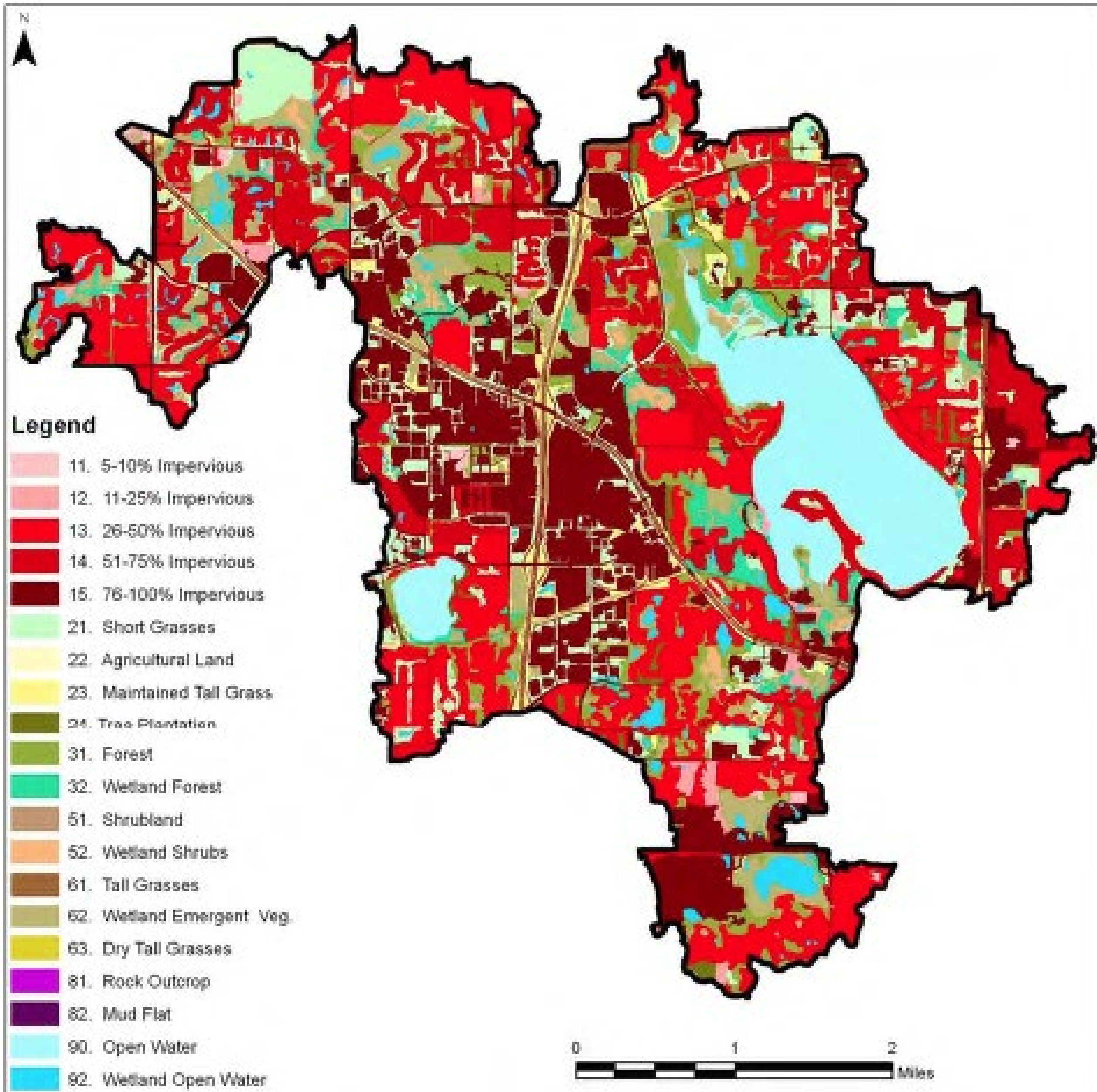


Figure 1-3. Medicine Lake Subwatersheds.



	City Land Cover (acres)							City Land Cover percentage						
Land Cover Type	Golden Valley	Medicine Lake	Medina	Minnetonka	New Hope	Plymouth	Grand Total	Golden Valley	Medicine Lake	Medina	Minnetonka	New Hope	Plymouth	Grand Total
5-10% Impervious	0.5	0.0	0.0	7.9	2.4	33.5	44.3	0.22%	0.00%	0.00%	0.88%	1.40%	0.33%	0.38%
11-25% Impervious	0.1	0.0	0.4	39.4	0.0	67.4	107.3	0.05%	0.00%	3.75%	4.37%	0.00%	0.67%	0.92%
26-50% Impervious	53.1	12.2	0.0	331.9	0.0	2,319.0	2,716.1	24.39%	5.31%	0.00%	36.81%	0.00%	22.97%	23.38%
51-75% Impervious	67.2	48.6	0.0	1.7	131.3	1,209.5	1,458.4	30.89%	21.20%	0.00%	0.19%	69.24%	11.98%	12.38%
76-100% Impervious	56.5	0.5	0.0	258.4	42.2	2,122.8	2,480.4	25.96%	0.24%	0.00%	28.66%	26.28%	21.03%	21.35%
Short Grasses	16.2	17.1	0.6	2.1	3.5	1,001.6	1,041.2	7.46%	7.46%	5.00%	0.23%	2.18%	9.92%	8.96%
Agricultural Land	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.00%	0.00%	0.62%	0.00%	0.00%	0.00%	0.00%
Maintained Tall Grass	4.4	0.0	0.0	2.3	1.4	342.1	350.1	2.02%	0.00%	0.00%	0.26%	0.84%	3.39%	3.01%
Tree Plantation	0.0	0.0	3.0	11.2	0.0	141.6	155.9	0.00%	0.00%	25.30%	1.24%	0.00%	1.40%	1.34%
Forest	8.8	0.0	4.9	75.4	0.0	644.1	733.2	4.06%	0.00%	41.05%	8.36%	0.00%	6.38%	6.31%
Wetland Forest	2.2	10.9	0.0	3.2	0.0	301.9	318.2	0.99%	4.76%	0.00%	0.36%	0.00%	2.99%	2.74%
Shrubland	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
Wetland Shrubs	0.0	0.0	0.0	0.0	0.0	57.1	57.1	0.00%	0.00%	0.00%	0.00%	0.00%	0.57%	0.49%
Tall Grasses	1.4	0.0	0.0	0.0	0.0	11.4	12.8	0.62%	0.00%	0.00%	0.00%	0.00%	0.11%	0.11%
Wetland Emergent Veg.	4.6	8.7	2.3	106.9	0.0	743.0	865.4	2.11%	3.81%	18.99%	11.86%	0.00%	7.36%	7.45%
Dry Tall Grasses	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Open Water	0.0	131.2	0.0	0.0	0.0	915.2	1,046.5	0.00%	57.22%	0.00%	0.00%	0.00%	9.07%	9.01%
Wetland Open Water	2.0	0.0	0.6	61.2	0.0	184.1	248.0	0.94%	0.00%	5.35%	6.79%	0.00%	1.82%	2.13%
Grand Total	217.6	229.3	12.0	901.6	180.7	10,095.1	11,616.3							

Figure 1-4. Medicine Lake Watershed Land Cover.

X. RESEARCH ADDENDUM: N/A

XI. REPORTING REQUIREMENTS:

Our project includes three full seasons of field work to be completed within 4 fiscal years beginning July 2015 and ending June 30, 2019. Periodic work plan status update reports will be submitted no later than October 1, 2015, April 1, 2016, October 1, 2016, April 1, 2017, October 1, 2017, April 1, 2018, October 1, 2018, and April 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

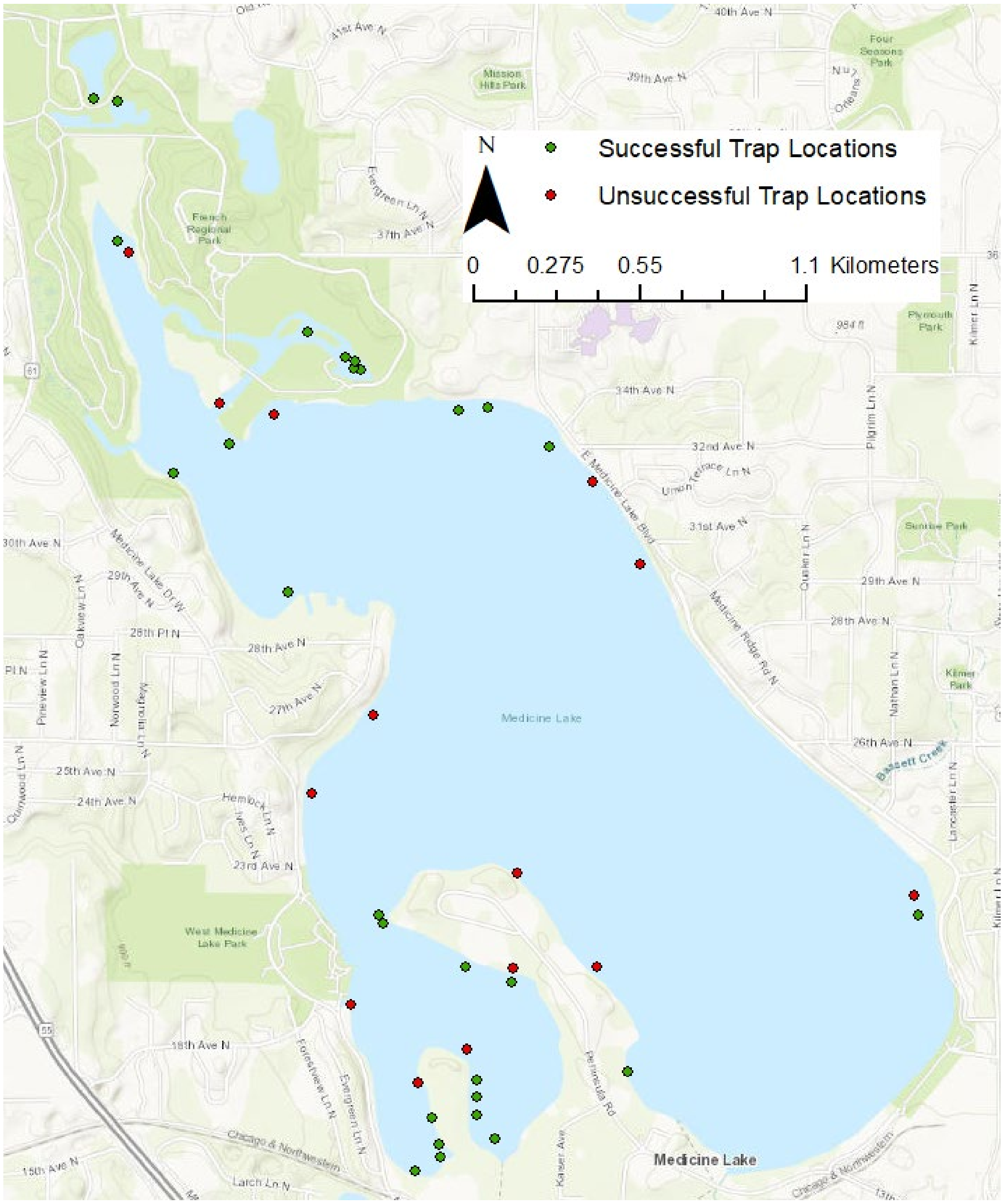
Environment and Natural Resources Trust Fund
M.L. 2015 Project Budget

Project Title: *Aquatic and Terrestrial Reptile Habitat*
Legal Citation: *M.L. 2015, Chp. 76, Sec. 2, Subd. 03m*
Project Manager: *Jennifer T. McGuire*
Organization: *University of St. Thomas*
M.L. 2015 ENRTF Appropriation: $ *250,000*
Project Length and Completion Date: *4 Years, June 30, 2019*
Date of Report: April 1, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	*Turtle Trapping and telemetry*			*Water Sampling and mapping*			*Habitat, water chemistry effects, management*				
Personnel (Wages and Benefits) University of Saint Thomas Personnel: Note: Drs. McGuire and Lewis are on normal academic 9 month (Sept.-May) salaried contracts and request 1 month of summer salary each to complete this work. Personnel Costs based on current wages and assumed increases	$58,500	$58,500	$0	$59,045	$59,045	$0	$19,280	$19,280	$0	$136,825	$0
Professional/Technical/Service Contracts											
DNA Analysis: DNA primer sequence $4000each * 3 species) plus 75 turtles *$14 per turtle analysis	$13,000	$10,085	$2,915							$13,000	$2,915
Internships at Three Rivers Park District: 2 summer interns separate from the UST team to facilitate activities 1 & 3. 2 summer interns for 10 weeks, 40 hours per week at a rate of	$22,280	$22,280	$0				$5,720	$5,720	$0	$28,000	$0
Equipment/Tools/Supplies											
nets and trapping supplies	$4,675	$4,675	$0							$4,675	$0
telemetry equipment (receivers, radios)	$25,300	$25,201	$99							$25,300	$99
Field supplies for Water sampling for sonde measurements plus ~300 unique spatial/temporal samples per year for 3 years. Estimated costs of $10, 650 in Year 1 (estimated				$18,500	$16,618	$1,882				$18,500	$1,882
Laboratory Supplies for Water Analyses: In years 1&2 estimated costs of $6500 (estimated 2 aqueous sample				$19,000	$13,482	$5,518				$19,000	$5,518
misc supplies such as gasoline, repair kits, and field supplies	$750	$610	$140	$750	$64	$686				$1,500	$826
Travel expenses in Minnesota											
Mileage to travel to Medicine Lake for PIs and Students from UST St. Paul Campus (19 miles one way). Note, this will provide support for 168 vehicle trips or roughly 60 per year.	$3,200	$734	$2,466							$3,200	$2,466
COLUMN TOTAL	**$127,705**	**$122,085**	**$5,620**	**$97,295**	**$89,209**	**$8,086**	**$25,000**	**$25,000**	**$0**	**$250,000**	**$13,706**

Visual Illustrations to post:

Zone Separation in Medicine Lake, Plymouth, MN. The study of water quality and turtle population dynamics conducted by the University of St. Thomas and the Three Rivers park districts separated the lake into 8 distinct zones to aid in data collection. All zones are outlined in white with Zones 1, 2 and 6 making up the deepest portions of the lake, reaching depths of 12 meters. Zones 3, 5, and 7 are shallower, grassy regions of the lake with a maximum depth of around 4 meters (Zone 3). Zones 4 and 8 are thick, marshy areas of the lake reaching around 1-2 meters in depth. Inlets and outlets for the lake are marked with a blue outline. Additionally, the two major highways in close proximity to Medicine lake are marked in red.



Medicine Lake Trap Location Success

Project Goals

The overall goal of this project was to analyze the aquatic and terrestrial habitat parameters that affect the use of urban lakes by a three species turtle community, measure genetic and demographic population parameters, and make specific management and conservation recommendations to protect and enhance their populations.

Background

I. Distribution and Population Status

Painted Turtles (*Chrysemys picta*), Snapping Turtles (*Chelydra serpentina*), and Spiny Softshell Turtles (*Apalone spinifera*) are three of the most widespread native turtle species in North America (Ernst and Lovich 2009). The Painted Turtle range spans all of southern Canada and continues south through the Pacific Northwest and the Midwest to Georgia, with scattered populations in New Mexico, Arizona, Texas, Colorado, and Utah (Ernst and Lovich 2009). Snapping Turtles occur from Nova Scotia, south through Florida, and west throughout the US and southern Canada to just east of the Rocky Mountains, with scattered populations throughout much of Central America (Steyermark et al. 2008). The Spiny Softshell Turtle ranges west to Wyoming and Colorado, north to Minnesota, east to North Carolina, and south to northeastern Mexico, with scattered populations throughout much of the US (Ernst and Lovich 2009). Painted, Snapping, and Spiny Softshell Turtles are widely distributed and abundant across Minnesota (Moriarty and Hall 2014) and North America and occur in both urban and rural environments (Ernst and Lovich 2009). Range-wide population trends are stable for all three species (van Dijk 2011a; van Dijk 2011b; van Dijk 2012).

II. Life History and Ecology

Northern populations of Painted Turtles are active from March–October and long-distance overland movements have been documented between bodies of water (MacCulloch and Secoy 1983). Painted Turtles may also make short winter movements for oxygen availability purposes (Hunt et al. unpublished data). Home-range size for Painted Turtles has been documented at 2.4-ha but home-range has not been sufficiently studied (Ernst 1969). Painted Turtles are not aggressive towards other turtle species, however, aggression between Painted Turtles at basking sites has been observed (Bury et al. 1979; Lovich 1988). Males will usually travel longer distances than females, oftentimes in search of mates (Tuberville et al. 1996). Painted Turtles are omnivores and regularly feed on plants and insects (Lagler 1943; Moriarty and Hall 2014). Painted Turtles obtain food by foraging along the bottom of the water and among aquatic plants, surface-skimming for floating vegetation, or by seeking out their prey (Ernst and Lovich

2009). Digestion rates are positively correlated with body temperature leading Painted Turtles to seek out basking habitats after feeding (Gianopulos and Rowe 1999). Painted Turtles will bask on any structure rising above the water, including logs, rocks, sand bars, small islands, muskrat lodges, or banks of their water body (Ernst and Lovich 2009).

Female Painted Turtles are typically larger than males (Rowe 1997; Janzen and Morjan 2002; Moriarty and Hall 2014). Females can reach a maximum carapace length (CL) of 25.4 cm and males can reach a CL of 15.3 cm (Ernst and Lovich 2009). Females mature later than males (6-10 years and 2-6 years respectively), but sexual maturity still occurs within the first 10 years of life and appears to be more dependent on body size than age for both males and females (Mitchell 1988; Shine and Iverson 1995). Painted Turtles exhibit temperature sex determination (TSD), specifically TSD-1a, with cooler incubation temperatures resulting in males and warmer temperatures resulting in females (Ewert and Nelson 1991). Clutch sizes are relatively small (range: 4-23 eggs, mean: 11.9 eggs), however females increase their fecundity by laying 1-5 clutches per season (Christiansen and Moll 1973, Snow 1980, Tinkle et al. 1981, Tucker 1978). Juvenile survivorship is low (0.46: Mitchell 1988), however this increases dramatically after maturity resulting in a high adult female survivorship (0.89) which is comparable to most other turtle species (Shine and Iverson 1995). Average lifespan is approximately 44 years in the wild (Congdon et al. 2003; Siess 2005).

Snapping Turtles are active from April–October with that activity often including lying in the mud in shallow water waiting for prey and periodically surfacing for air (Ernst and Lovich 2009). Female Snapping Turtles are mostly inactive and stationary during May but activity increases during the nesting period in late May and early June (Brown and Brooks 1994). Snapping Turtles are primarily aquatic but will make long overland movements periodically for nesting and to search for mates (Obbard and Brooks 1980). Documented home-ranges do not differ between males and females and range from 1.8–3.4 ha (Ernst 1968; Obbard and Brooks 1981), however urban home-ranges and interactions with other turtle species are understudied. Spacing is maintained by aggression among individual Snapping Turtles but they are not truly territorial (Galbraith et al. 1987). Snapping Turtles are generalist omnivores and thereby consume a wide variety of prey; fish, carrion, insects, and plants dominate their diets with juveniles actively foraging for food and adults lying in ambush to seize prey (Lagler 1943; Schneider 1998; Ernst and Lovich 2009). Brown and Brooks (1991) found that Snapping Turtles often buried themselves in the substrate in shallow water and became less active after feeding as an alternative to basking to increase body temperature for digestion.

Male Snapping Turtles grow larger than females with males reaching a CL of 49.4 cm and females reaching a CL of 36.6 cm (Gibbons and Lovich 1990). Females display delayed sexual maturity, laying their first clutch at carapace lengths of 23–26 cm (12–20 years old), whereas males reach sexual maturity at carapace lengths of 18–20 cm (4–6 years; Shine and Iverson 1995; Aresco et al. 2006). Snapping Turtles exhibit a TSD-2 pattern, with females produced when incubated at low temperatures, males at mid-range temperatures, and females at the highest temperatures (Ewert and Nelson 1991; Ewert et al. 1994). Clutch sizes average 35.2 eggs per nest and some research shows that clutch sizes are larger further north (Iverson et al. 1993). Therefore, Snapping Turtles have high fecundity even though they do not double clutch (Congdon et al. 1994). Juvenile survivorship is relatively high (0.77) and increases with maturity resulting in one of the highest reported adult female survivorship estimates (0.97; Shine and Iverson 1995). The average lifespan for Snapping Turtles is 37 years in the wild (Ernst and Lovich 2009) although this is largely understudied and many researchers believe that they live for much longer.

Spiny Softshell Turtles are active from April–October and may initiate activity as early as March in southern populations or as late as May in northern populations (Ernst and Lovich 2009). Current research shows that most activity takes place during daylight hours (Smith and Iverson 2004); although, some nocturnal activity has been inferred (Wade and Gifford 1965). Home-range has not been widely studied, and estimates vary dramatically based on location and type of water body; Plummer et al. (1997) found home-ranges as low as 0.70 ha in a southern US stream habitat, while Galois et al. (2002) obtained estimates upwards of 3206 ha in a northern lake. Spiny Softshell Turtles will crawl or swim along the bottom of the water thrusting their snouts under stones and into masses of aquatic vegetation and will sometimes actively pursue prey or take prey in ambush (Lagler 1943; Moriarty and Hall 2014). Spiny Softshell Turtles are carnivores and largely consume crayfish and insects as prey sources (Ernst and Lovich 2009; Lagler 1943). Although Spiny Softshell Turtles do frequently bask in spring and early summer (Ernst and Lovich 2009; Moriarty and Hall 2014; Smith et al. 1981), the role of basking in relation to digestive rates for Softshell Turtles, as opposed to hard-shelled turtles, is not well understood. Habitat use of Spiny Softshell Turtles is well known for riverine systems, but little is known about their behavior in lake systems (Moriarty and Hall 2014).

There is a significant size difference between female and male Spiny Softshell Turtles with females reaching a CPL of 54.0 cm and males reaching a CPL of 21.6 cm (Ernst and Lovich 2009). Females reach sexual maturity at a carapace length of 18–20 cm, while males reach sexual maturity at carapace lengths of 9–10 cm (Barko and Briggler 2006). Although age at maturity is unknown, using the same extrapolations from carapace length as Breckenridge (1955), males likely mature between 2–3 years and females between 4–5 years. Average clutch size is 17.9 eggs, and *A. spinifera* lay up to 3 clutches each season (Ernst and Lovich 2009; Personal Observations 2016). Unlike most turtles, Spiny Softshells exhibit genetic sex determination (GSD; Ewert and Nelson 1991). Juvenile survivorship is estimated at 0.72, and adult female survivorship is estimated at 0.84 (Plummer et al. 2008). Average lifespan of *A. spinifera* is unknown. One individual was known to have lived 25 years in captivity (Snider and Bowler 1992).

III. Habitat Requirements

Painted and Snapping Turtles can be found in almost any freshwater habitat but prefer slow-moving, shallow bodies of water with abundant vegetation, and are less commonly found along the edges of deep lakes and rivers (Ernst and Lovich 2009). Both species remain in shallow water as juveniles before venturing out into deeper areas as adults (Congdon et al. 1992). Snapping Turtles prefer water with minimal turbidity (Bodie et al. 2000). Spiny Softshell Turtles are primarily a riverine species (Bodie et al. 2000; Vandewalle and Christiansen 1996) but can also inhabit large lakes, small creeks, ecotonal areas, marshes, ponds, impoundments, bayous, and roadside and irrigation ditches (Galois et al. 2002; Plummer et al. 1997). Areas with a soft sand or mud bottom, aquatic vegetation, and downed woody debris are the preferred habitat for the three species, and emergent basking structures are required (Ernst and Lovich 2009; Moriarty and Hall 2014).

Painted and Snapping Turtles are generalists for nesting. Painted Turtle hatchlings incubated in moist substrates have higher levels of success and hatch with higher body mass than dry substrate (Tucker and Paukstis 2000). Similarly, Snapping Turtle hatchlings from nests with higher moisture content have a distinct advantage in survival, locomotion, and growth (Finkler 1999; 2006; Miller 1993). Spiny Softshells prefer sandy soil near the safety of a waterbody for nesting, resulting in many nests often being laid in a concentrated area, which can increase predation. Moisture content of the substrate does not have a significant effect on metabolism, growth, or hatchling success (Packard et al. 1979, 1981), although nests too close to the water are prone to flooding and are usually unsuccessful.

IV. Conservation Importance

Turtles are among the most threatened organisms in the world (Buhlmann et al., 2009), with approximately 61% of the 356 modern species of turtles and tortoises listed as threatened, endangered, or already extinct (Lovich et al. 2018). Turtles are an ancient taxonomic group whose evolutionary successes allowed them to survive the catastrophic event that drove most dinosaurs to extinction, but humans of the modern world threaten to wipe out these unique vertebrates. Long-lived organisms, such as turtles, have evolved with life history traits that limit their ability to respond to a changing environment, particularly increased mortality of any age class (Dunham et al. 1989; Congdon et al 1993). Due to the long life-span of turtles and the delayed sexual maturity of certain species, recovery from a mortality event could span multiple decades, if such a recovery were even possible. Turtle populations are threatened by many factors including predation, climate change, illegal collection, overharvest, road mortality, habitat loss/fragmentation, and pollution.

Turtles are some of the largest contributors to the overall biomass of the ecosystems they inhabit, with biomass estimates being comparable to or greater than large schools of fish (Lovich et al. 2018). Their large contributions to biomass and secondary productivity has a disproportionately large impact on ecosystem processes (Lovich et al. 2018). Thus, turtles are strongly interconnected with the overall health and functionality of ecosystems through resource subsidies, top-down food web effects, mineral cycling, bioturbation, and seed dispersal and enhancement of germination (Lovich et al. 2018). Their unique ecology includes substantial and important activities both on land and in the water, and therefore, they contribute substantially to both aquatic and terrestrial systems. In fact, predated and unsuccessful nests are a major mechanism of redistributing energy and nutrients between aquatic and terrestrial habitats (Moss 2017, Lovich et al. 2018). Turtle presence has been linked to a significant increase in invertebrate abundance and density (Lindsay et al. 2013), and the presence of turtles as an apex predator in aquatic ecosystems has been linked to dramatic and long-term effects on the community structure and function (Wilbur 1997, Garig 2017).

Despite documented freshwater turtle declines, some species such as Painted Turtles, Snapping Turtles, and Spiny Softshell Turtles can maintain robust population sizes even in compromised landscapes, such as urban areas. However, the persistence of adult turtles does not guarantee that recruitment is taking place, and thus it is especially important to study urban populations of turtles to rule out the possibility that the long lifespan of adults is masking a lack of recruitment of juveniles. Common species, such as those mentioned above, can be important indicators of environmental change and also provide opportunities for research and the development of conservation plans that can be used as a proxy for other species of conservation concern (McGeoch 1998; Duelli and Obrist 2003). Additionally, common species can become rare quickly if management and conservation efforts become complacent. Many species of conservation concern today were once common species, highlighting the importance of studying all species, regardless of their current conservation status (Lindenmayer et al. 2011).

V. Threats in Medicine Lake

Medicine Lake is an urban 364-ha eutrophic lake surrounded by over 300 residential properties that extend to the shoreline. Populations of Painted Turtles, Snapping Turtles, and Spiny Softshell Turtles coexist in Medicine Lake, making it an ideal site to investigate how these species interact in an urban environment. Urbanization further exposes turtles to known threats such as isolation, habitat loss and fragmentation, human disturbance, increased pollution, disease, and the introduction of dangers such as roads, anthropogenically-subsidized predators, and household pets (Budischak et al. 2006).

Medicine Lake is surrounded by roads, some of which are within meters of the shoreline, and aquatic connectivity with other lakes and rivers is largely lacking, potentially isolating the resident turtles. Urban turtle populations are vulnerable to the negative effects of isolation because of specific habitat requirements, obligate dispersal between aquatic and terrestrial habitat for nesting, and increased road-induced mortality (Ernst and Lovich 2009; Patrick and Gibbs 2010). Evaluating and maintaining genetic diversity within wild populations is important because genetic variation is essential for a population to be able to respond to a changing environment and avoid inbreeding (Mockford et al. 2007). Habitat fragmentation reduces gene flow between populations, which then leads to isolation of populations, followed by inbreeding, increased genetic drift, and a subsequent loss of genetic diversity (Reed et al. 2002, Reed et al. 2004). Reduction of gene flow also causes an increase in genetic differentiation between subpopulations and an increased probability of local extinction (Lande 1988, Segelbacher et al.

2010). Inbreeding decreases reproductive fitness and in urban areas the effects of isolation and inbreeding are heightened due to stress (Rubin et al. 2001, Reed et al. 2002).

Much of Medicine Lake's shoreline habitat has been modified with retaining walls or rip-rap, rendering these stretches of shoreline unsuitable for turtles and greatly limiting both nesting and basking habitat. Nesting and successful recruitment of hatchlings into the population is essential for population persistence, and thermoregulation through basking is essential for survival of adult turtles, especially in northern populations. Basking and nesting opportunities are also limited by human disturbance in Medicine Lake, particularly for Softshells because of their extremely skittish nature. Softshells will abandon nesting and basking activities and return to the water when approached by humans. Levels of human recreation on the lake are high, and Smith et al. (2006) found increased mortality in a population of Painted Turtles likely attributed to an increase in shoreline development and subsequent increase in boat and watercraft usage. Garber and Burger (1995) documented the extirpation of a Wood Turtle population in Connecticut due to human recreation, and Ryan et al. (2013) observed negative impacts on turtle populations in response to human activity such as residential and commercial development. Turtles are susceptible to propeller strikes and being hooked by anglers, particularly Softshells due to their highly aquatic status. Overwintering turtles are susceptible to human disturbance, because they oftentimes hibernate in large groups and a catastrophic mortality event could wipe out many important individuals.

The lake is completely within the Mississippi River – Twin Cities watershed which is essentially fully developed. Development has greatly affected the water quality of Medicine Lake, and it was placed on the Minneapolis Pollution Control Agency's impaired waters list in 2004 due to the inability to meet various water quality goals. The close proximity of roads increases surface runoff into the lake. It is unknown exactly how contaminants in the water affect turtle species, but it is believed that Spiny Softshell Turtles are more susceptible than other turtle species because of high cutaneous permeability (Dunson 1960). Additionally, because turtles are long-lived, bioaccumulation of contaminants and toxins is a concern.

The nest stage is the most vulnerable life stage for all three turtle species. Urban areas are known for human-facilitated predators, such as coyotes and raccoons, both of which predate turtle nests frequently (Marchand and Litvaitis 2004). Egg survivorship to hatching is low for Snapping Turtles, with nest predation being as high as 100% in certain years (Congdon et al. 1987). Egg survivorship to hatching varies for Spiny Softshell Turtles, with reported nest predation being as high as 69.1% (De Solla et al. 2003). Juveniles of the three species are preyed upon by large fish, larger Snapping Turtles, snakes, gulls, crows, muskrats, raccoons, otters, foxes, and coyotes. Adult Painted Turtles are taken by birds of prey, otters, and raccoons, but the largest sources of mortality for adult Painted Turtles are human related. Similarly, once fully grown, the only species which poses a real predatory threat to Snapping Turtles and Spiny Softshell Turtles are humans.

Summary of Trapping

We trapped a total of 314 turtles in Medicine Lake over the course of the project: 192 Painted Turtles, 76 Snapping Turtles, and 46 Spiny Softshell Turtles. Of the 192 Painted Turtles, 78 were female, 110 were male, and 4 were not yet sexually mature; of the 76 Snapping Turtles, 44 were female, 29 were male, and 3 were not yet sexually mature; and of the 46 Spiny Softshell Turtles, 35 were female, 10 were male, and 1 was not yet sexually mature. We trapped in all areas of the lake in which we had homeowner cooperation, but only some areas were successful as seen in Fig. 1.

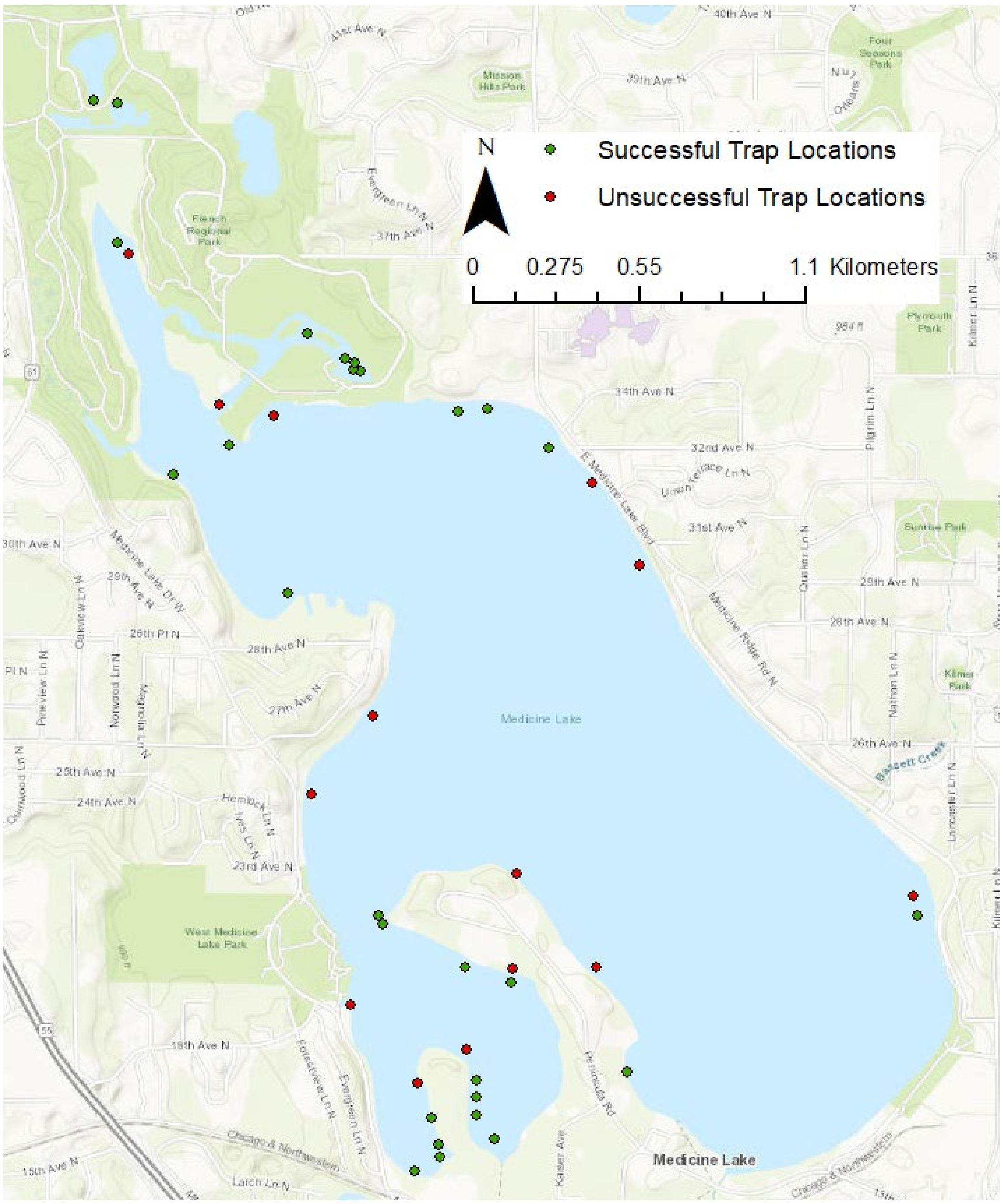


Figure 1: Medicine Lake Trap Location Success

Population Demographics

We approximated ages for every individual for all three species based on size and growth rate estimates developed by Frazer et al. (1991) for Painted Turtles, Galbraith et al. (1989) for Snapping Turtles, and Breckenridge (1955) for Spiny Softshell Turtles. When body sizes of the turtles in our study did not fall within the range of body sizes studied from the aforementioned publications, we had to extrapolate from the available data. We had no turtles with known ages, and growth rates can vary greatly even in a single population, thus the ages we determined are simply a best approximation from the data available. However, size and age distributions can be helpful tools for managing a population, and identifying key age classes that may be struggling. The netting for our hoop traps did not allow for trapping the smallest size classes of all three species, therefore we expected that our population sample would be biased towards larger/older turtles. However, environmental factors such as increased nest predation from human facilitated predators and a subsequent lack of recruitment would also

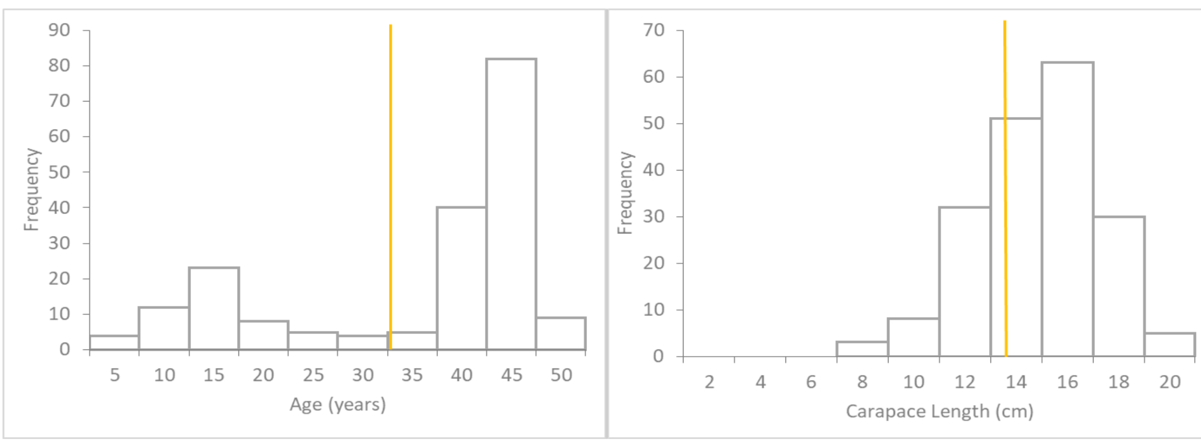


Figure 2: Painted Turtle age and size structure depicted in left and right panels respectively. Yellow vertical lines represents average values of 33.4 years and 13.8 cm.

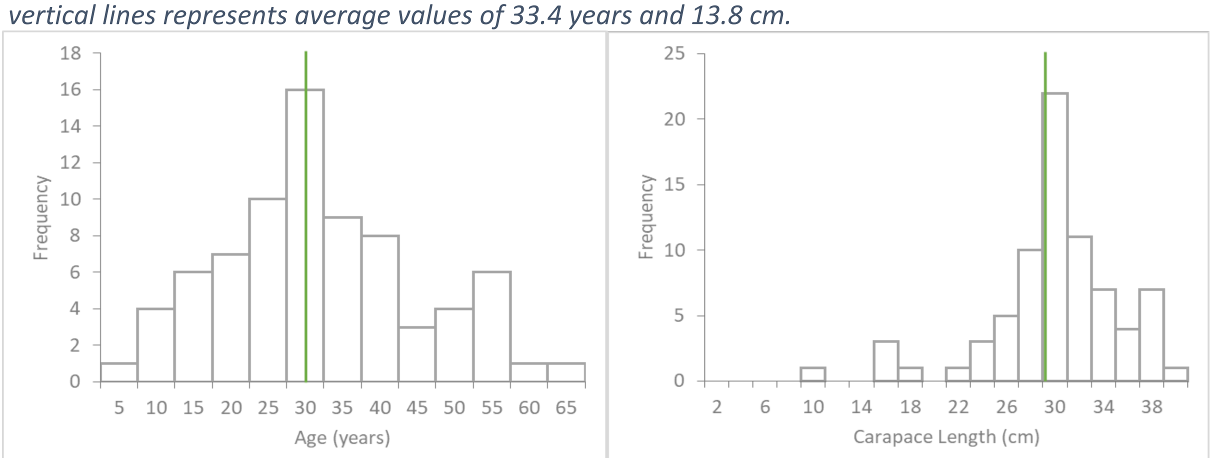


Figure 3: Snapping Turtle age and size structure depicted in left and right panels respectively. Green vertical lines represents average values of 30.1 years and 29.1 cm.

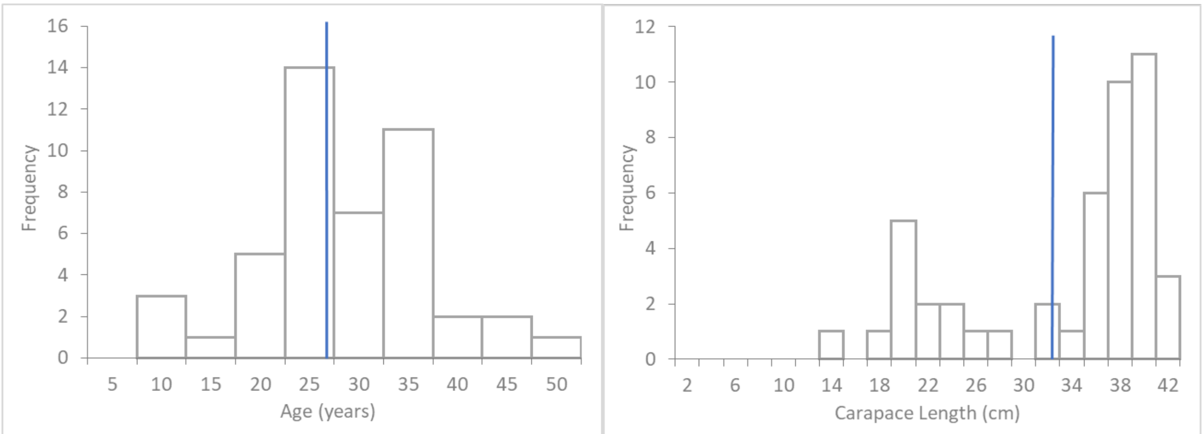


Figure 4: Spiny Softshell age and size structure depicted in left and right panels respectively. Blue vertical lines represents average values of 26.0 years and 32.4 cm.

produce an age range skewed towards larger/older turtles, and is a point of conservation concern for these populations that should not be overlooked.

Genetics

An understanding of the genetic variation and population structure present in a population is a valuable tool for accurately evaluating population trends and viability and for informing management decisions. We analyzed 10 microsatellite loci for Snapping Turtles, 11 microsatellite loci for Spiny Softshell Turtles, and 10 microsatellite loci for Painted Turtles in Medicine Lake. We found no population substructure for any species within Medicine Lake indicating that all three species exist as continuous populations in the lake. Within Medicine Lake the number of alleles, allelic richness, expected heterozygosity, and observed heterozygosity did not significantly differ between Snapping Turtles and Spiny Softshell Turtles. Number of alleles, allelic richness, expected heterozygosity, and observed heterozygosity were significantly higher for Painted Turtles than either of the other two species. This could be due to the smaller body size of Painted Turtles, which could allow for a higher population size within Medicine Lake and thus higher levels of genetic variation. All three species were less related than we would expect under random mating, however this is likely a product of sample size and not biologically meaningful. From confidence intervals associated with inbreeding statistics we found low but significant inbreeding for Snapping Turtles and Painted Turtles but inbreeding was not significant for Softshells. However, quantitatively we found no significant differences in inbreeding among the three species. Effective population size for Softshells was significantly lower than that of Snapping Turtles and Painted Turtles, which did not differ from each other, as shown by non-overlapping confidence intervals. Population sizes (derived from effective population size estimates) range from 406-2028 individuals for Snapping Turtles, 77-384 individuals for Softshells, and 1238-6190 individuals for Painted Turtles.

In order to test for genetic isolation of the turtle population residing in Medicine Lake, we expanded the spatial scope of our study by analyzing genetic samples from two other sites in

Minnesota: Fort Snelling in St. Paul and Weaver Dunes near Wabasha. Approximate distances between sites are as follows: Medicine Lake is 22 km Euclidean distance and 37 km flow distance from Fort Snelling; Fort Snelling is 124 km Euclidean distance and 152 km flow distance from Weaver Dunes; and Weaver Dunes is 145 km Euclidean distance and 187 km flow distance from Medicine Lake. Land-cover surrounding Medicine Lake was the most developed, followed by Fort Snelling, and land cover surrounding Weaver Dunes was the least developed.

Effective population size did not significantly differ among sites for Snapping Turtles or Painted Turtles, whereas effective population size was significantly lower at the Medicine Lake site for Spiny Softshells compared to the other sites. Genetic differentiation between populations was low for all three species. However differentiation was highest between the Softshell populations at Medicine Lake and Fort Snelling, which coincides with one of our most notable findings. We found that Spiny Softshell Turtles most likely exist as two populations in the region, and that Medicine Lake is isolated from the Mississippi River population. This is surprising as Fort Snelling and Weaver Dunes are over twice as far apart as Medicine Lake and Fort Snelling. The Softshell population within Medicine Lake could be isolated due to several non-mutually exclusive hypotheses: 1) impermeability of the urban landscape; 2) lack of aquatic connectivity in the landscape; and 3) long-term isolation due to the St. Anthony falls dam on the Mississippi River. Our habitat resistance analysis revealed that the isolation is likely due to a lack of aquatic connectivity in the landscape surrounding Medicine Lake, which is consistent with this species being highly aquatic (Ernst and Lovich 2009, Holman 2012, Moriarty and Hall 2014), and suggests that the final 2.5 km of Bassett Creek being underground is likely a barrier to Spiny Softshell dispersal.

The isolation of the Medicine Lake Spiny Softshell population is concerning because reduction of gene flow and subsequent increase in genetic differentiation between populations may result in an increased probability of local extinction (Lande 1988, Segelbacher et al. 2010). However, we found no evidence of reduced heterozygosity or heightened inbreeding or relatedness, although we did find significantly lower measures of allelic diversity and effective population size at Medicine Lake. A reduction in the number of alleles which is not reflected by a loss of heterozygosity is characteristic of a population bottleneck (Piry et al. 1999), and thus, the possibility of a recent population bottleneck in Medicine Lake cannot be overlooked. Urbanization has a differential impact on populations of Snapping Turtles, Painted Turtles, and Spiny Softshell Turtles, with populations of Snapping Turtles and Painted Turtles potentially being able to persist in urban habitats whereas populations of Spiny Softshells may become isolated, leading to a reduction in effective population size and a loss of genetic variation. However, given the long lifespan of turtles, any indication of an impact of urbanization is cause for concern, and the lack of evidence for Snapping Turtles and Painted Turtles simply necessitates continued monitoring of urban turtle populations. Additionally, the delay in genetic responses for these species provides managers and conservationists with an opportunity to intervene before the onset of negative effects (Marsack and Swanson 2009). Full analysis and information regarding genetic analysis is being submitted for publication (Schneider et al. unpublished data).

Spatial Analysis

We radio-tagged and tracked a total of 78 turtles between May 2016 and August 2018. We tracked 25 Painted Turtles (19 females and 6 males), 25 Snapping Turtles (18 females and 7 males), and 28 Spiny Softshell Turtles (23 females and 5 males). In summary, Spiny Softshell Turtles use the entire lake (undeveloped and developed) with core habitat areas focused around available nesting habitat. Painted Turtles and Snapping Turtles are positively associated with and use small, localized and undeveloped areas of the lake. Complete spatial analysis is being submitted for publication (Frahm et al. unpublished data).

I. Home Range

We calculated home range sizes in R using the adehabitatHR package. Both minimum convex polygons (MCPs) and kernel density estimates (KDEs) were calculated for each individual turtle. Individual home range sizes were only calculated for individuals with >20 relocations and consecutive MCP sizes reaching an asymptote. This resulted in 12 female and 4 male Painted Turtles for a total of 16 Painted Turtles included; 18 female and 6 male Snapping Turtles for a total of 24 Snapping Turtles included; and 16 female and 1 male Spiny Softshell Turtle for a total of 17 Spiny Softshell Turtles included. We only used one relocation per day in our home range estimates to avoid spatial autocorrelation and reduce bias. We used non-parametric tests for assessing differences in home range estimates among species because these estimates did not follow a normal distribution. Relocation/sampling effort was consistent across all three species. We found no difference in home range size between males and females for any of the three species. We found that Spiny Softshells have a significantly larger home range size than both Snapping Turtles and Painted Turtles. We found no significant difference in home range size between Snapping Turtles and Painted Turtles.

II. Habitat Use

To determine the shoreline habitat use of the Medicine Lake turtles, we used MNDNR 'Score Your Shore" data in conjunction with our turtle relocation data. We buffered the shoreline at 1, 5 and 10 meters to examine only turtle locations which fell into these buffers and then assigned turtle locations to the nearest shoreline land use type. We used a correspondence analysis in R to investigate the relationship between count data and land use type. Commercial development, single-family residential areas, and undeveloped non-wetland areas were the most important variables for turtle use of the shoreline. Painted Turtle and Snapping Turtle use was positively associated with undeveloped non-wetland areas and negatively associated with commercial areas and single-family residential areas. In contrast, Spiny Softshell Turtle use was positively associated with commercial areas and single family residential areas and negatively associated with undeveloped non-wetland areas.

III. Seasonal Movements

From preliminary observations, it appears that Spiny Softshell Turtles in Medicine Lake utilize backwater areas and basking structures (i.e. logs, mud-flats, cattail beds, rocks) in the early spring prior to nesting. They move out into the open water and utilize the larger portion of the lake after nesting occurs, expanding their home ranges. We mainly observed female Softshell Turtles basking during the pre-nesting season, and we believe that thermoregulation may be important for egg development. Male Snapping Turtles and Painted Turtles have increased terrestrial movement prior to nesting season due to searching for mates, while female terrestrial movement increases during nesting season to find suitable nesting sites. After the breeding and nesting seasons, Snapping Turtles and Painted Turtles return to their smaller home ranges.

Nesting

Staff of Three Rivers Park District observed female Spiny Softshells attempting to nest on the north swimming beach on Medicine Lake within French Regional Park in 2005. In 2009, sand was brought into the park to expand the sandy shoreline west of the French Regional Park swimming beach to attract turtles and create a nesting sanctuary. The Softshell Turtles learned to use the site quickly and Three Rivers staff installed a fence to keep people away so female turtles could come ashore with less intrusion from the public. Since 2009, volunteers have watched for nesting turtles so nests could be identified for protection with wire predator exclosures. The sanctuary is also monitored and raked each morning during the nesting season by Three Rivers staff to locate and protect additional nests by following Softshell tracks. The turtles have continued to nest here in high numbers through the 2018 field season.

There were at least 6 nests within the fenced enclosure in 2009 and 17 nests were protected in the 2011 season. In 2014, 30 nests were protected and 15 previously unknown nests were identified from emergence holes for a total of 45 confirmed Spiny Softshell nests laid within the sanctuary in 2014. In 2015, 37 nests were protected and 10 unprotected nests were identified from emergence holes and coyote predation for a total of 47 confirmed Spiny Softshell nests for 2015. This was the highest number of recorded nests since protection efforts began in 2009. In 2016, 19 nests were protected and after monitoring for emergence holes and predation 39 Spiny Softshell nests were confirmed within the sanctuary. Multiple major rain events occurred throughout the summer of 2016, causing lake water levels to rise considerably, resulting in a high level of unsuccessful nests that were laid close to the shoreline. In 2017, 36 nests were protected and a total of 40 Spiny Softshell nests were confirmed within the sanctuary. In 2018 25 nests were protected and 10 were predated resulting in 35 confirmed Spiny Softshell nests in the sanctuary. The earliest recorded nest was laid on May 30th, 2012. The latest recorded nest was laid on July 22, 2014. The earliest recorded nest emergence at the sanctuary was August 10, 2017, and the latest recorded nest emergence was October 10, 2014.

In 2016, in conjunction with the urban turtle study, temperature loggers were installed in all protected nests, distance from the nest to the water was recorded, and nest success was monitored to investigate any potential factors impacting nest success. We tested for correlations between distance from the water and average incubation temperature and found a positive correlation between the two variables (r = 0.549). We also found that nests laid further from the water with higher incubation temperatures had a higher likelihood of producing successful hatchlings (Fig. 5).

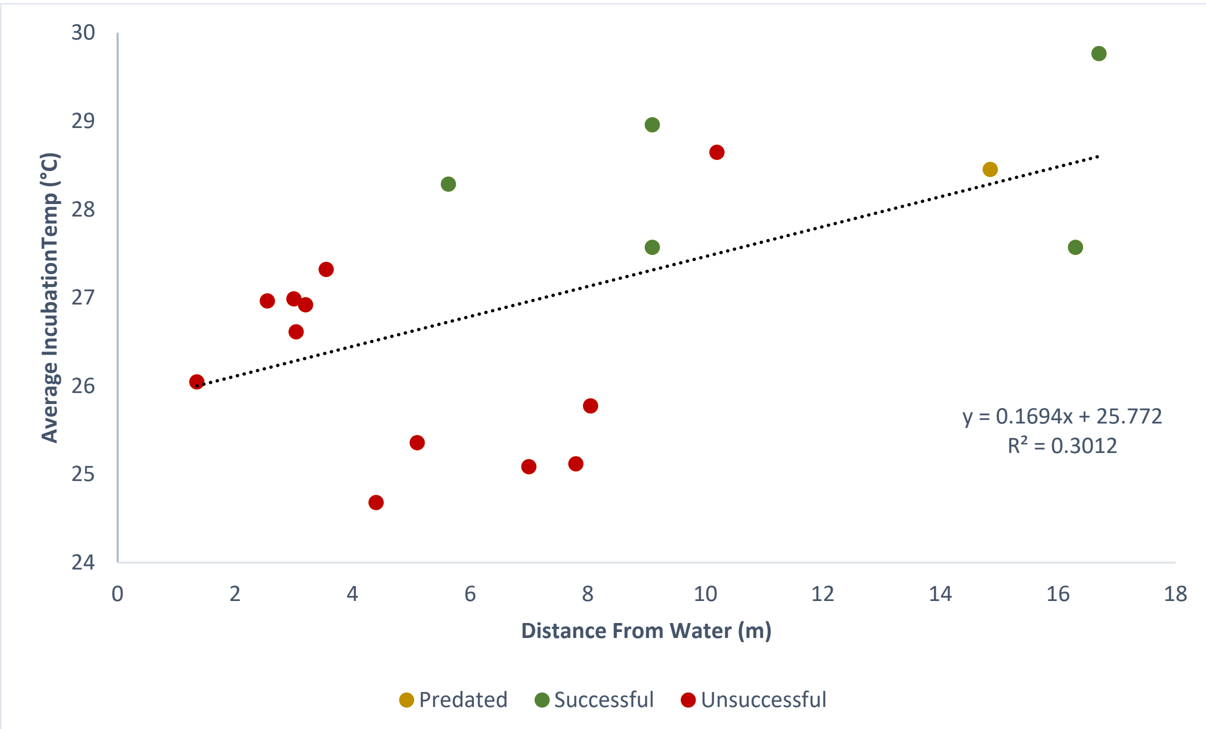


Figure 5: Spiny Softshell 2016 nest success with distance from water plotted on the x-axis and average incubation temperature in degrees Celsius on the y-axis. Nest success is color coded to indicate whether the nest was successful, unsuccessful, or predated. Correlation coefficient (r) was equal to 0.549, indicating a positive correlation between distance from the water and average incubation temperature.

Throughout the three year urban turtle study we compiled Spiny Softshell nesting observations from both researchers and homeowners in order to identify known sites used by Softshells for nesting (Fig. 6).

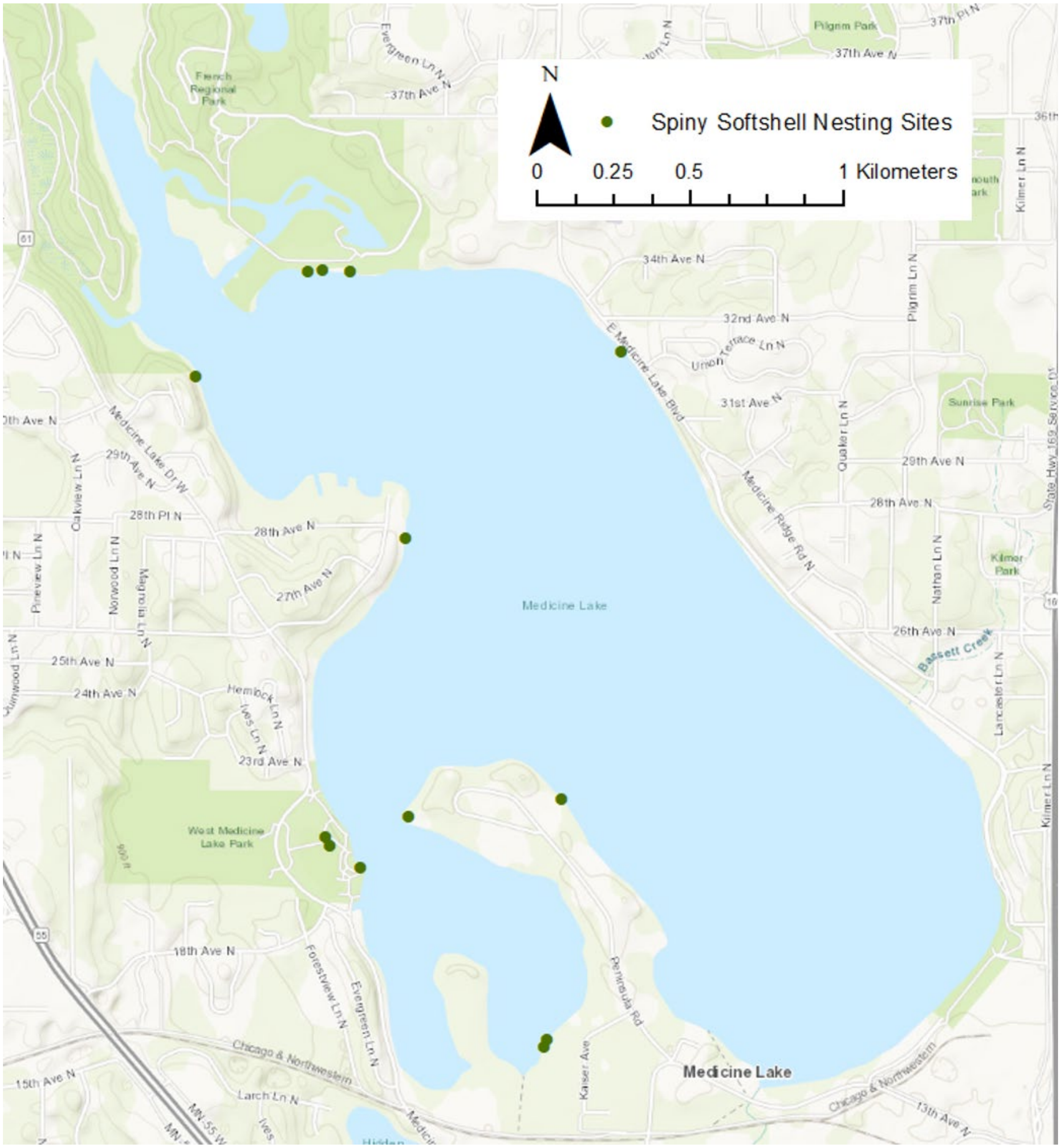


Figure 6: Confirmed Spiny Softshell Turtle nesting sites from observations from researchers and homeowners.

Overwintering Sites

Snapping Turtles and Painted Turtles were easily located in shallow waters using radio telemetry during the winter months, and no individuals from either species hibernated far from their summer home-ranges. One Snapping Turtle was presumed to be overwintering within an old muskrat lodge during the 2016-2017 winter season. Spiny Softshell radio signals were undetected during the first winter of the project (2016-2017), even with substantial search efforts by researchers. In early January of 2018, 15 Spiny Softshell signals were picked up within meters of one another in an area of the lake with a depth of ~6 m (Fig. 7), after months of searching most other areas of the lake with no success. An ice dive was carried out in partnership with the MidWest School of Diving in early March 2018; divers went beneath ~0.7 m of snow covered ice with limited visibility. The team was able to locate seven Softshells, only one of which had a radio attached. Therefore, using a ratio of 6:1 non-radioed turtles to radioed turtles, we estimated a minimum of 105 Spiny Softshell Turtles overwintering in this small 0.8-ha portion of the lake.

Figure 7: General location in which 15 out of the 21 radioed Spiny Softshells were located; yellow square is not to scale as the area was only ~0.8-ha, less than 1% of the 364-ha lake.

Activity Patterns

Some of the radio transmitters attached to Snapping Turtles and Spiny Softshell Turtles were equipped with acceleration activity loggers. These loggers recorded the day, hour, minute, temperature, and percent activity of the respective turtle every five minutes for the duration of time that the transmitter was activated. Percent activity is measured as the percentage of the sample time that the turtle was active. This data could only be obtained by recapturing the turtle and removing the transmitter to download the recorded data. We obtained data from six female Spiny Softshell Turtles and two Snapping Turtles, one male and one female. We analyzed the data in Program R to determine both the yearly activity patterns and daily activity patterns. Complete analysis of activity has been submitted for publication in *Herpetological Review* (Schneider et al. unpublished data).

I. Yearly Activity

For the 2017 calendar year, we obtained data from four female Spiny Softshell Turtles and two Snapping Turtles, one male and one female. We calculated the average daily activity and average daily temperature and plotted these metrics by Julian day. We found that specific activity patterns are unique depending on each individual turtle, however, essentially zero activity is seen when temperatures drop below 7-8°C for the four Spiny Softshells. In contrast, the two Snapping Turtles maintain very low activity levels year-round, although activity levels do drop substantially when temperatures drop below 7-8°C. This drop in activity in response to temperature agrees with the literature that these turtle species are most active from the beginning of April through the end of October. This is not surprising as turtles are ectothermic, and their body temperature and metabolism is dependent on the temperature of their environment. We found that Softshell activity peaked in July, whereas Snapping Turtles were most active during June.

II. Daily Activity

We analyzed data from the active months of April to October to determine the daily activity patterns for these species. We calibrated the data to account for sunrise and sunset times for the respective month and year in order to determine the percent of the total activity that was occurring during daylight hours and at night. Current research shows that most activity takes place during the daytime (Smith and Iverson 2004); although, some nocturnal activity has been inferred (Wade and Gifford 1965), however, this has never been directly measured. We recorded nocturnal activity for both species, resulting in the first record of directly measured nocturnal activity for both Snapping Turtles and Spiny Softshell Turtles using activity loggers. We also found that as activity levels increase in the summer months, most of this increase is attributed to an increase in daytime activity.

III. Basking Activity

We used the ambient temperature recorded from the data loggers to investigate basking behavior for one full year for each turtle. Turtles were considered basking in the activity logger temperature reached 30°, due to our maximum recorded lake temperature being 29.5°C using YSI meters. We calculated the percentage of days in which basking occurred for each turtle during the active season, and the average number of basking events per basking day. We found that Snapping Turtles rarely bask out of the water, while Spiny Softshell Turtles bask more frequently. Our data does not provide information on aquatic basking, but it is likely that both species bask aquatically for thermoregulation purposes.

Water Chemistry

The University of St. Thomas also had a team of students who came out to the lake periodically to collect water chemistry data. The team recorded pH, specific conductance, water temperature, salt (chloride) levels, nitrate levels, ammonium levels, oxidation-reduction potential, and dissolved oxygen at over 500 unique geographic locations around the lake. We tested for correlations between overall turtle point density, species-specific point densities, and the various water quality parameters that were measured. We did not find substantial positive or negative correlations between turtle densities and any of the measured water quality parameters ($-0.5 < x < 0.5$). Thus although some studies have found that water pollution can cause oxidative stress on freshwater turtles (Venancio et al. 2013; Héritier et al. 2017) and there is the concern that Spiny Softshell Turtles may be more susceptible than other turtle species because of high cutaneous permeability (Dunson 1960), it does not seem that Snapping Turtles, Spiny Softshell Turtles, or Painted Turtles are selecting for habitat based on water quality. This is consistent with our knowledge of Snapping Turtles being particularly tolerant of most environmental contaminants (Hall 1980; Duoros et al. 2015), but may indicate that they are not alone in this ability to tolerate habitat with reduced water quality.

Public Engagement

We considered public engagement to be a very important aspect of this project. For social media outreach we created a Facebook page, Turtles of Medicine Lake, with over 150 organic followers. This page was updated with fun facts about the three species of turtles included in this project, relevant new research, and any other project updates that were appropriate. Additionally, we had media coverage from local news channels and local papers throughout the duration of the study. Eric Nelson from Channel 12 Local News and CCX Media filmed and aired a segment in July, 2016. Jeff Edmondson from Kare 11 covered all three years of the project and filmed and aired segments in August of 2016, 2017, and 2018. Sonya Goins from Channel 12 Local News and CCX Media came to the lake to film a segment covering the winter ice dive in March, 2018. And Lastly, Kristen Miller published an article in the Sun Post, also covering the winter ice dive in March, 2018. Bridging the gap between scientific research and the public is one of the most important aspects of science and we were successfully able to this for the Medicine Lake Urban Turtle Study.

Management Recommendations

1. Protect and conserve natural shorelines

Natural shorelines with either sandy or vegetated habitat with many emergent structures for basking is important for two main reasons. First, open sandy shorelines are required for optimal nesting habitat that can reach incubation temperatures required for successful nests. Second, basking is a very important activity for turtles because it is the way in which they regulate their body temperatures and metabolic rates.

2. Do not disturb basking or nesting turtles

Human recreation and disturbance have the potential to substantially alter the behavior of freshwater turtles, including limiting valuable opportunities for nesting and basking. This is especially true for Spiny Softshell Turtles who are extremely skittish and will abandon nests and basking sites readily if even slightly disturbed by a potential threat. Predation is already a major issue which limits successful nests in urban areas, thus allowing turtles to nest undisturbed is very important. Similarly, frequent basking disturbance makes it more and more difficult for turtles to regulate their metabolic rates and body temperatures successfully.

3. Maintain aquatic connectivity between water bodies

To maintain high genetic diversity and reduce inbreeding in urban turtle populations, we recommend that aquatic connectivity between water bodies be maintained and conserved if at all possible. We realize that this is more the responsibility of city councils and planners than it is wildlife managers. However, we hope that responsible parties will recognize that maintaining existing aquatic connectivity is probably important for many species and is worth prioritizing.

4. Maintain diverse shoreline habitat to support a diverse turtle community

We found that shoreline habitat use is different among the turtles in Medicine Lake. Spiny Softshell Turtles use the entire lake, and are positively associated with commercial and single-family residential land use types and negatively associated with undeveloped non-wetland areas. The opposite was true for Snapping Turtles and Painted Turtles, who showed positive associations with undeveloped non-wetland areas and negative associations with commercial and single-family residential land use types. Therefore, it is important to have diversity of shoreline habitat in lakes to support a diverse population of turtles.

Acknowledgements

We thank the Environment and Natural Resources Trust Fund (ENRTF) for funding this project as recommended by the Legislative-Citizen Commission on Minnesota Natural Resources (LCCMR). We would like to thank Jeff Lang for the loan of turtle traps and other field equipment. We thank Advanced Telemetry Systems, specifically Tom Garin, for transmitter design and logistical support. We thank St. Olaf College, specifically Dr. Steve Freedberg for the collaborative efforts and donation of samples. Thank you to the 18 students of Team Turtle for countless hours in the field. We also thank Central Michigan University for funding and supporting two graduate student projects that have contributed to this research. We thank the University of St. Thomas and Three Rivers Park district for logistical support, many volunteers, and intensive collaboration.

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