Population and Status Assessment of the Snapping Turtle *Chelydra serpentina* in North Dakota

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Abstract

Research was conducted on snapping turtles in North Dakota for two field seasons (2012-2013) to (1) estimate length weight relationships, age structure, growth and population size in three reservoir systems, (2) determine overwintering locations, and nesting areas; (3) determine and characterize statewide distribution at the county level; and (4) estimate snapping turtle harvest. During two seasons 62 individuals were captured. Eleven radio-tagged turtles were found during winter sampling; all were located in close proximity to each other. Most females made a migration upstream from the bay at some point (Figures 25-29). Several management recommendations are made moving forward to help preserve the existing turtle populations, including the need to (1) develop a Management Plan for snapping turtles in North Dakota, (2) Incorporate turtle recording into standard statewide fish surveys, (3) Reduce fisheries netting mortality of snapping turtles, (4) Develop sound, scientifically defensible harvest management regulations and reporting.

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Dedication

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Introduction

The snapping turtle (*Chelydra serpentina,* Family Chelydridae), is one of the earliest of the chelonians, an ancient survivor, and one of two species in the genus extant in North America. It is characterized by an olive drab color, large body, slightly rounded carapace, large head, powerful jaws, powerful limbs with webbed feet, and forelimbs covered with scales (Pritchard 1979; Ernst et al. 1994). Its distribution extends from southern Canada to the Gulf of Mexico and westward to the Rocky Mountains. Typical snapping turtle habitat consists of sluggish rivers and a variety of various standing waters, including lakes, reservoirs, ponds and marshes (Pritchard 1979). In addition to being an important component of many waters, the snapping turtle also has potential as a useful biomonitor for contaminants in aquatic systems (Bonin et al. 1995; Overman and Krajicek 1995).

Snapping turtle life history is characterized by slow growth, late age at maturity, iteroparity, low adult mortality and a long lifespan (Gibbons 1987). The adaptiveness of this protracted life history strategy is strongly dependent on a consistently low mortality rate among adult turtles (Brooks et al. 1991). Like many long lived species, its life history characteristics make the species vulnerable to overharvest (Pritchard 1980; Brooks et al. 1991). Adequate recruitment is necessary at sufficiently regular intervals to maintain the populations; enough turtles must reach a sufficiently large size to where their natural mortality rate becomes low and remains low (Pritchard 1980; Galbraith and Brooks 1987; Brooks et al. 1991). Any unnatural factors such as highway deaths (Haxton 2000; Gibbs and Steen 2005), pollution, unnaturally high predator mortality, or overharvest that affect adult turtles can have serious impacts on turtle population sizes, reproductive success and population viability. Habitat destruction or alterations can reduce nesting and rearing success and can reduce juvenile survival, adult survival, and recruitment (Musick 1999). With such a long-lived, slowly-developing species, the negative impacts may be ongoing and not easily detectable until well after populations have begun to decline, even in some cases to eventual extirpation (Congdon 1994; Musick 1999). Achieving adequate recruitment, maintaining adequate turtles of reproductive age and creating and maintaining overall habitat conditions that result in low adult mortality are thus critical to species survival (Brooks et al. 1991).

Information from various investigations suggests that long-term sustainability of snapping turtles may be less certain for populations in the more northerly portions of their range, such as in Ontario or North Dakota. Abundance and densities of snapping turtles are typically much higher in the southerly areas (Galbraith et al. 1988). In the north, where turtles have a more protracted life history than farther south, age at maturity may be 20 or more years (Congdon et al. 1994; Galbraith et al. 1989) compared to 4-10 years in more southerly populations. In addition, individuals from more northerly populations may not reproduce each year and devote less than maximum energy to each reproductive event, on the basis that they will reproduce numerous times through their life, which may exceed 40 years (Ernst, 1994; Galbraith, 1989). The slow strategy can be adaptive over evolutionary time in northern localities such as North Dakota, but its adaptiveness can be seriously compromised where human development and resulting rapid changes in habitat conditions (Congdon et al. 1994) lead to increases in adult mortality (Brooks et al. 1991).

The eastern snapping turtle (*Chelydra serpentina serpentina*), the subspecies found in North Dakota, is designated a species of conservation priority in that state and is the subject of this study (Johnson 2010; Dyke 2014). Although snapping turtles have been documented as occurring widely throughout the state (United States Department of the Interior 2006), little is known about the behavior, life history, population size, growth, age structure, or the specific waters they inhabit.

In the past century in North Dakota, reservoir and lakeshore development, stream and river modifications (including channelization, sedimentation, and dewatering), other agricultural impacts, oil and gas production, and other developments have rapidly modified landscapes and aquatic habitats for snapping turtles (Angradi et al. 2004). Oil and gas development are major activities in the western half of the state; agricultural usage dominates all portions of the state. Both activities can negatively affect snapping turtles.

A scientifically-supported management plan is needed for snapping turtles in North Dakota, one based on an understanding of the status of the species and factors affecting reproductive (nesting) success, juvenile survival, growth, recruitment and adult mortality. Important mortality factors affecting turtles include predation, harvest, and being crushed by vehicles on roads (Ernst 1994). Little is known about current mortality or harvest rates in North Dakota. In assessing status of snapping turtles in North Dakota, four key ecological aspects where more information is needed are 1) availability of suitable habitat for nesting and hatching, 2) habitat requirements for overwintering, 3) growth patterns, and 4) the current age structure. Intensive efforts to identify suitable nesting and hatching sites and characterization of those habitats would make it easier to identify such sites in other localities where intensive studies cannot be done. A major knowledge gap exists on factors affecting overwinter survival and how a combination of North Dakota winters and habitat changes may affect it. Studies show that in general, turtles form groups during winter (Meeks and Ultsch 1990; Steyermark et al. 2008). Growth rates and age structure information can be related to survival and nest success.

For effective management of snapping turtles in North Dakota, more information is needed on life history, distribution, demographics, and harvest. As a species of great ecological and evolutionary importance but limited direct economic importance, an ongoing status assessment must necessarily be conducted in a cost effective way. The objectives of this study were to: (1) Estimate length weight relationships, age structure, growth, and population size in three reservoir systems (2) Determine overwintering locations and nesting areas; (3) Determine and characterize statewide distribution at the county level; and (4) Estimate snapping turtle harvest by fishing license holders in North Dakota. In meeting these research objectives, I would able to achieve the two management-level outcomes of the project I was charged with: (1) developing an assessment protocol for long-term monitoring that could be incorporated into ongoing regional fisheries sampling by NDGF personnel, and (2) assisting NDGF in developing a framework management plan for snapping turtles and other turtles.

Chapter 1: General Background on Snapping Turtles

This study focused on the common snapping turtle found in North Dakota. The names common snapping turtle (*Chelydra serpentina)* and eastern snapping turtle (*Chelydra serpentina serpentina*) are used interchangeably in the literature (Steyermark et al. 2008; Ernst 1994). For the purpose of this study all specimens will be referred to as common snapping turtles (*Chelydra serpentina*).

Taxonomy, biogeography, and distribution

Fossil records place some of the early ancestors of the family Chelydridae in the Late Cretaceous period (Steyermark et al. 2008). The common snapping turtle can be traced to the Pliocene and Pleistocene (Devender and Tessman 1975; Hibbard 1960; Holman 1964). Fossil records indicate the turtles were once present west of the Great Divide (Devender and Tessman 1975; Hibbard 1960; Holman 1964), although they were not native there at the time of their scientific descriptions. Possible causes of the extirpation of common snapping turtles west of the Rockies include climate change and the reduction of water on the landscape, because places where fossil records are found east of the Rockies have extant populations (Devender and Tessman 1975; Holman 1964), There are two living subspecies on the North American continent, the eastern snapping turtle) and the Florida snapping turtle (*Chelydra serpentina osceola*; Steyermark et al. 2008).

Life history and habitat requirements

Snapping turtle reproduction occurs in late spring and early summer, depending on the latitude, with spawning typically occurring later farther north (Obbard 1987; Ernst 1994).

Female snapping turtles have been documented migrating to nesting sites; males have been documented patrolling their home ranges during the spring and moving to natural migration bottlenecks to intercept females on their way to nesting sites in order to mate with them (Brown 1993). In some cases the nesting site might be the bank of the water body in which the individual resides, whereas in other cases females may travel up to several kilometers away from their home body of water to find a suitable site (Obbard 1980). One study conducted in Ontario, Canada showed an average migration of 5.3 km away from a nesting site after eggs were laid (Obbard and Brooks 1980). Most females use waterways as migration corridors to suitable nesting sites. When water corridors are absent, they have been recorded crossing land to get from one body of water to another (0.05 km overland movement; Obbard and Brooks 1980).

Whether courtship occurs, and to what extent, seems to vary widely among snapping turtle populations. In some cases the male may mount the female without any preceding courtship (Ernst, 1994). In other cases they have been documented performing courtship behaviors on the bottom by mirroring each other’s neck movements or by inhaling and up-heaving water (Taylor 1933; Legler 1955; Ernst et al. 1994).

Female snapping turtles use many natural and human-created sites for nesting. Females often prefer open areas of loam, loose sand, or vegetative debris with little to no live vegetative cover on the soil surface (Steyermark et al. 2008). Both natural and unnatural sites are used, including sawdust piles at old mills, fire lanes, shoulders on roads, railroad beds, yards, agricultural fields, shorelines, sandbars, muskrat houses, beaver dams and lodges, gardens, and private driveways (Ernst et al. 1994; Steyermark et al. 2008). The large variety of possible nesting locations can make finding nesting sites difficult for researchers. Clutch size varies by latitude and by the size of females, ranging from 6 to 104, getting larger with increasing latitude and body size. The size of the eggs varies from 23-33mm in diameter and round in shape (Ernst et al. 1994; Steyermark et al. 2008).

Once females have oviposited and buried the eggs they migrate from the nesting areas, the newly deposited eggs are left to hatch (Obbard and Brooks 1980; Ernst et al. 1994; Steyermark et al. 2008). The eggs that make it through to hatching have their sex determined through temperature dependent sex determination (TSD). Male snapping turtles are produced at temperatures below 28^{o}C, females are produced at temperatures above 28^{o}C, and it is believed that at 28^{o}C a 1:1 ratio of males to females would be produced (Janzen 1992). With TSD, long term warming or cooling trends can impact populations through soil moisture and temperature changes, skewing sex ratios and thereby future reproductive potential. Eggs hatch in 60 to 90 days depending on incubation temperature (Janzen 1992; Yntema 1978). Studies have not conclusively shown what mechanism hatchlings use to find their way to water. Robinson’s (1989) extensive review of other dispersal theories and her research led to the conclusion that movement downhill with gravity may be the main mechanism for finding water.

Habitat preferences change somewhat with age and size. Hatchling and small juvenile snapping turtles are believed to prefer small streams and then move into the lakes and ponds when they are close to maturity (Graves 1987). Both adults and juveniles are commonly found in and around obstructions, buried in mud, and in often times less than one meter of water (Froese 1978; Graves et al. 1987). When confined in such habitat turtles have to use very little energy to carry out basic functions, such as breathing, food acquisition, and hiding from threats. The optimum water temperature for snapping turtles is 28.1°C, with a maximum of

39.5°C (Graves et al. 1987; Hutchison et al. 1966). Adult snapping turtle habitat consists of shallow, still or slow-moving water full of obstructions (Froese 1978; Graves et al. 1987).

Food habits of snapping turtles vary across their range. Studies from more southern localities show a heavy reliance on aquatic vegetation as food (Aresco and Gunzburger 2007). Other studies of turtle diets indicate highly omnivorous and opportunistic feeding habits. Diets have consisted of aquatic vegetation, fish, birds, terrestrial insects, aquatic insects, amphibians, crustaceans, and carrion (Graves et al. 1987; Pritchard 1979; Richmond 1936). The diet that included terrestrial insects was an isolated incident in which a large hatch of cicada (family Cicadidae) had occurred (Richmond 1936), but the result indicates how opportunistic snapping turtles are. Prey acquisition in adult snapping turtles is generally done by ambush; they generally wait without moving until the prey is in range, striking with quick bites (Ernst 1994). Hatchling snapping turtles will pursue their prey (Steyermark et al. 2008).

In northern localities where ice forms on lakes and lake surfaces remain frozen for months, finding suitable overwintering habitat is critical for snapping turtle survival. The time at which snapping turtles move to their hibernacula sites and enter into a dormant cycle for the winter varies depending on the latitude. In northern parts of their range they may become dormant as early as October, whereas farther south it may be initiated in December. They may not come out of dormancy until May in the north and as early as February in the south (Obbard and Brooks 1981). Snapping turtles can often be found overwintering in groups; Meeks and Ultsch (1990) suggested that the species may typically have limited numbers of overwintering sites throughout their home range and this may be one reason for group overwintering.

Mortality and limiting factors

Effective management of snapping turtles requires knowledge of factors causing juvenile and adult mortality. Snapping turtle eggs, hatchlings, and juveniles less than 2 years of age experience higher mortality rates than older juveniles and adults (Congdon, 1994). Predation on snapping turtle eggs can be extremely high throughout its range. Studies have shown that nest predation can claim as much as 60% or more of nests each year (Hammer, 1969). Nest predators include numerous vertebrates including skunks (family Mephitidae), raccoons (*Procyon lotor*), foxes (family Canidae), coyotes (*Canis latrans),* crows (*Crovus brachyrhynchos*), mink (*Neovison vison*), and snakes (order Squamata; Ernst, 1994). Once snapping turtles have hatched, they remain vulnerable to predation from additional vertebrates including snakes, frogs, alligators (*Alligator mississippiensis*), fish, other snapping turtles, and various birds (Ernst, 1994; Hammer, 1969). Their swimming capability at early ages is limited; a study by Hammer (1969) showed that hatchlings drowned after venturing only a short distance from vegetation in deep water. Adequate prey acquisition for hatchlings younger than four months was also a challenge.

The main mortality threat to adult snapping turtles is humans. Harvest can be a major source of mortality. There are documented cases of boxcar loads of snapping turtles being taken to the east coast to be served in restaurants in the early part of the 1900's (Ernst 1994; Congdon 1994). There are also other vertebrates that prey on adults including bears, coyotes, alligators, and otters (*Lontra canadensis*) (Ernst 1994). One Canadian study showed a considerable mortality of snapping turtles in one winter as otters ate the viscera out of hibernating turtles (Brooks 1991).

Another source of mortality in snapping turtles is being run over by motorized vehicles on the ever expanding road network that crisscrosses the nation (Gibbs 2005). Gibbs and Steen (2005) suggested that the mortality of turtles on roadways might be skewed more towards females, because of their tendency to undertake nesting migrations. Beaudry (2010) discussed this potential problem with Blanding's turtle (*Emydoidea blandingii*) in Maine, the need to assess when turtles are making these overland migrations, and the need to use that data to determine times when the risk of mortality is greatest. The same approach may be applicable to snapping turtles. Snapping turtles tend to migrate in the spring and early summer during nesting and mating season (Brown 1993; Ernst 1994; Obbard 1980; Obbard 1987); it is then that they are most vulnerable to mortality from motorized vehicles.

Abnormally high mortality rates at any life stage as a result of human activities can alter the status of turtle populations from increasing or stable to decreasing or even extirpated. However, it is very difficult to assess the consequences of human development or other human impacts on populations of long-lived species such as the snapping turtle. Although assessment of population status and causes of mortality factors are necessary, such as assessment can present challenges. First, assessment of hatchling and juvenile (less than 2 years of age) snapping turtles abundance is often difficult because younger turtles do not recruit well to trap nets, the preferred sampling gear (Congdon 1994). Losses at hatchling or juvenile life stages may not be detected for years or even decades (Musick 1999). In northern localities, there are potentially at least 10-15 immature year classes. Difficulties assessing young life stages often leads to management decisions being based on adult life stages that are recorded at places such as nesting grounds (Musick 1999). In general, snapping turtle populations are not sufficiently well known nor are their harvests monitored closely enough for refined, scientifically defensible harvest management.

Chapter 2: Study Sites

Site selection in this study was designed to provide two general kinds of information: (1) detailed information on abundance, movements, age structure, and growth from three reservoir systems and (2) presence or absence information (i.e., distribution) based on more cursory sampling statewide from numerous other lakes and reservoirs in various North Dakota counties.

Turtles were intensively sampled from three reservoirs and their inflows in three different regions of the state: Lake LaMoure (southeast), Nelson Lake (central), and Patterson Lake (western). Lake LaMoure (Figures 1,2; hereafter, LaMoure), is situated in LaMoure County at 46°17’58.36” N and 98°16’12.79” W, has a surface area of 165 Ha, a shoreline of 17.2 km, an average depth is 4.4m, and a maximum depth of 10.1m (http://www.gf.nd.gov/fishing/lakedata.html March 2012). The dam was constructed in 1973 to hold back the waters of Cottonwood Creek (United States Environmental Protection Agency 2012). Nelson Lake (Figures 1,3; hereafter Nelson), situated in Oliver County at 47°07’45.65” N, 101° 13' 9.9978", has a surface area is 231 Ha, a shoreline of 20.43km, an average depth is 4.7m, with a maximum depth of 10.7m (http://www.gf.nd.gov/fishing/lakedata.html March 2012). Nelson was constructed in 1968 to provide cooling water for the Milton R. Young power plant and is fed by Square Butte Creek. Water levels can also be adjusted by Minnkota Power as needed with water from the Missouri River (Minnkota Power Cooperative Inc. 2014). Patterson Lake (Figures 1,4; hereafter, Patterson), situated in Stark County at 46° 52' 2.0382"N and 102° 49' 57.165" W, has a surface area of 386 Ha, a shoreline of 31.2 km, average depth of 2.74m, and a maximum depth of 8.1m (http://www.gf.nd.gov/fishing/lakedata.html March 2012). Patterson was created in 1950 by impounding the Heart River with Dickinson Dam. Although the primary purpose of the construction was irrigation and flood control. The reservoir also provides recreation opportunities and wildlife habitat (United States Department of the Interior, Bureau of Reclamation 2013).

Chapter 3: Methods

Snapping turtles were sampled with baited Wisconsin-type trap nets with leads (9m lead, 1.2 m x 1.8 m frame and 1.09 cm mesh) and hoop nets (3-1m diameter hoops, 2.5 cm mesh, and 2.1 m total length), baited with chopped fish viscera. The bait was placed in coffee cans that had been outfitted with wooden covers with bungee cords to keep the lid in place. Holes were drilled in the coffee cans to allow scent to disperse. The cans were attached inside the net at the cod end. When possible approximately half of the can was left in the water and half outside the water. Trap nets were set in shallow water with at least 7.5 cm above the water line. When possible the leads were fully extended. In areas where the water would have completely submerged the net, the leads were shortened so turtles were able to access the water surface for air. Hoop nets were typically set in locations that had flowing water. If no flowing water was present they were set in small bays; as with trap nets, at least 7.5 cm of the nets were left above the waterline. LaMoure was sampled first (4 nights, Jun25-29, 2012), followed by Nelson (13 nights, Jul 10-26, 2012) and then Patterson (seven nights, Aug 3-10, 2012). The target catch for each lake was at least 15 turtles. Once sampling was completed on the three main study lakes, the state-wide distribution sampling was conducted (May 20-Jun 4, 2012, Jun 15-24, 2012, Jun 31- Jul 03, 2012, and May 27- Jul 15, 2013). To improve the efficiency of this broader scale sampling, prior to site selection, a review was conducted of existing turtle catch records obtained from the NDGF fisheries data base, contacts with NDGF field personnel, and U.S. Fish and Wildlife Refuge personnel at Des Lacs, J. Clark Salyer, and Long Lake National Wildlife Refuges. Counties with records, the oldest dating back to 1993, of snapping turtle capture were not sampled so that coverage could be more efficient for evaluating turtle presence or absence in all of North Dakota’s 53 counties. Of the records more than 12 years old, only three counties had those as the only reference to turtles in the county, but all of the counties had large rivers running through them that have records of snapping turtle presence less than 12 years old. In counties that did not have any record on snapping turtle presence, multiple lakes were sampled over two to three day periods.

Objective 1 – *Estimate length weight relationships, age structure, growth, and population size in three reservoir systems*

All turtles captured from the three reservoirs were measured for carapace length, weighed, and their sex determined by the distance of the cloacal opening from the edge of the plastron (Obbard 1983). After brief cleaning of the carapace using soft bristle brushes, digital photos were taken of the fourth vertebral scute; counting the annuli of this scute has been used in other studies as an effective, non-lethal method for determining the age of snapping turtles (Hammer 1969; Obbard 1983; Galbraith and Brooks 1989). As part of population estimation, prior to release, all turtles had ring (disk) tags attached to a marginal scute at the posterior end of the carapace or were marked with notches in the carapace (Congdon et al. 1994). The disk tags were 33mm in diameter, individually numbered, and contained contact information for North Dakota Game and Fish in case the turtle was captured or harvested. Tag retention was assumed to be at or close to 100%; other studies have shown great success and little tag loss with tags attached to holes drilled through the turtles shell (Hammer 1968). All turtles were released alive as close as possible to the location where they were captured.

Length-weight relationships were developed for turtles based on the expression $W = aL^b$ where W is weight, L is carapace length, and a and b are parameters. An analysis of covariance (ANCOVA; SAS) was conducted on the length and weight data for the study lakes; this allowed me to compare the length-weight relationships of populations among lakes. In an effort to assess size selectivity of nets, length-frequencies of snapping turtles were also compared with length-frequencies of painted turtles (*Chrysemys picta*), which were commonly caught in the same nets at higher frequencies than snapping turtles.

The images of the fourth scute were aged in double-blind results format (Forsberg 2001; Maceina et al. 2007) with two independent agers using Image Pro system at the University of Idaho. Once each observer independently completed their aging, the primary ager compiled the results. All age discrepancies were re-aged by the primary and secondary agers together. Once annuli were agreed upon, distances from the focus of the scute to each annulus along the vertebral axis and to the edge of the scute were measured using Image Pro software.

The estimated ages and annuli measurements were used to evaluate the growth of turtles. Two approached to growth were used, back calculation and von Bertalanffy growth models. The expression used to back calculate length at age was $L_i = \frac{S_i}{S_c} * L_c$ where L_i is the back calculated carapace length at age, S_i is the distance from the focus to each annulus i, S_c is the distance from the focus to the edge of the scute, and L_c is the carapace length at capture (Le Cren, 1977).

Von Bertalanffy growth was expressed as $L_t = L_\infty[1 - e^{-K(t-t_0)}]$ were L_t is the length at a given age t, L_∞ is the length of an infinitely old turtle, K is a curvature parameter, and t_0 is an initial condition parameter. L_∞, K, and t_0 were all found using statistical software SAS. Growth models were calculated for two sets of turtle data: LaMoure turtles as a group and all turtles captured in the study. Growth was also expressed with the weight-converted von-Bertalanffy equation, expressed as $W_t = W_\infty[1 - e^{-K(t-t_0)}]^3$, where W_t is weight at a given age, W_∞ is the weight of an infinitely old turtle, derived from $W_\infty = aL_\infty^{\ b}$. An ANCOVA was run on length equations for each sex to determine if there was a significant difference between the growth rates for each sex.

Population estimates and confidence intervals were attempted for each of the three study reservoirs, LaMoure, Nelson, and Patterson, using the program MARK and the closed population full likelihood model (White and Burnham 1999). The model used for all three reservoirs assumed the probability of capture to be the same for all individuals the first time, but that the probability of recapture was not assumed to be the same among reservoirs. This assumption was made because of the scarcity of recaptures at all three reservoirs and the possibility of individuals becoming trap shy. In addition, I assumed that the probability of capturing an adult female or male was equal, but that the probability of capturing an adult was different than for a juvenile turtle. This assumption was made because of the scarcity of juveniles trapped and the possibility of trap bias towards older individuals. An assumption for all of the models was that no deaths, tag loss, immigration, emigration occurred during the sampling periods.

Objective 2 -- Determine overwintering locations, nesting areas, and what impact these areas may have on survival.

Radio telemetry was used in an effort to find nesting and overwintering sites in the three reservoirs and their inflows. Turtles were captured in nets as described in Objective 1. With the number of turtles to be tagged targeted at 15 per reservoir, LaMoure yielded 15 turtles but Nelson and Patterson yielded only 10 turtles each. Similarly, the target of 75 percent females and 25 percent males to be radio-tagged was not able to be met. A total of 22 males and 13 females were radio tagged. All 35 turtles captured from the three reservoirs had VHF tags attached to the posterior edge of the carapace in accordance to the designs and plans from Advanced Telemetry Systems for attaching them to shells. The VHF tags used weighed 14 grams with the ratio of tag to body weight in all cases no higher than 1.2%, well below the 5% limit to be avoided (Obbard 1983). The tags had a battery life of 535 days. The duty cycle was 12 hours on 12 hours off with the active period being from approximately 10:00 through 22:00. This duty cycle allowed the turtles to be tracked throughout the year with emphasis on being able to find the hibernacula sites (Meeks and Ultsch 1990) and nesting sites. There were no mortality signals on the tags due to the inactivity of the turtles during the winter.

For winter tracking, observers tried to locate the turtles when the ice on reservoir surfaces was sufficiently thick to support equipment and personnel. Tracking was conducted by driving or walking along the shoreline with the receiver and loop antenna to detect signals. Once a turtle was detected, its location was pinpointed by turning down the gain until the signal was only detectable when directly over the turtle. A hole was then drilled in the ice 0.5-1.0 m away from the turtle and an underwater camera (Cabela’s Angler Advantage Underwater Camera) with a 60’ cord and 12 UV led lights was sent down the ice hole to confirm the exact position of the turtles. Once a radio tagged turtle was located, I counted the number of turtles associated with the tagged turtle, their arrangement, and if any were previously sampled turtles. Turtles were determined to be previously sampled if they carried a visible radio tag or disk tag. I hypothesized that the turtles would overwinter in groups, consistent with what was described in the literature (Meeks and Ultsch 1990).

Tracking during the spring was conducted by walking the shoreline and from a boat. Females were tracked daily and had their positions recorded if they moved from their previously recorded position. Male locations were checked when locating females. If the location of the males changed they were recorded.

Objective 3-- *Determine statewide distribution at the county level*.

I used a combination of existing data and field sampling for verification to determine overall distribution of snapping turtles in North Dakota. Historical data from NDGF records from standard and non-standard fisheries sampling was reviewed to obtain general information on distribution and abundance. Information was also obtained by contacting refuge managers at National Wildlife Refuges located throughout the state. Information was then entered into a geographically-based format to depict distribution and abundance patterns using GIS mapping techniques.

During two field seasons, two-day field surveys were conducted from waters strategically located throughout the state to ascertain if turtles are found statewide. All turtles captured were measured for carapace length, weighed, and identified externally as to sex as in Objective 1.

Objective 4 -- Estimate current statewide harvest

To estimate statewide harvest, a brief (six-question) survey was sent out to 10,000 fishing license holders with the assistance NDGF personnel. From the survey, I attempted to identify areas within the state that received the most harvest, when the most harvest occurs, the most common means for taking snapping turtles. The initial contact was made by email and a link was provided for the individuals to go to Survey Monkey ©, a survey response website, to complete the survey. NDGF uses this website to complete all of their online surveys. As with all survey methods, some biases are associated with email surveys. Not every license holder has access to the internet and response rates may be lower than those found with traditional mail surveys (Sax et al. 2003; Shin et al. 2012). The questions asked of the survey recipients were: (1) Did you harvest any snapping turtles during 2012; (2) If so, how many did you harvest; (3) What body of water did you harvest them from; (4) When did you harvest them; (5) How did you harvest them; (6) Why did you harvest them. The results for harvest location were plotted using GIS to determine the primary locations where turtles were harvested. The total number of turtles harvested in the state was estimated by assuming that the turtle harvest of fishing license holders surveyed was representative of all fishing license holders in the state.

Chapter 4: Results

Length weight relationships, age structure, growth and population size in three reservoir systems

Capturing snapping turtles presented a challenge. Over the field seasons only 62 individuals were captured. Snapping turtles captured had a carapace length ranging from 16cm to 44cm (Figure 5-10). The median length for all snapping turtles was between 32cm and 35cm. The length frequency shows that the size of snapping turtle captured ranged widely but did not include small individuals. In LaMoure there were several length classes with multiple individuals. The mean length at LaMoure for snapping turtles was 34cm and a median length was 35cm.

Length- weight relationships differed among the three lakes (ANCOVA; p=0.0029)) Based on the relationships, a turtle of 300-mm carapace length weighed 6.57 kg in LaMoure, 8.47 kg in Nelson, and 8.09 kg in Patterson. The differences in the size of each sex was visually noticeable and statistically significant (ANCOVA $p<0.0001$). The growth and size difference of male and females can be seen by back calculating their length at age (Figure 11). The difference in the number of turtles caught and those used for back calculation was due to aging. I was unable to age some turtles due to the condition of the shell (Figures 12 & 13). Some turtles were also excluded from back calculation due to irregular scute shapes or an inability to measure the scute accurately from photographs. I was able to age 52 of the turtles captured (83%). Of those 52 turtles, 17 were excluded from the back-calculation process.

Turtles at LaMoure grew faster than turtles in the entire sample considered as a whole. The von Bertalanffy growth equation for all turtles combined was

$L_t = 485.8[1 - e^{-0.0707(t+2.6531)}]$ and for LaMoure it was $L_t = 517.8[1 - e^{-0.053(t+6.653)}]$ (Figures 14-16). Based on those equations, for all turtles an individual that is 300mm long would be 11 years old and for LaMoure the individual would be 9 years old. In terms of weight, W_∞ for all turtles was calculated as $W_\infty = 0.001 * 485.8^{2.7647}$ and for LaMoure it was $W_\infty = 0.0005 * 517.8^{2.8859}$. and $W_t = 34022.815[1 - e^{-0.053(t+6.653)}]^3$ for Lake LaMoure (Figure 17-18). A turtle weighing 20kg would be 16 years old for all lakes considered together and 10 years old in LaMoure. At LaMoure a significant difference was found between the growth of males and females (ANCOVA; $p<0.0001$). LaMoure's adult and male population was estimated at 40 turtles with lower and upper 95% confidence intervals of 34 and 60, respectively. The estimate for juveniles was 8 with lower and upper 95% confidence intervals of 3 and 11 (Figure 19).

O*verwintering locations, nesting areas, and survival.*

Telemetry was most effectively used to track turtles in LaMoure. Efforts to determine nesting activity were then concentrated mostly on that reservoir, where there were more females tagged and a larger population of turtles existed. Approximately a month was spent tracking the turtles there.

Tracking turtles over winter at LaMoure also proved fruitful. Eleven of the 15 tagged turtles were found during the winter sampling (13-20 January, 2013). All eleven turtles were located in close proximity to each other; the longest distance between any of the tagged turtles was 45 meters (Figures 20-21). I was able to get video of only two tagged turtles. Other tagged turtles could not be located due to high turbidity of the water, and in some cases, the location of the turtle down in the substrate. The turtles that were observed were sitting on top of the substrate facing the shoreline (Figures 22-24). One of the tagged turtles also had an untagged turtle directly behind it. This turtle was also facing the shoreline. Upon returning the following day to make video recordings of turtle locations, the untagged turtle had moved out of view from the hole used to see it the previous day. None of the turtles were observed buried under the substrate or stacked upon each other. They were all located in an area with approximately 43 cm of ice cover and 60 cm of water or less under the ice.

The results of winter tracking on the other two reservoirs Nelson and Patterson were much poorer and similar to each other. Only about one third of Nelson Lake froze during the winter of 2012-2013; heated water effluent from the coal fired power plant that uses the lake as a cooling reservoir (the intended purpose of the lake) kept much of the lake ice-free. One tag was detected in a portion of the upper end of the lake dominated by cattails (Typhaceae). The cattails had been partially submerged in water during the summer of 2012. Due to a water level draw down the area was no longer covered with water. The tag was tracked to a dirt portion of the cattail area. An attempt was made to dig down to the tag but the ground was frozen. During spring tracking the tag was located in the same spot and it was covered with water. It is unconfirmed if the turtle was still there alive, the turtle had died, or if the tag had fallen off some time prior. Attempts were made to locate the other tags but none were found. I traveled as far up the inflow creek as possible and drove around the rest of the shoreline within the range that the tags could be detected.

Winter tracking on Patterson Lake did not result in the location of any of the tagged turtles. Several attempts were made to find the tagged individuals. The entire shoreline in the lake proper was covered in an attempt to locate the turtles. I also went as far up the Heart River (approximately 1.5 miles) as ice conditions would allow. The tags were still operational when the turtles were tracked in the spring, so it is unknown where they overwintered or why the tags were not detectable during the winter. In discussion with the tag manufacturer the tags would not have been able to transmit if they had become embedded in the ice. Due to the tag's location on the turtles carapace it is likely that if the tag was embedded in the ice the turtle would have also been entrained in the ice. Entrainment in ice is fatal for snapping turtles so it clear this did not happen because the turtles were tracked during the spring.

At LaMoure, female turtles were tracked daily in an attempt to determine when and where they nested. The average daily movement was minimal until early June, when their movement increased significantly and it is believed that they began moving to their nesting sites. Although no tagged individuals were observed nesting, their movements were tracked to areas in close proximity to where other turtles were observed nesting and areas that mirrored habitat used by other turtles at the lake. The longest distance traveled between consecutive days was 1341 m by one turtle (No. 384); the average maximum distance traveled by individual turtles was 1942.8 m. I was able to observe one female that traveled approximately 5,000 meters from the upper end of the lake, past the dam, and into the tributary below the dam before she lost her radio tag (though not her disk tag. The radio tag was found 150 meters upstream from where I captured her. Most of the turtles were located in the same area they were trapped the year before. Most females made a migration upstream from the area where they were captured and overwintered (Figures 25-29). Some migrations were short and only lasted a day or two; others lasted several days. The location of sightings for radio-tagged males did not vary as much as the females. Males typically stayed within the area they were captured the year before and did not show any signs of migrating (Figures 30). Most of the time the turtles were located in the same bay they were captured in, they moved out of that bay for a short period of time (less than five days) and then returned. The males were not observed outside of the bay (Figure 31). The water depth averaged 1 to 2 meters in the bay; the perimeter consisted of cattails and submerged aquatic vegetation grew throughout the bay.

Although I was unable to document any of the tagged turtles nesting, I was able to track them to areas where I documented other turtles nesting. The study turtles stayed within the stream system flowing into and out of the lake. I did not document any overland migrations of study turtles. I did document one overland migration of an untagged turtle. She moved to an area uphill from the lake to lay her eggs in the middle of a road. With the exception of her nest the rest were within five meters of water.

Non-tagged individuals were documented nesting in 3 different locations: a gravel bar located upstream from LaMoure, a gravel road that led to campers along LaMoure, and a gravel road that ran along the James River (approximately 6,000 m from LaMoure) (Figures 32-34). At the gravel bar I witnessed a mature female attempt to dig a nest; she was scared off by our presence when I moved in closer to attempt to document her nesting. Once she had left, I examined the gravel bar and noticed other nest attempts or possible nest completions. I did not dig into the possible nest because I did not want to disturb them. I was unable to document any other nesting attempts at the gravel bar do to a rain event that brought up creek levels to a point where water covered a majority of the gravel bar.

The nesting female that was observed on the gravel road traveled the farthest distance (214 meters) I documented away from water to nest... Once at the site she nested in the middle of the road. I was able to observe most of her nesting. I first noticed her once she had already started digging her nest. During our observation I witnessed her completion of digging, ovipositing, burying of her eggs, and packing the nest. Once she had completed her nesting event I documented the nest and took pictures of the female's scutes for aging purposes.

At the third location a series of roads totaling approximately 1861 meters followed or crossed the James River. On these roads I observed evidence of multiple nesting attempts, completed nests, and nests that had been preyed upon. Turtles were also witnessed on the roads attempting to nest. The turtles I witnessed were not disturbed by our vehicle on the road and continued to nest. Nests were under approximately 10-15 centimeters of tightly packed dirt. The nest hole was approximately 25 centimeters in circumference. Nests were packed with a similar hardness to the surrounding road bed. I also documented several attempted nests on the roads surrounding the river; it is likely that the turtles were scared off by vehicles while they were in the early stages of digging the nests. Along with attempted nests I found nests that had been preyed upon. These nests looked similar to attempted nests, but upon closer examination fragments of egg shells could be found in and around the nest. I was unable to determine what type of animal preyed upon the nests.

I was also able to document several nesting locations at LaMoure from personal observations and those of others; the locations identified included dams, gardens, gravel bars, gravel roads, putting greens, and sand volleyball courts. One characteristic shared by the identified sites was that they were well drained.

Statewide turtle distribution by county

I was able to ascertain the presence of snapping turtles in 41 of 53 counties (Table 1 and Figure 35). Of the 12 counties for which I do not have records of snapping turtles, I was unable to sample 10 of them. Twenty-four of the counties with snapping turtles present had records listed in the fisheries database; for 17 other counties information was gathered from various sources: four counties from USFWS personnel, 11 counties from NDGF personnel, and two additional counties from our turtle surveys. Two of the 12 counties with no snapping turtle records were sampled and no snapping turtles were found. There were a few counties where, after I had sampled, information became available to us from various sources confirming that snapping turtles were present there.

During the two field seasons I sampled 21 bodies of water in 12 counties across North Dakota in an attempt to find snapping turtles (Table 2). Catches were scarce. Of the seven bodies of water that snapping turtles were trapped I only caught more than one turtle in four bodies of water: three turtles at Bowman-Haley Reservoir, 10 at Patterson, 12 at Nelson Lake, and 35 at LaMoure.

Statewide harvest of snapping turtles

Of the 10,000 turtle harvest questionnaires sent out to licensees, 733 responses were received, a 7.33% return rate. Of the responses to the surveys received, 13, or 2%, stated they had harvested turtles in 2012. The average number of turtles harvested by these 13 individuals was 4.5 and the median was 1. The maximum harvested by a single individual was 23 and the minimum harvested by a single individual was 1. A total of 55 turtles were harvested among the 13 individuals. Three individuals accounted for 41 turtles or 74.45% of overall harvest reported. The other 10 individuals harvested one or two turtles each. Harvest occurred in different areas across the state including lakes and rivers; I depicted it at the county level because some rivers traverse multiple counties (Figure 36). The lake with the most reported harvest (23 turtles) was Smishek Lake in Burke County, in the northwest portion of the state.

For all waters, 88.2% of all reported harvest occurred during the summer, followed by fall (23.5%), spring (17.6%), and winter (5.9%). Five individuals used hook and line to harvest turtles, four used nets, two caught them by hand, one used a shotgun and one used a harpoon. Eight of the individuals the harvested turtles did so for food, one individual for turtle races, one individual for sport, one individual because the turtle was close to death after being reeled in, one individual because the turtle hooked itself and one individual because it was too close to swimming and fishing areas.

Chapter 5: Discussion

The estimated age and size structure of snapping turtles across North Dakota consisted mostly of adults; few young snapping turtles were captured. In addition, the estimated individual ages of turtles in the populations may be underestimates because some research suggests that annuli might not be laid down every year after maturity is reached (Galbraith and Brooks, 1987). The scarcity of juvenile snapping turtles caught throughout this study, along with the ease of capture of painted turtles of small size (Figures 5-7) indicated that either young snapping turtles are not equally vulnerable to the nets as older turtles or that actual recruitment is low or non-existent in some years. Although gear bias against juvenile snapping turtles has been cited in other studies as a possible reason for low numbers of juveniles in samples (Congdon et al. 1994), this explanation for low juvenile numbers is inconsistent with the high catches of painted turtles with my sampling gear. Painted turtles were captured as small as 9mm in carapace length (Figure 5), but the smallest snapping turtle caught had a carapace length of 16mm. I should have been able to catch small snapping turtles with the gear if they were present. Trap net locations at the study sites included the inflow streams and shallow areas that are habitat areas small turtles occupy (Graves et al. 1987).

A more likely explanation for low catches of juvenile and older snapping turtles is that this long-lived species is not abundant throughout most of its statewide range. Sporadic recruitment of snapping turtles is well documented in other localities, with predation rates 60% or higher (Hammer, 1969), low hatchling survival rates, and nesting that may not take place every year. Sporadic recruitment of may be especially likely near the edges of a species range, as in the case of snapping turtles in North Dakota.

One likely cause of poor or inconsistent recruitment may be predation during the nesting and early life stages, a common problem for the species. Hammers (1969) showed nest predation between 40% and 60% in some areas of LaCreek Refuge in South Dakota. In that refuge, there were multiple nesting areas which could have improved the likelihood of escaping predation. Robinson and Bider (1988) discussed the possibility that clustered nesting sites may increase the chances of nests being preyed upon. At their study site nests within 1m of other nests had a 3% survival rate, compared to nests farther apart that had a survival rate of 39%. A scarcity of suitable nesting areas can lead to high nest densities increasing the number of nests preyed upon. These factors can result in low numbers of young turtles (i.e., sporadic recruitment) and ultimately a population often consisting of mostly older turtles. In this scenario, if the eggs hatch and the young make it past early mortality threats; they may be able to persist for years if not killed by humans.

Pre-nesting and nesting activities and locations in this study were similar to those reported in other studies. The observed overland migration distances are well within the distances discussed in other papers (Obbard and Brooks 1980). The well-drained nesting locations have also been identified as a common requirement in the literature (Ernst and Lovich, 1994; Steyermark et al. 2008). Most of these areas are also places where the turtles could come in contact with humans, including roads. The greatly increased rural road traffic in much of North Dakota associated with the energy development may be an additional source of mortality that should be investigated. Based on the low numbers of juveniles observed, the locations that turtles are nesting deserve protection, including restrictions on activities. Areas where the only suitable nesting habitat remaining is roads and other manmade areas could benefit from artificial nest sites where the turtles would not be disturbed by human activity.

Another worthwhile step would be to increase public awareness through pamphlets or articles in newspapers about what to do when turtles nest on their property, how not to disturb the area where turtles nest, and about how long it will be necessary to take precautions until the eggs hatch.

In this study, the use of overwintering sites with soft substrate, undercut banks, and flowing water, similar to conditions described Meeks and Ultsch (1990). The clustering behavior I observed in Lamoure calls for additional study to determine if these sites remain used from year to year. The inflow at Lamoure contains moving water throughout most winters. Substrate in the creek allows for turtles to burrow into it. If so, and in view of the apparent low recruitment, such overwintering sites would also deserve protection from disturbances and harvest. Further work needs to be done to determine if overwintering habitat is a limiting factor for North Dakota snapping turtles.

The inability to locate turtles on two of the three study lakes hampered the efforts to understand the overwintering and nesting locations throughout the state. Had I been able to determine the locations of overwintering and nesting at all of the lakes, I could have gained a better understanding of how the requirements might vary throughout their range in North Dakota. More work is needed statewide on these critical aspects of snapping turtle life history.

In comparing growth rates for our study population to those of other populations throughout North America (Figures 37-41), rates varied significantly by latitude (ANCOVA $p=<0.0001$) and by sex. North Dakota turtles grew larger than turtles in the three other areas examined (Iowa, Nebraska, and South Dakota). Larger growth with increasing latitude was also found by Steyermark et al. (2008), with the largest turtles being located in Nebraska and South Dakota.

The sexual size dimorphism seen in this study, where males are larger than females is similar to what has been found in other studies. For example, Christiansen and Burken (1979) found that growth of the two sexes in Iowa were similar until approximately 50mm plastron length, at which point males grew faster ; Ceballos and Valenzuela 2011 found that there was a greater plasticity in the growth of males (the larger sex) than females in turtles. The reason for this consistent pattern could be related to the cost associated with reproduction. Once females start developing ovaries their growth slows and male growth continues (Ceballos and Valenzuela 2011). Although I found no research that shows direct competition for females by male snapping turtles, such competition would be a plausible explanation for the observed sexual size dimorphism (larger males) and should not be ruled out.

The observed variations in population sizes and apparent densities in waters in this study, (10-48 total turtles depending on the lake) is typical; not only numbers but densities of snapping turtles vary widely across their range (Galbraith et al. 1988, Hammer, 1969, Froese, 1975). The differences could result from many factors, including habitat and harvest. According to the local landowners, the area around Nelson Lake has been subject to high snapping turtle harvest due to an annual turtle feed. In an area where continual harvest of long lived species occurs one would not expect to see large populations. Patterson has several large bays, a river inflow and a large marsh area where turtles could be spread out and I would not have been able to sample them effectively. Lake LaMoure, in contrast, contains a few small bays, a smaller inflow and a small marsh area where snapping turtle could reside and was close to a large slow moving river that contained another population of turtles. Turtle records are too incomplete throughout North Dakota for a reliable assessment of these factors to be made.

The sampling efforts aimed at determining statewide distribution suggest that snapping turtles can be found throughout the state of North Dakota, but that distribution is patchy and localized. Although it was a challenge to trap turtles at all locations, a common characteristic of the lakes that had turtles was that was they all had some sort of inflow and outflow, a river or stream. The Oliver County Sportsman's Club Pond, which did not have an inflow but yielded a single snapping turtle in our sampling, was less than 1km from flowing water. McIntosh and Rolette counties, which contain few bodies of flowing water, were the only two counties sampled that yielded no snapping turtles. The reports and information gathered from other sources which were used to establish the statewide distribution map show a similar pattern of turtles being located in areas where they have access to flowing water. In contrast, the areas where we were unable to locate turtles often did not have inflows, outflows, or were not located within a few kilometers of flowing water.

One possible reason for their absence in areas without flowing water could be because of localized population extirpation and inability to easily recolonize. In these isolated situations, local extirpation could result a myriad of factors including harvest, predation of both eggs and juveniles, loss of habitat, increased mortality due to human factors, or the lack of suitable overwintering habitat. Because there are no travel corridors, in the form of rivers and streams, turtles may not be able to repopulate these areas. The proximity to flowing water thus seems to be a specific, and potentially limiting, requirement for snapping turtles in North Dakota. This need for available flowing water did not seem to apply to painted turtles, however, as I encountered them in all but one body of water sampled. Their higher densities may make them less subject to chance extirpation in smaller, more isolated lakes and ponds than the snapping turtle.

Management recommendations

Several management recommendations came out of this study, as identified and discussed below.

Develop a Management Plan for snapping turtles in North Dakota

As one of the most ancient living species in North Dakota, snapping turtles deserve special attention. There has historically been no management plan for snapping turtles or other turtles in the state. A combination of agricultural expansion, energy development and rapid population increases throughout much of the formerly sparsely populated state will require that more attention be paid to species such as the snapping turtle that are slow reproducers and prone to increasing juvenile and adult mortality. A more comprehensive management plan is needed for this species, including habitat, population assessment at local and landscape scales, as well as harvest management (if harvest is a viable long-term option) and information and education components.

Incorporate turtle recording into standard statewide fish surveys

Cost-effective monitoring of snapping turtles and other turtle species can be best accomplished by incorporating it into current NDGF fisheries surveys. Basic length-frequency and weight-frequency data can be useful in monitoring recruitment and size and age structure of snapping turtles in waters statewide. Data that should be collected and entered into the statewide fisheries data base should include, as a minimum, turtles caught per net set, carapace length and individual weights. This data could allow managers to look at overall population trends in a similar manner to that for long lived fish species. As thought needed or desired, photographs of scutes could be taken for aging purposes to allow for closer monitoring and to provide better information on recruitment at various localities.

Reduce fisheries netting mortality of snapping turtles. To reduce the mortality of turtles captured in fisheries sampling, biologists need to leave a portion of the net above the water. During my research I left an average of 7-8cm of the net above the water line, thereby allowing the turtles to surface for air. I would also recommend that at the very least a bycatch reduction device (BRD) be placed on all modified fyke nets used for fisheries surveys in deep water. Fratto et al. (2008) describe a BRD that was effectively used in their study to reduce the bycatch of turtles without significantly affecting the capture of fish species; their results would need to corroborate in North Dakota by pairing BRD nets with control nets and determining if there is any difference in capture.

Nesting and overwintering sites should be protected and, where feasible, enhanced.

Females should be protected from harvest during the nesting season, which should be defined. Halting the turtle harvest during nesting periods allows them to complete an important life stage. When the females are moving across land they are also easily exploited.

In locations where turtles are found to be nesting amidst excessive human activity, efforts should move forward to provide safer nesting areas, which would reduce usage of roads and other high-risk areas. There is no current literature on artificial nesting sites for snapping turtles. But the creation of nesting areas has been done for marine turtle’s species and may have merit for inland species.

Overwintering sites also need to be protected. Once turtles enter hibernation they are slow to react to stimulus that would normally invoke a fight or flight response. Along with slowed movement, they tend to congregate in just a few locations allowing for easy exploitation of large portions of the population.

Develop sound, scientifically defensible harvest management regulations and reporting.

The current interpretation of snapping turtle harvest regulations in North Dakota is that if a person is angling and catches a snapping turtle, the angler is permitted to keep two such turtles a year. However, any person can harvest an unlimited number of turtles a year by non-angling methods such as capture by hand, capture by net, bow fishing, harpoon, or firearms (Patrick Isakson, NDGF, Personal Communication). Surrounding states have daily limits and possession limits, but no yearly harvest limits. South Dakota allows 2 daily and 4 in possession. Nebraska allows 5 daily and 10 in possession. Minnesota allows 3 daily and 3 in possession. In comparing snapping turtle harvest regulations (e.g., length of season, daily bag limit, possession limit, yearly limit, and any length restrictions) for every state that has snapping turtles to those of North Dakota (Table 3), 12 states, including North Dakota, do not have any stringent regulations pertaining to the number of turtles that can be harvested, 23 states have some regulations pertaining to daily limits, with some also having limits on total possession. Only 4 states, Connecticut, Georgia, New York, and North Carolina limit the number of turtles that can be harvested within a season or year. Only one state (Florida) does not allow harvest; the reason for the prohibition is that snapping turtles closely resemble other protected species Suwannee cooters (*Pseudemys concinna suwanniensis*), Barbour's map turtles (*Graptemys barbouri*), and alligator snapping turtles (*Macrochelys temminckii*), within the state. Nationally, the lax regulations for this ancient, slow growing species indicate an overall lack of concern.

In some southern states with more productive waters and more productive, strongly reproducing, earlier maturing turtle populations, concerns for extirpation may be unwarranted at present. However, in more northerly populations such as North Dakota where turtles are slower growing, later maturing, in lower abundance (as indicated in this study), and additionally, subject to increasingly intense habitat changes from agriculture, off-road usage, and energy development, the needed for more cautious management of this ancient species should be more carefully scrutinized. Statewide snapping turtle harvest should not be expanded or encouraged until more data is gathered to determine the status of the turtles in all lakes throughout the state. Some lakes with consistent recruitment may be able to support limited harvest if closely monitored. However, these lakes need to be determined on a case by case basis by developing long-term data sets for monitoring population trends.

A better harvest management and reporting process needs to be developed within North Dakota to better understand and monitor harvest within the state. Current annual harvest within North Dakota would be approximately 18,400 turtles if the survey accurately sampled the people who harvest turtles. This estimate was reached by extrapolating harvest rates out to encompass all licenses sold in the state. Even a more conservative estimate of yearly harvest from removing individuals who illegally harvested large numbers of turtles from the data set would amount to 6,500 turtles harvested each year. However, the estimates from the survey may not accurately portray the harvest. In Ontario, a fisheries survey that included questions about turtle harvest did not provide the best view of harvest within the province (Patrick Hubert, Ministry of Natural Resources, Ontario Canada, Personal Communication). A change in harvest regulations and a reporting process yielded more reliable information. Online forms should be developed where harvesters enter the location of harvest, carapace length, location, and time of harvest for each turtle they keep. There should also be a category for number of snapping turtles released. Those responding should also be sent relevant information on the species.

If certain waters are experiencing heavy harvest, steps can be taken to protect local populations to prevent local extirpations. Area closure may be required where there are signs of poor recruitment. More harvest enforcement is also needed. Tagging systems such as for deer/elk (family *cervidae*) or paddlefish (*Polyodon spathula*), another ancient species, issued at one or two tags per year per person, might be considered as a requirement for harvesting or possessing a snapping turtle. A tagging system would facilitate reporting and enforcement.

Information and Education on the value of snapping turtles

The snapping turtle is a unique and important species in North Dakota. Working to preserve them for future generations should be a top priority. There should also be an information and education effort regarding the special characteristics of snapping turtles and their value to North Dakota aquatic habitats. There should also be information provided to discourage malicious molesting of snapping turtles, a common occurrence in many localities. Penalties should result from any improper activity affecting the species.

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Tables

County	Present	Information Source
Adams	Yes	Fisheries Database
Barnes	Yes	Fisheries Database
Benson	No	No Data
Billings	No	No Data
Bottineau	Yes	USFW Refuge Personnel
Bowman	Yes	Turtle Research Project
Burke	Yes	Fisheries Database
Burleigh	Yes	Game and Fish Personnel
Cass	Yes	Game and Fish Personnel
Cavalier	No	No Data
Dickey	Yes	Fisheries Database
Divide	No	No Data
Dunn	Yes	Game and Fish Personnel
Eddy	Yes	Game and Fish Personnel
Emmons	Yes	Fisheries Database
Foster	Yes	Game and Fish Personnel
Golden Valley	Yes	Fisheries Database
Grand Forks	No	No Data
Grant	Yes	Fisheries Database
Griggs	Yes	Game and Fish Personnel
Hettinger	Yes	Fisheries Database
Kidder	Yes	USFW Refuge Personnel
La Moure	Yes	Turtle Research Project And Database
Logan	Yes	Fisheries Database
McHenry	Yes	USFW Refuge Personnel
McIntosh	No	No Data
McKenzie	Yes	Fisheries Database
McLean	Yes	Fisheries Database
Mercer	Yes	Turtle Research Project
Morton	Yes	Fisheries Database
Mountrail	Yes	Fisheries Database
Nelson	No	No Data
Oliver	Yes	Turtle Research Project And Database
Pembina	No	No Data
Pierce	Yes	Turtle Research Project
Ramsey	No	No Data
Ransom	Yes	Fisheries Database
Renville	Yes	USFW Refuge Personnel
Richland	Yes	Fisheries Database
Rolette	No	No Data
Sargent	Yes	Game and Fish Personnel
Sheridan	Yes	Game and Fish Personnel
Sioux	Yes	Fisheries Database
Slope	Yes	Fisheries Database
Stark	Yes	Turtle Research Project And Database
Steele	Yes	Game and Fish Personnel
Stutsman	Yes	Fisheries Database
Towner	No	No Data
Traill	Yes	Game and Fish Personnel
Walsh	No	No Data
Ward	Yes	Fisheries Database
Wells	Yes	Game and Fish Personnel
Williams	Yes	Fisheries Database

Table 1. Snapping turtle distribution by county and the sources used for determining presence

Body of Water	County	Sampling Period in Days	Snapping Turtles Trapped
Bowman-Haley Reservoir	Bowman	17	3
Cherry Lake	Kidder	2	0
Frettim Lake	Kidder	2	0
Lake LaMoure	LaMoure	4	35
Mundt Lake	Logan	2	0
Buffalo Lodge Lake	McHenry	2	0
Lehr WMA	McIntosh	2	0
Blumhardt Dam	McIntosh	2	0
Coldwater Lake	McIntosh	2	0
Harmony Lake	Mercer	1	0
The Knife River	Mercer	1	1
Nelson Lake	Oliver	17	11
Oliver County SCP	Oliver	1	1
Balta Dam	Pierce	2	0
Buffalo Lake	Pierce	1	1
Dion Lake	Rolette	2	0
School Section Lake	Rolette	2	0
Willow Lake Creek	Rolette	2	0
Buffalo Lake	Sargent	2	0
Silver Lake	Sargent	2	0
Patterson Lake	Stark	7	10

Table 2. Sampling period and snapping turtles trapped by individual bodies of water.

State	Season length	Daily limit	Possession limit	Yearly limit	Length restrictions
Alabama	Year-round	2	2	None	None
Arkansas	Year-round	None	None	None	None
Colorado	April 1- Oct. 31	None	None	None	None
Connecticut	July 15-Sept. 30	5	30	30	13" min length
Delaware	June15-May15	None	None	None	11" min length
Florida	NO HARVEST				
Georgia	Year-round	10	10	10	None
Illinois	June 15-Aug 31	2	4	None	None
Indiana	Year-round	25	50	None	None
Iowa	Year-round	100 lbs live 50 dressed	100 lbs live 50 dressed	None	None
Kansas	Year-round	8	24	None	None
Kentucky	Year-round	None	None	None	None
Louisiana	Year-round	None	None	None	None
Maine	Year-round	None	None	None	None
Maryland	Year-round except Charles County	1	1	None	4" min length
Massachusetts	Year-round	None	None	None	6" min width
Michigan	July 15-Sept 15	2	4	None	13" min length
Minnesota	Year-round	3	3	None	None
Missouri	Year-round	5	10	None	None
Nebraska	Year-round	5	10	None	None
New Hampshire	July 16-May14	2	4	None	None
New Jersey	June 16-April 30	3	None	None	None
New York	July 15-Sept 30	5	30	30	12" min length
North Carolina	Year-round	10	100	100	None
North Dakota	Year-Round	None	None	None	None
Ohio	July 1-April 30	None	None	None	13" min length
Oklahoma	Year-round	6	None	None	None
Ontario	Year-round	2	5	None	None
Pennsylvania	July 1-Oct31	15	30	None	None
Rhode Island	Year-round	None	None	None	12" min length
South Carolina	Year-round	None	None	None	None
South Dakota	Year-round	2	4	None	None
Tennessee	Year-round	5	10	None	12" min length
Texas	Year-round	None	None	None	None
Virginia	Year-round	5	None	None	None
West Virginia	July 16-May14	10	20	None	None
Wisconsin	July 15-Nov 30	3	3	None	12" min 16" max length

Table 3. Snapping turtle harvest regulations by state (Alabama Department of Conservation and Natural Resources, 2013, Commonwealth of Massachusetts Department of Fish and Game, 2014, Conneticut Department of Energy and Environmental Protection, Illinois Administrative Code (a) 2013, Illinouis Administratvie Code (b), 2013, Delaware Department of Natural Resources and Environmental Control: Division of Fish and Wildlife, 2013, Florida Fish and Wildlife Conservation Commission, 2013, Georgia Department of Natural Resources: Wildlife Resources Division, Indiana Department of Natural Resources, 2013, Ministry of Natural Resources, 2013, Missoui Department of Conservatoin, 2014, Nanjappa, P. and P. M. Conrad, 2011, Nebraska Game and Parks Commission, 2013, New Hampshire Fish and Game Department, 2013, New York Department of Environmental Conservation, 2013, Ohio Department of Natural Resources Division of Wildlife, 2013, Oklahoma Department of Wildlife Conservation, 2013, South Dakota Department of Game, Fish and Parks, 2013, State of Rhode Island and Providence Plantions Department of Environmental Management Division of Fish and Wildlife, 2013, Tennessee Wildlife Resources Agency, 2013, Virginia Department of Game and Inland Fisheries, 2014, West Virginia Division of Natural Resources, 2014, Wisconsin Department of Natural Resources Bureau of Fisheries Management, 2013).

Figures

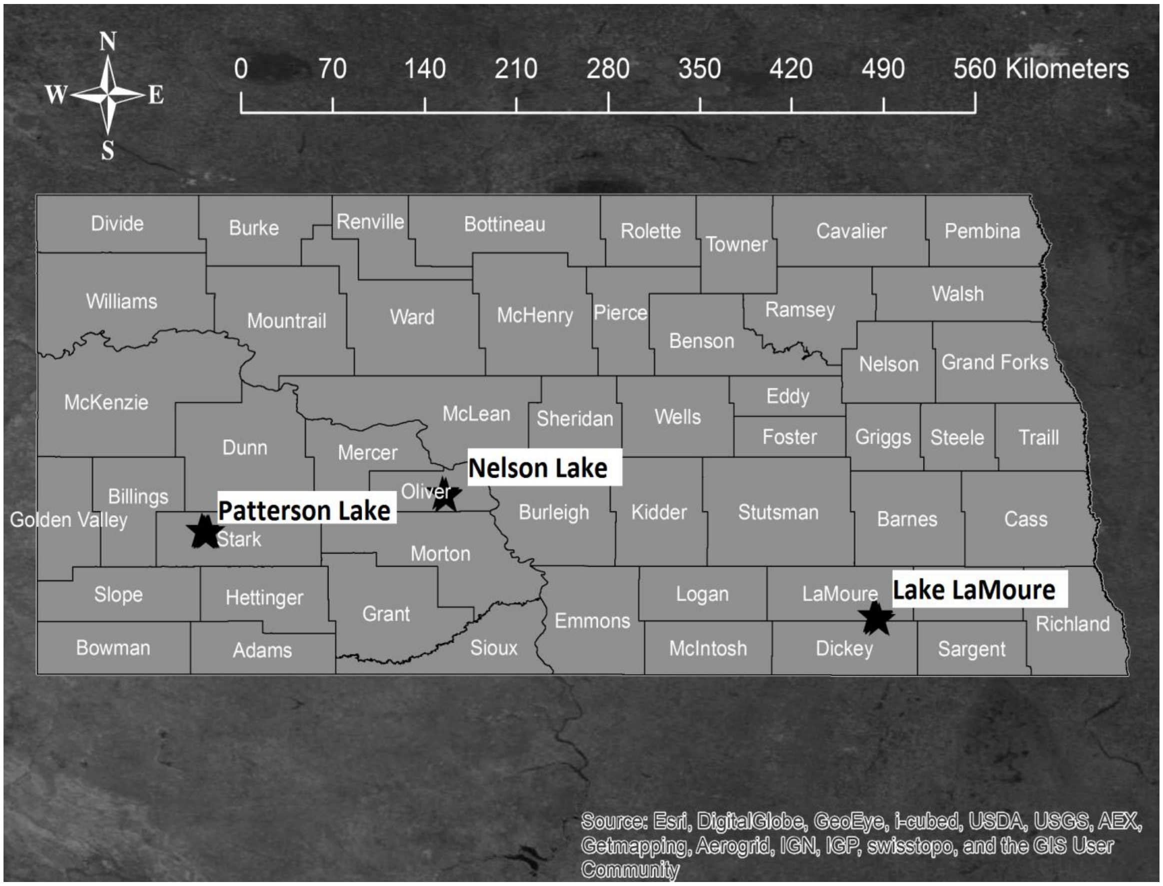


Figure 1. Map showing the locations of the study lakes within the state of North Dakota, stars indicate the locations.

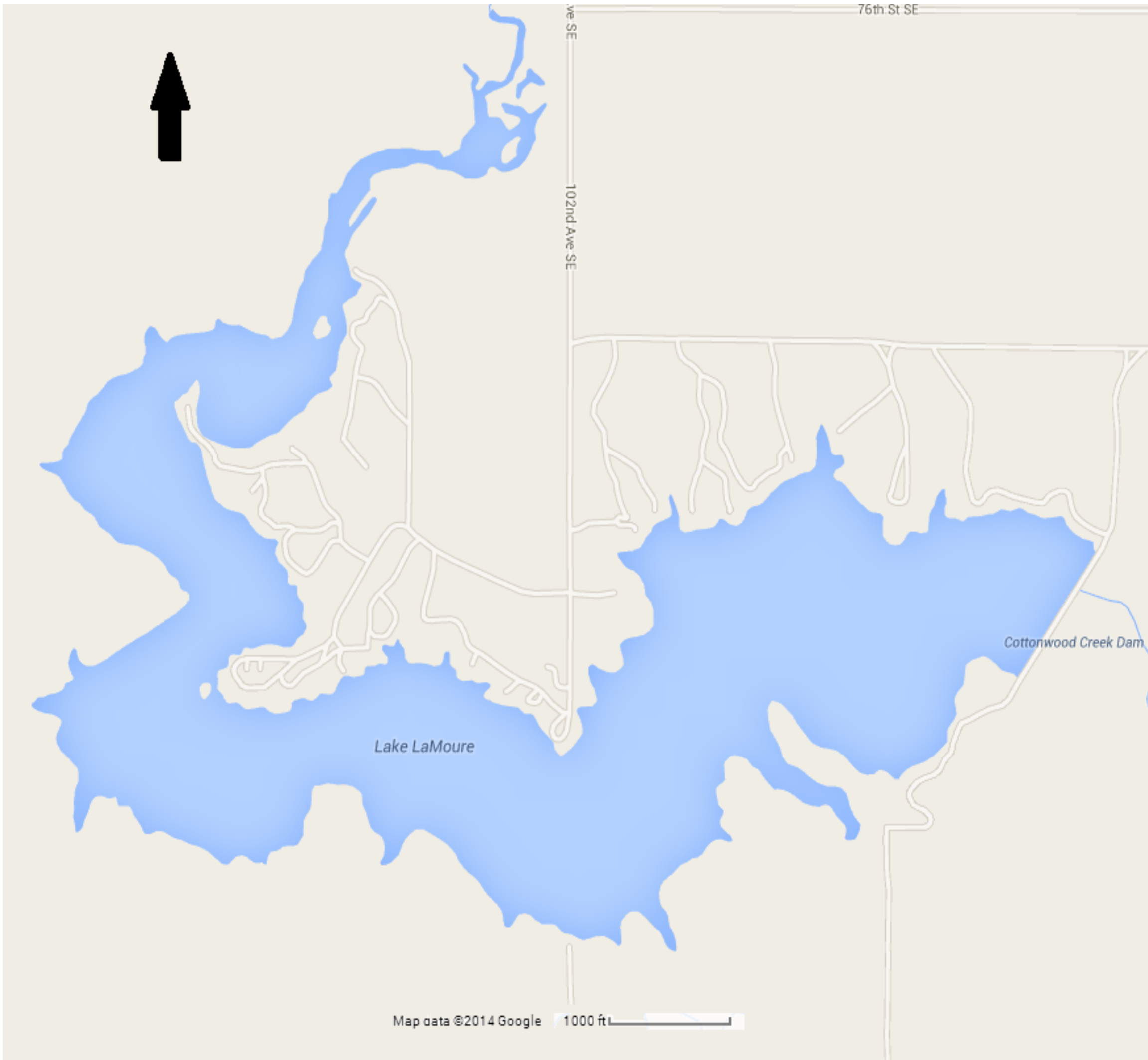


Figure 2. Map of Lake LaMoure.

Figure 3. Map of Nelson Lake

Figure 4. Map of Patterson Lake.

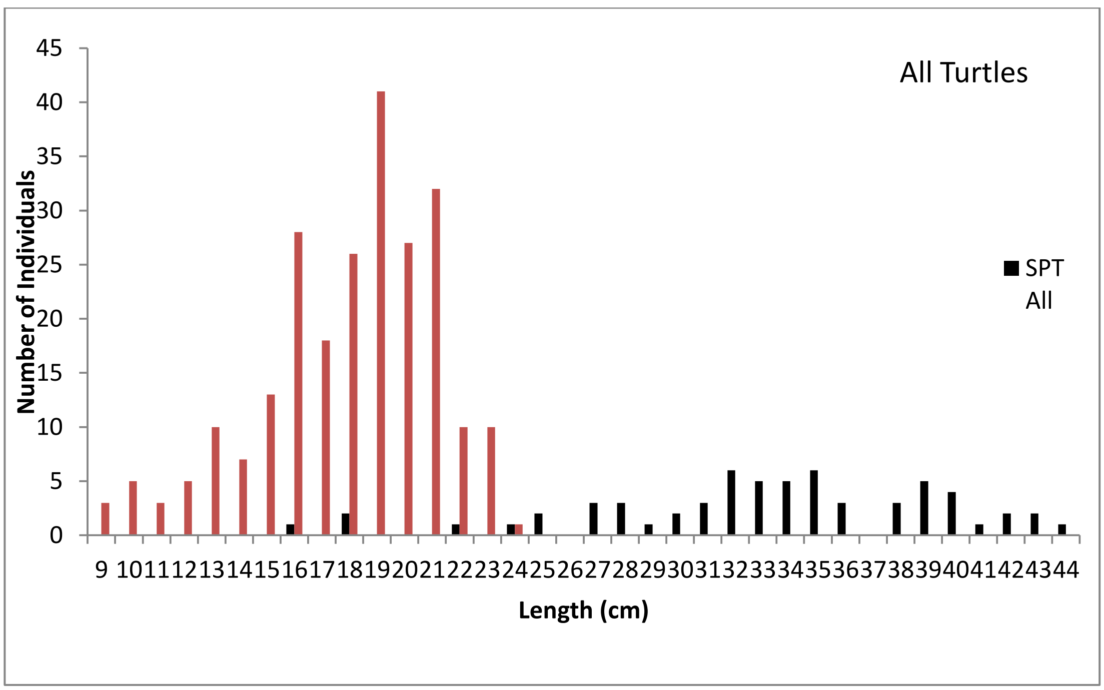


Figure 5. Length frequency histogram for all painted turtles and snapping turtles captured in North Dakota.

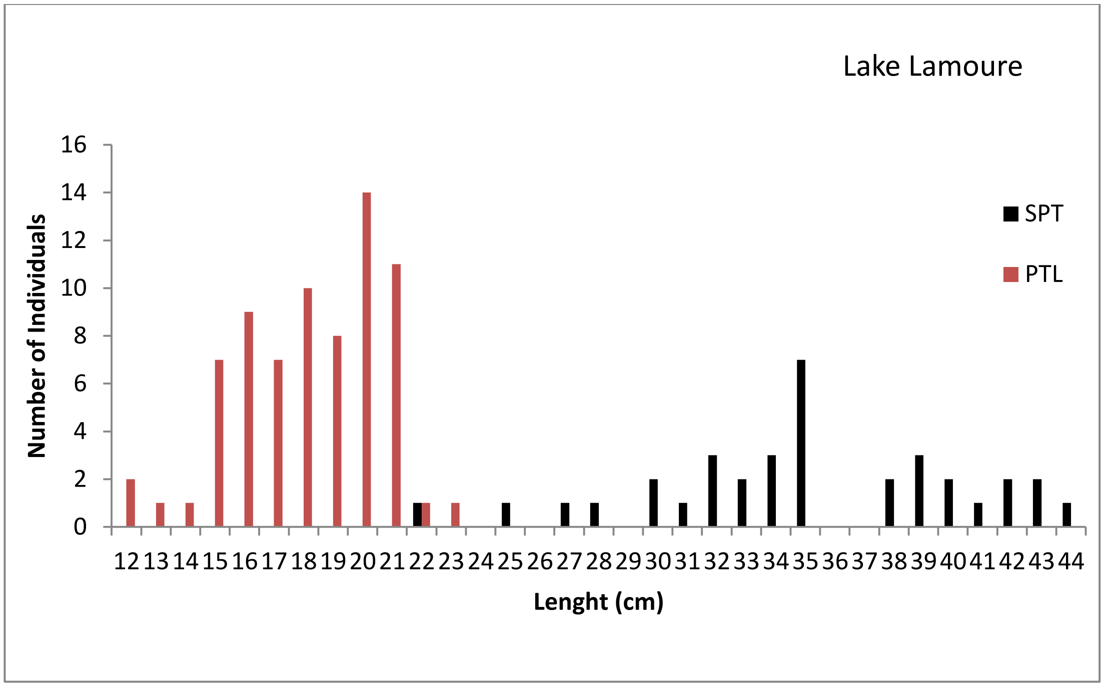


Figure 6. Length frequency histogram for painted turtles and snapping turtles captured at Lake LaMoure.

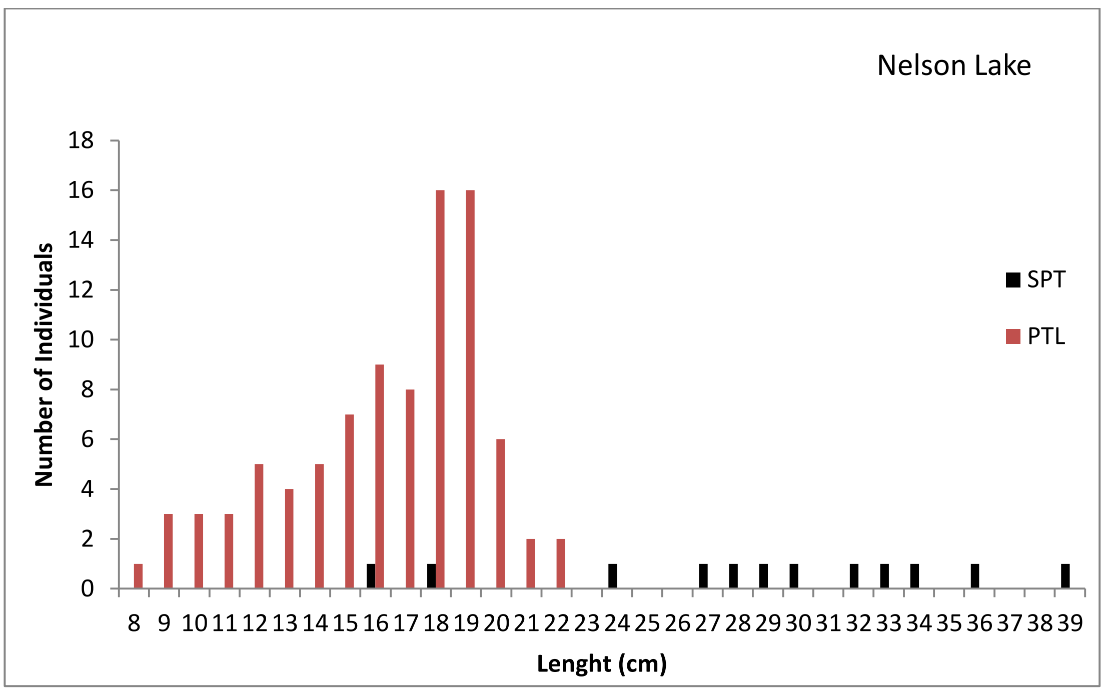


Figure 7. Length frequency histogram for painted turtles and snapping turtles captured at Nelson Lake.

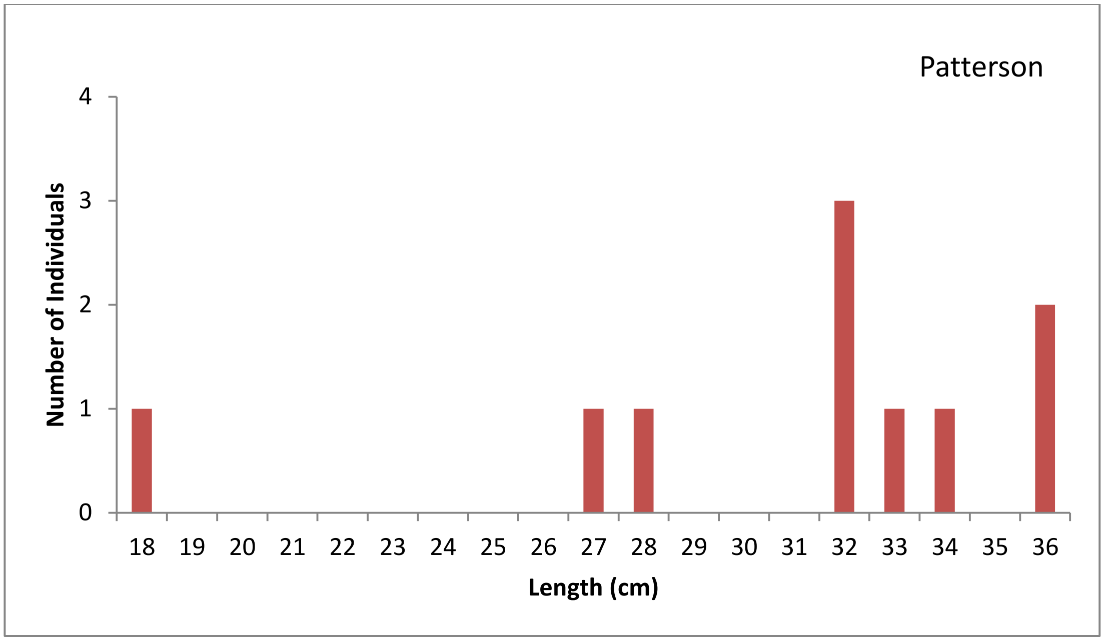


Figure 8. Length frequency histogram for snapping turtles captured at Patterson Lake.

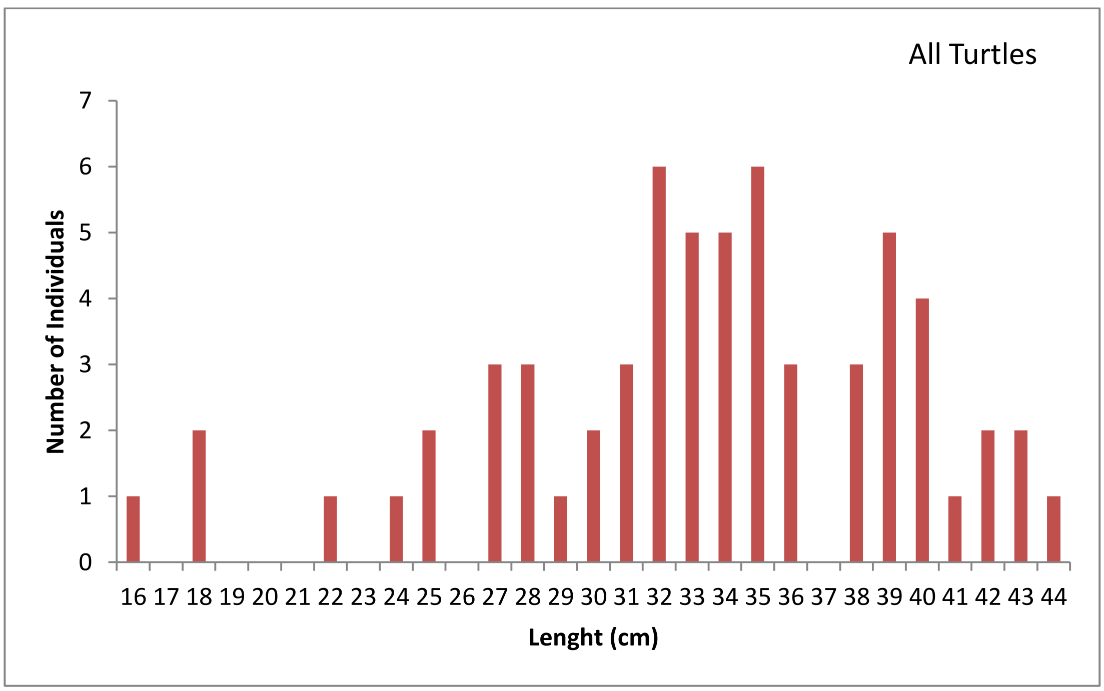


Figure 9. Length frequency histogram for all snapping turtles captured in North Dakota.

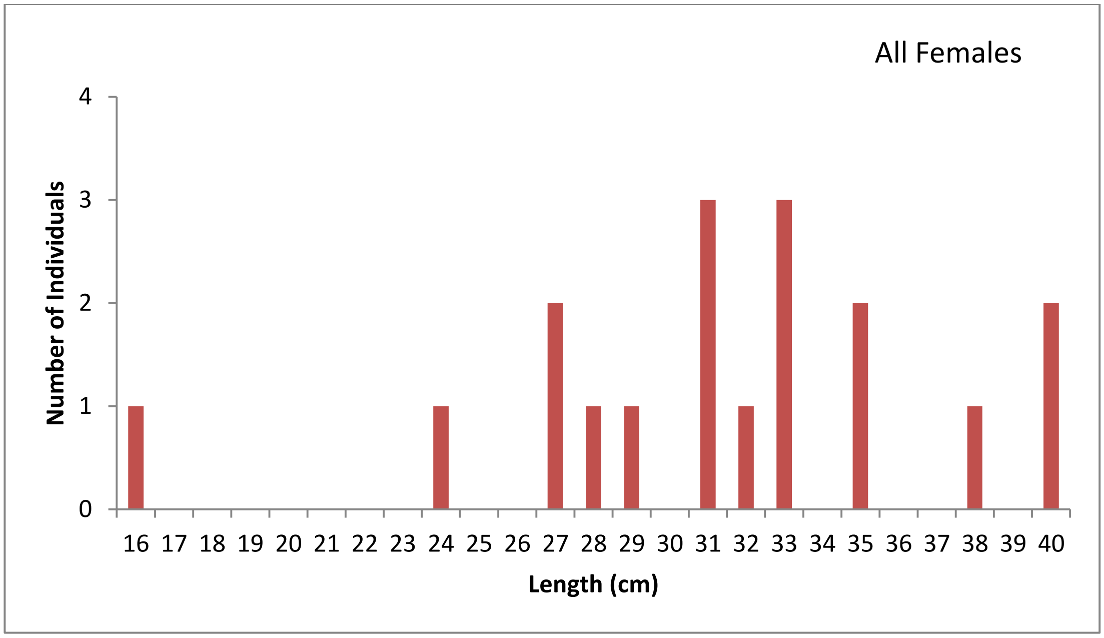


Figure 10. Length frequency histogram for all female snapping turtles captured in North Dakota.

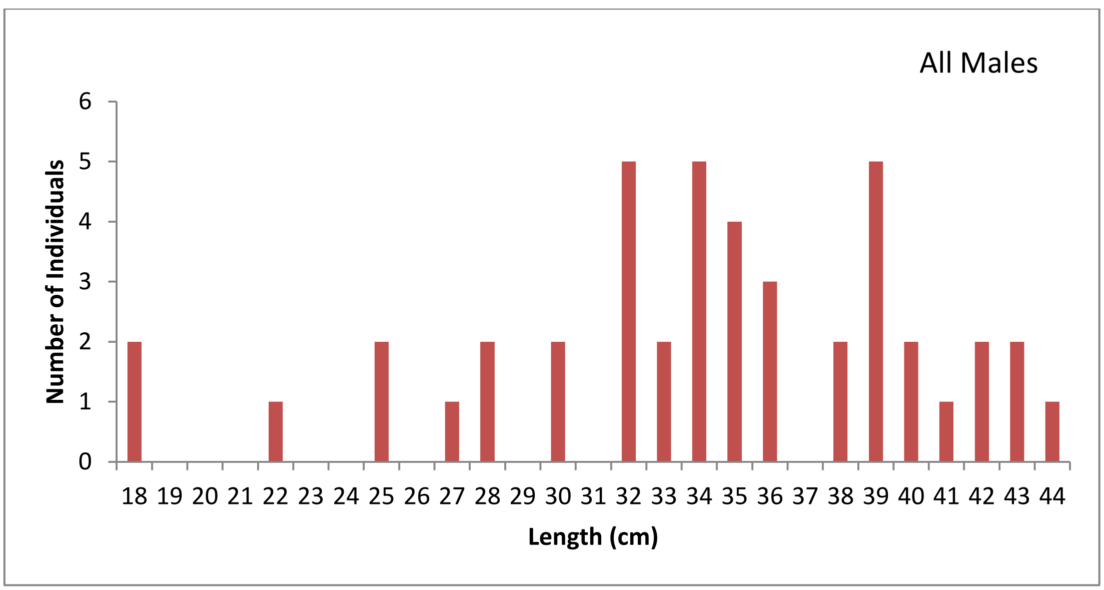


Figure 11. Length frequency histogram for all male snapping turtles caputred in North Dakota.

Figure 12. Estimated 25 year old snapping turtle.

Figure 13. Unknown age snapping turtle.

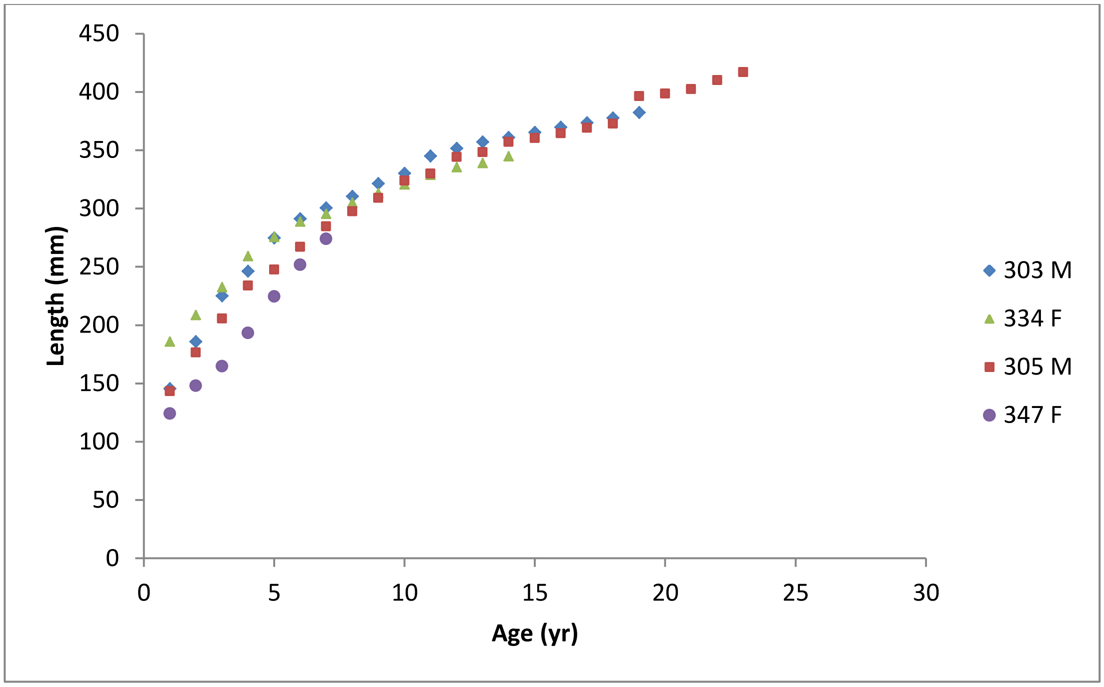


Figure 14. A representation of the back calculated growth patterns of four turtles captured in North Dakota. Along the x axis age is denoted in years and along the y axis length is denoted in millimeters. The equation used to back calculate length at age was $L_i = \frac{S_i}{S_c} * L_c$ where L_i is the back calculated carapace length, S_i is the distance from the focus to the annuli, S_c is the distance from the focus to the edge of the scute, and L_c is the carapace length at capture (Le Cren, 1977).

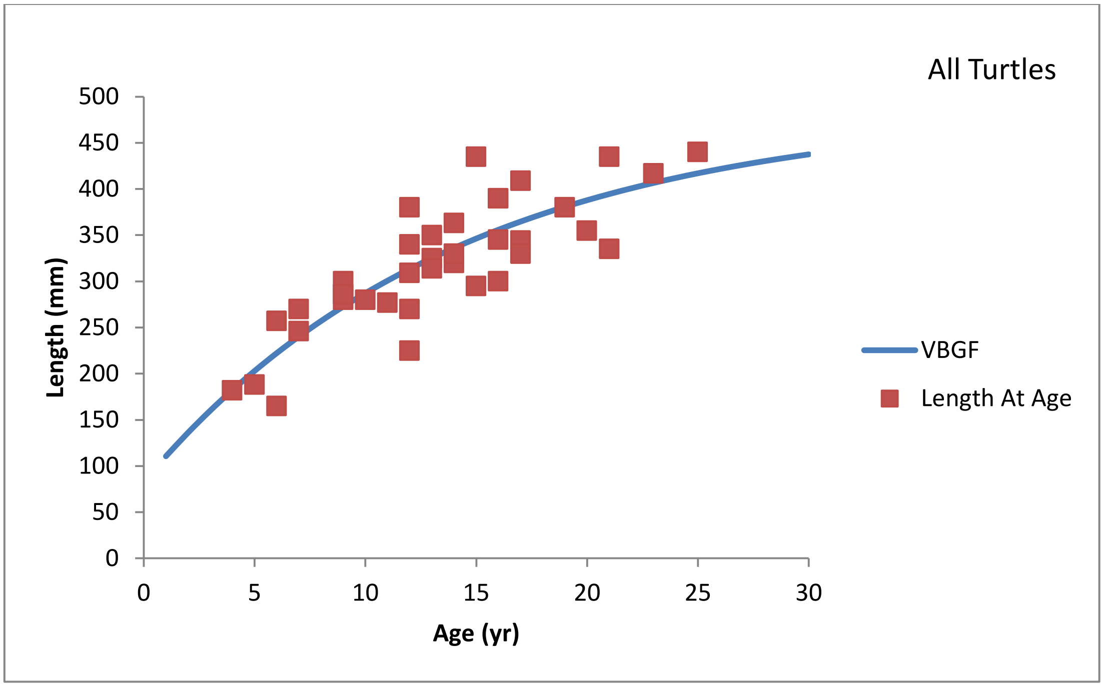


Figure 15. Von Bertalanffy growth function for length at age of snapping turtles captured in North Dakota. Along the x axis age is denoted in years and along the y axis length is denoted in millimeters. The equation for Von Bertalanffy is $L_t = L_\infty[1 - e^{-K(t-t_0)}]$. The specific equation for all turtles in North Dakota is $L_t = 485.8[1 - e^{-0.0707(t+2.6531)}]$.

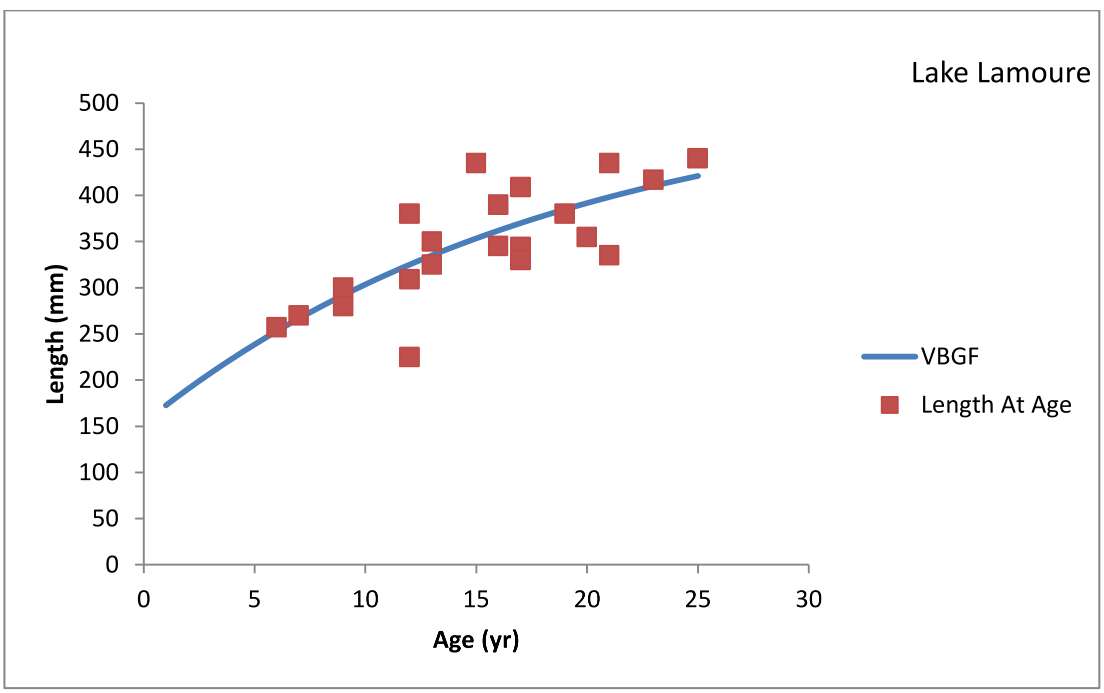


Figure 16. Von Bertalanffy growth function for length at age of snapping turtles captured at Lake LaMoure. The equation used was $L_t = 517.8[1 - e^{-0.053(t+6.653)}]$.

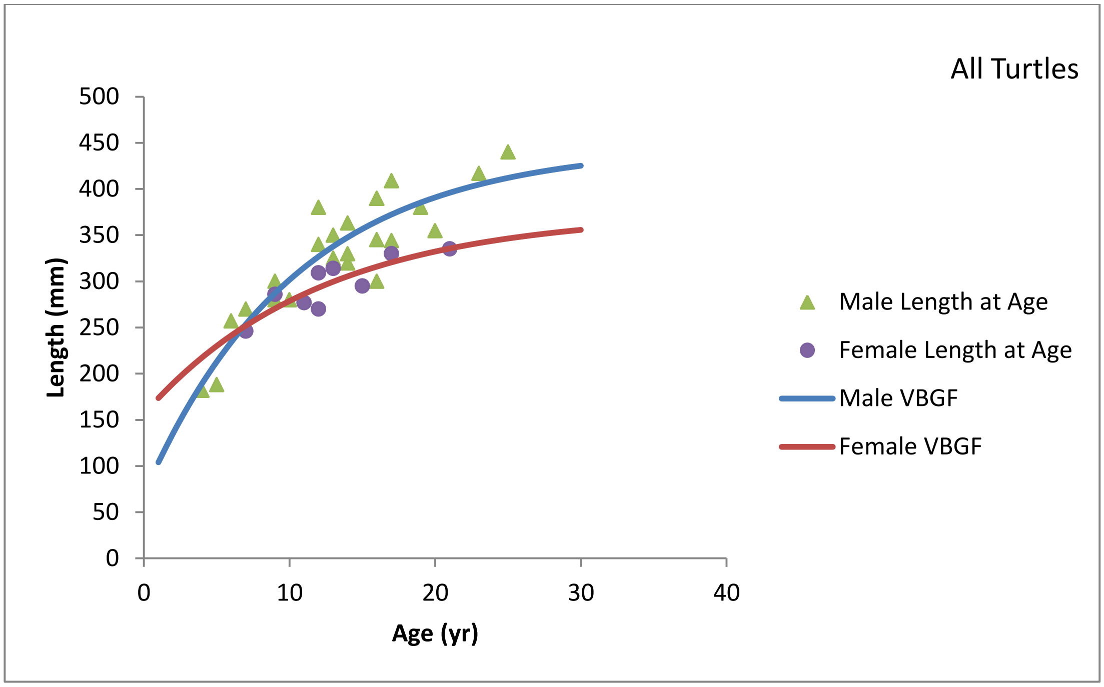


Figure 17. Von Bertalanffy growth function for length at age of male and female snapping turtles captured in North Dakota. The equations used are $L_t = 446.6\left[1 - e^{-0.0956(t+1.7728)}\right]$ and $L_t = 374[1 - e^{-0.0826(t+6.5525)}]$ respecively.

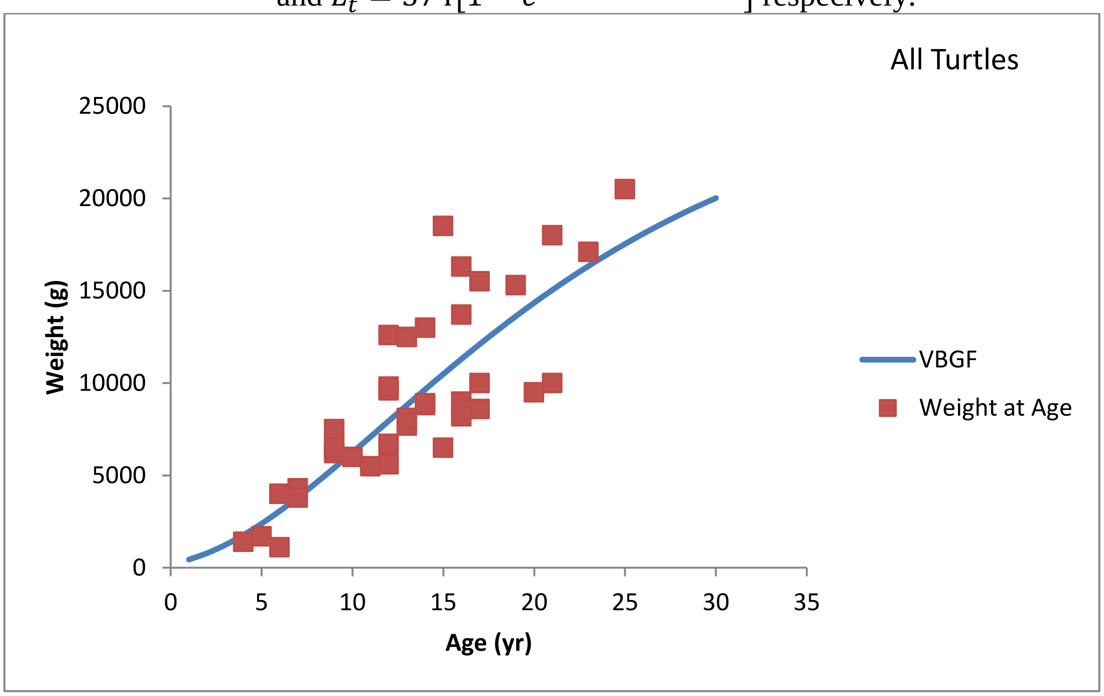


Figure 18. Von Bertalanffy growth function for weight at age of turtles captured in North Dakota. The general equation is used was $W_t = W_\infty[1 - e^{-K(t-t_0)}]^3$ and specifically for this data $W_t = 26745.4[1 - e^{-0.0707(t+2.6531)}]^3$.

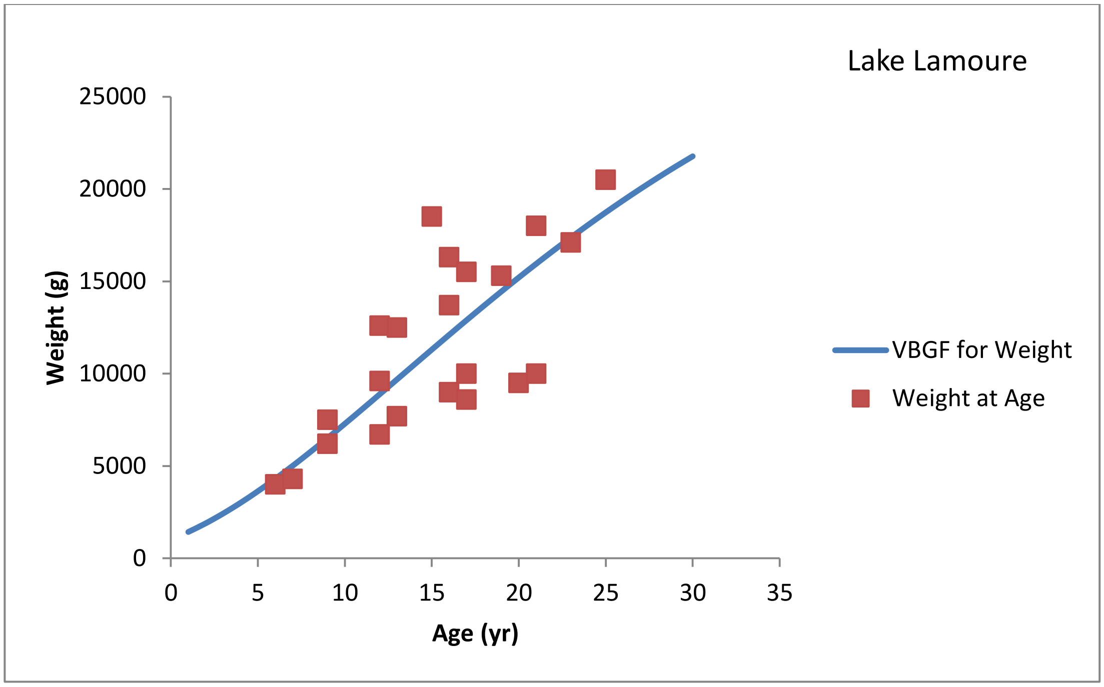


Figure 19. Von Bertalanffy growth function for weight at age of turtles captured at Lake LaMoure. The equation used was $W_t = 34022.815[1 - e^{-0.053(t+6.653)}]^3$.

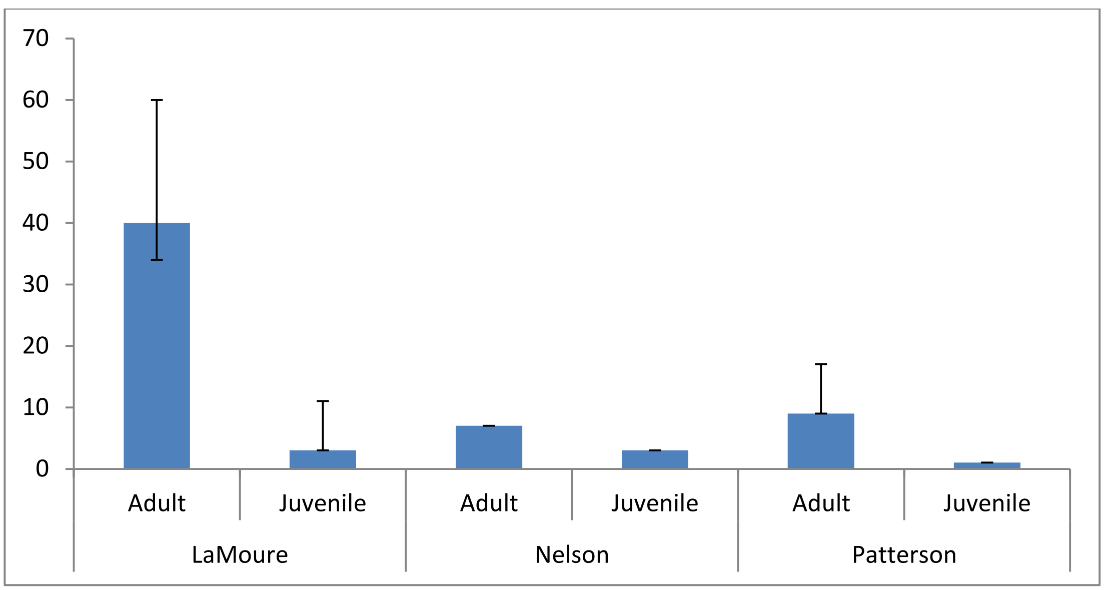


Figure 20. Population estimations from Program Mark with 95% confidence intervals.

Figure 21. Overwintering locations at Lake LaMoure.

Figure 22. Overwintering locations in reference to the entire lake at Lake LaMoure.

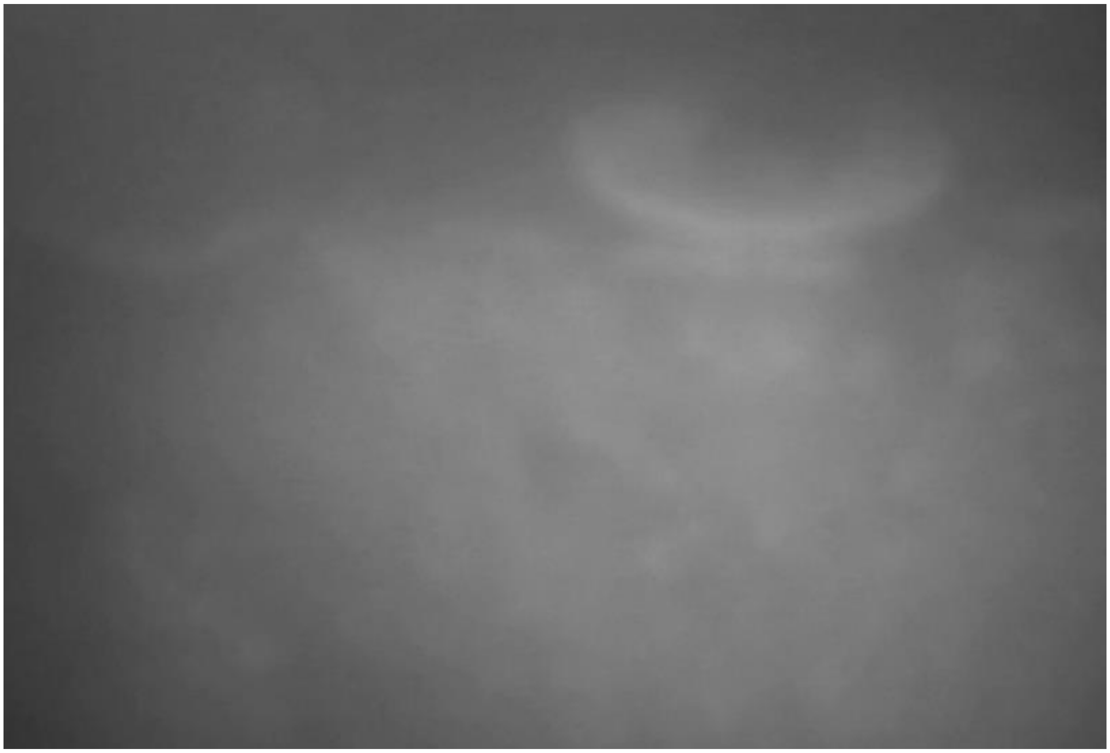


Figure 23. View of disk tag underwater during the winter.

Figure 24. View of disk tag underwater during the winter.

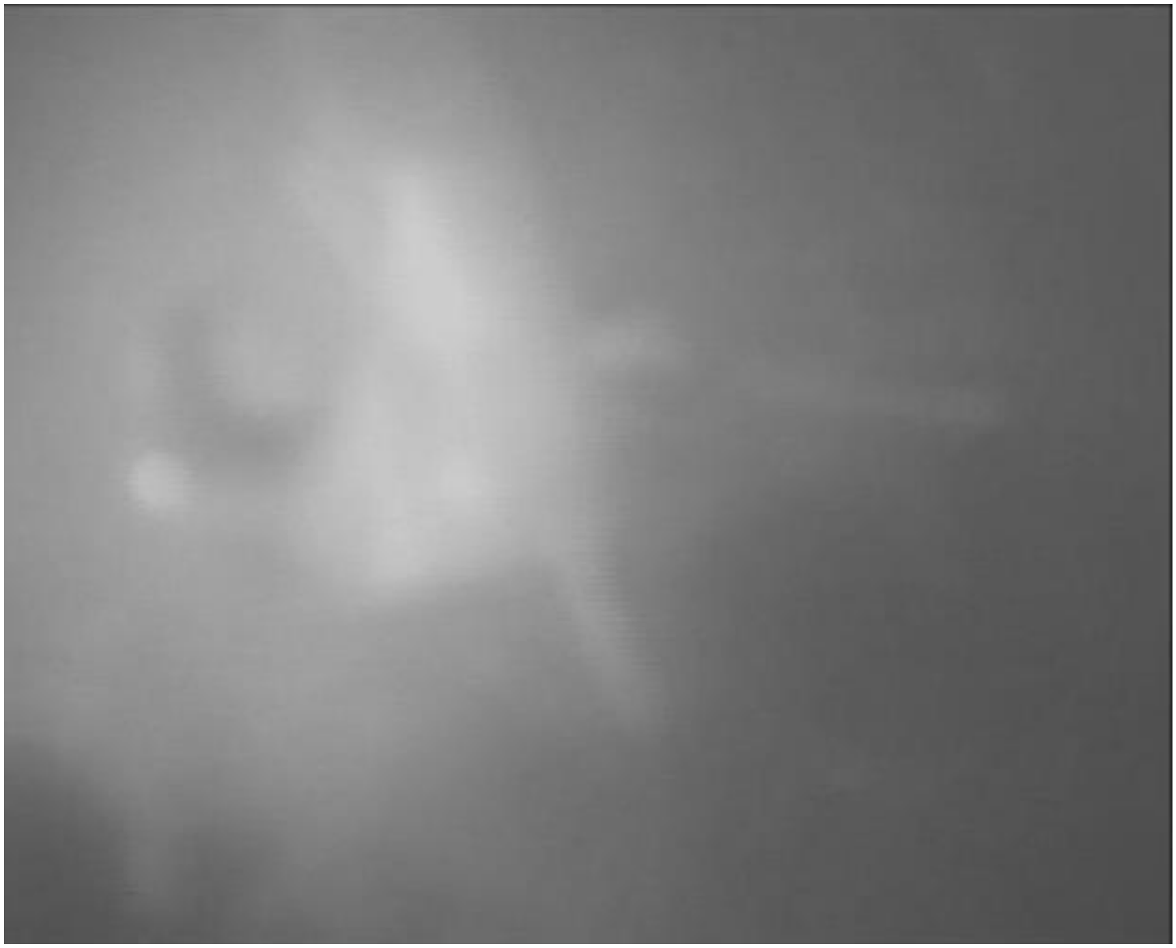


Figure 25. View of radio tag underwater during the winter.

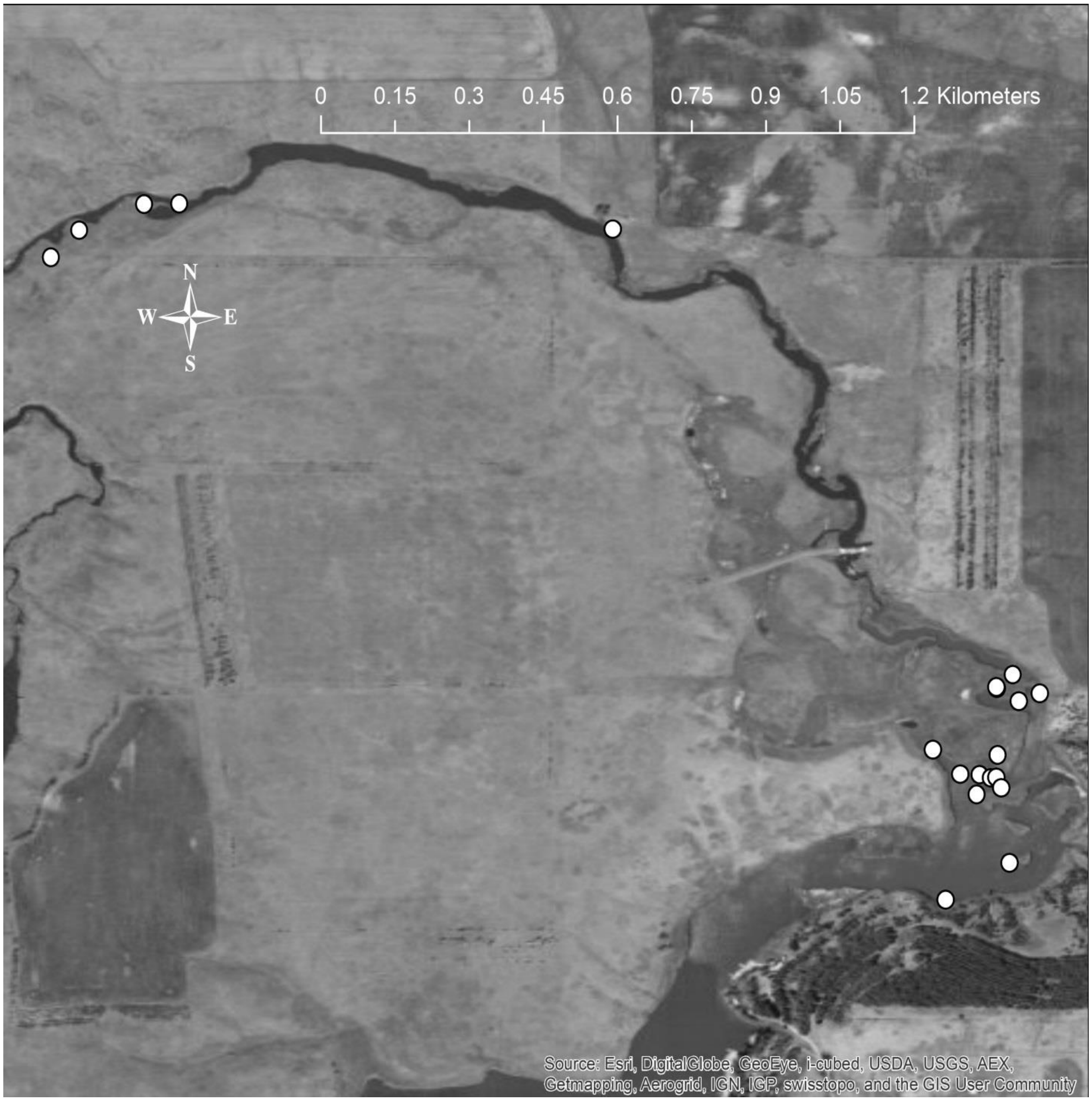


Figure 26. Movements for female turtle 384.

Figure 27. Movements for female turtle 454.

Figure 28. Movements for female turtle 484.

Figure 29. Movements for female turtle 494.

Figure 30. Movements for female turtle 495.

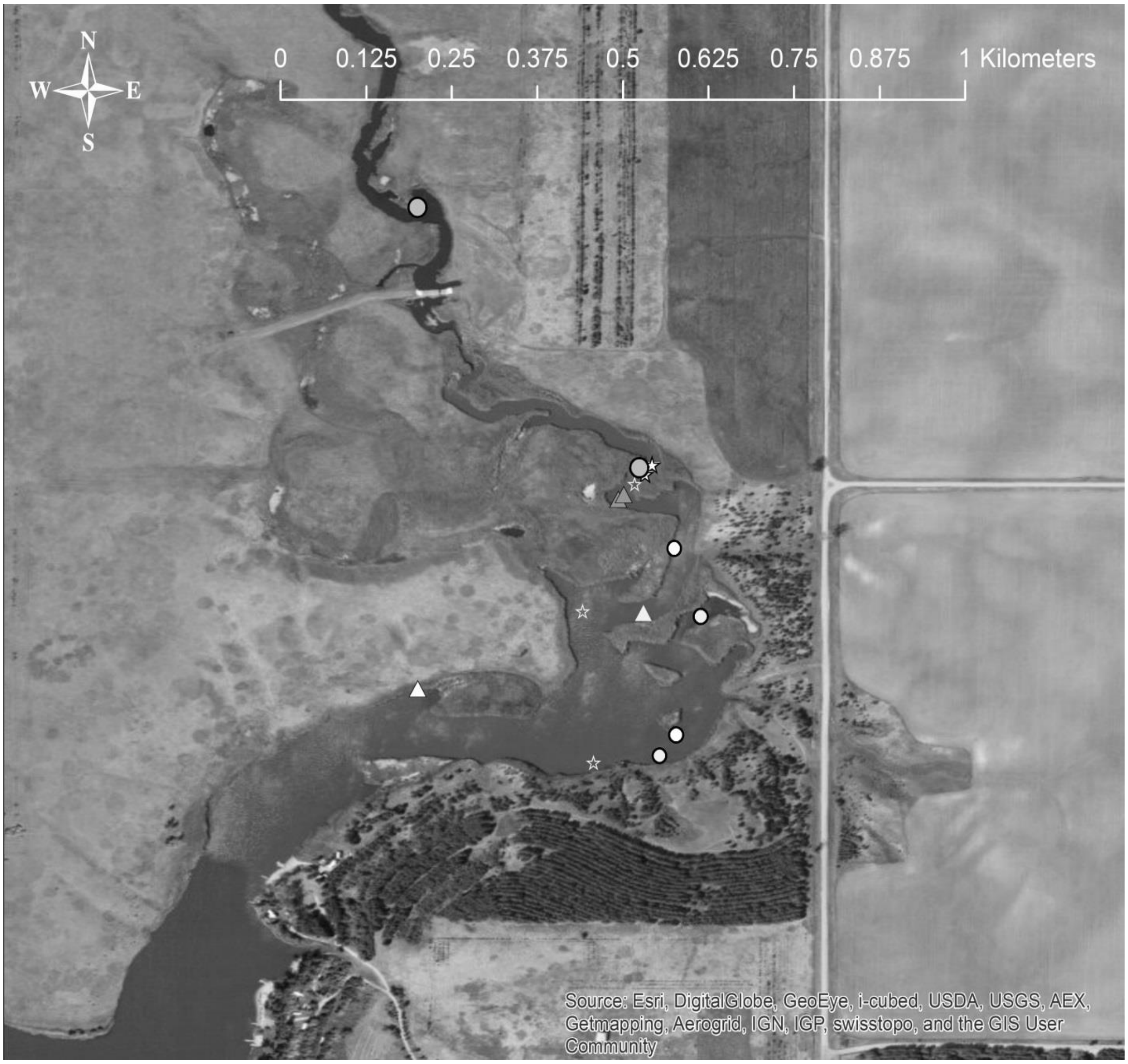


Figure 31. Movements for all male turtles, each male is represented by its own symbol.

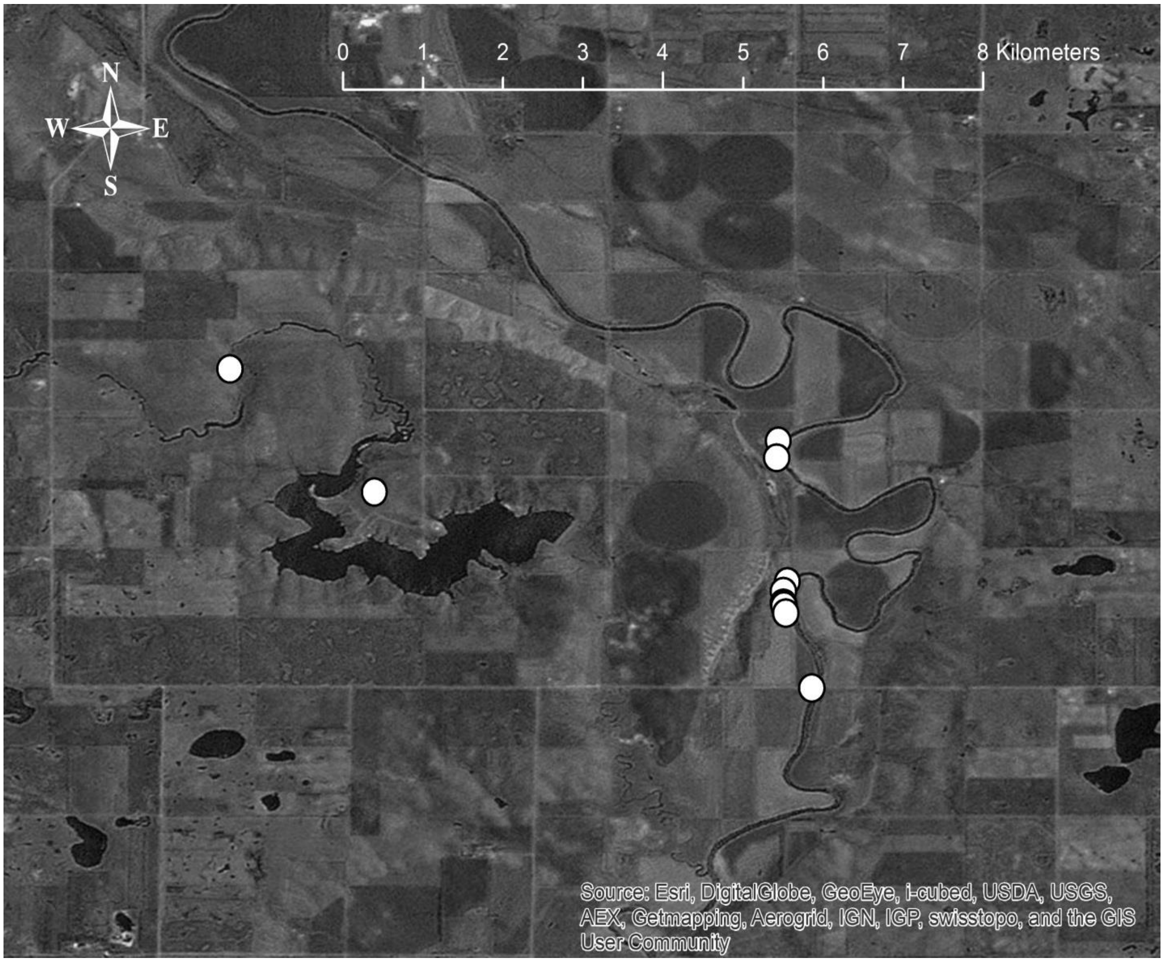


Figure 32. All nesting locations found at Lake LaMoure.

Figure 33. Nesting locations along the James River by Lake LaMoure.

Figure 34. Nesting location on a gravel bar located on Cottonwood Creek, Lake LaMoure's inflow.

Figure 35. Nest location on a gravel road surrounding Lake LaMoure.

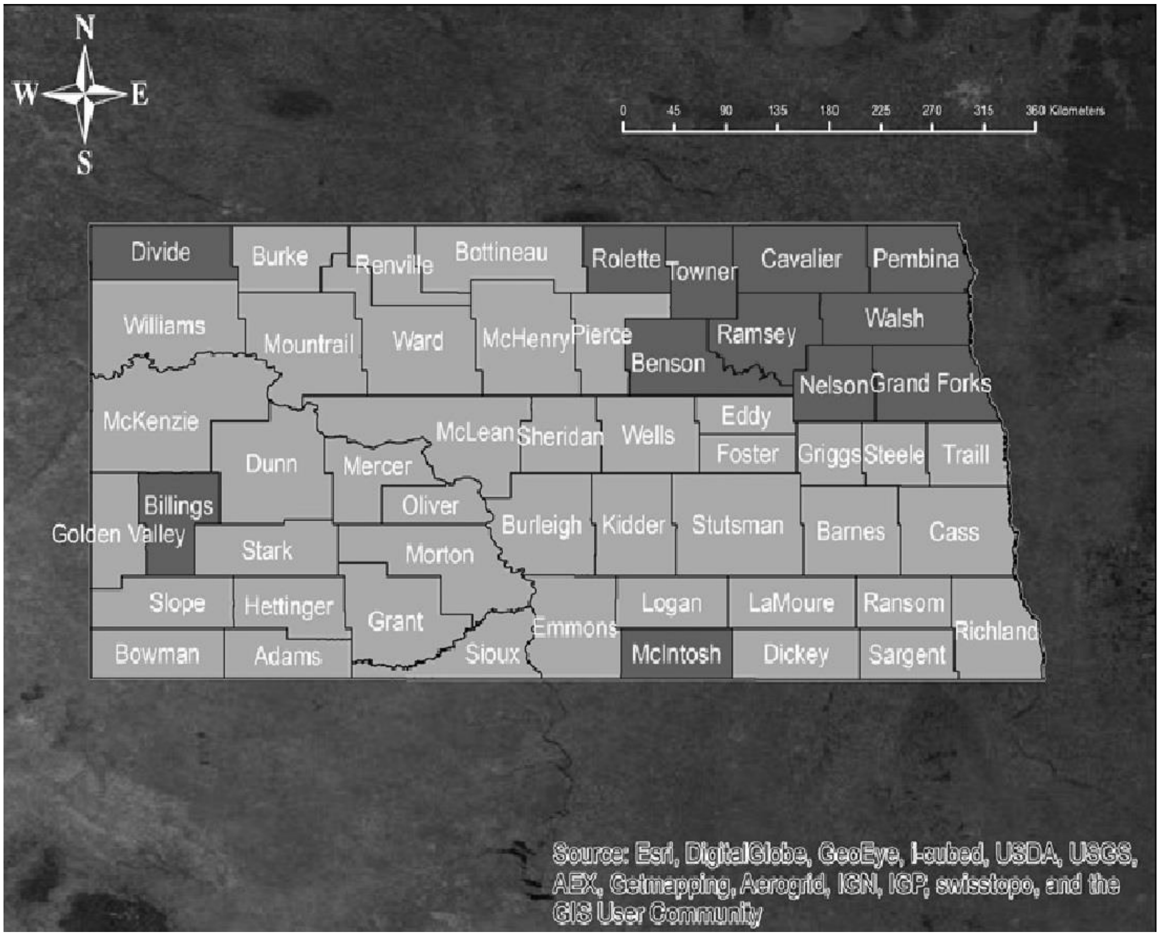


Figure 36. Statewide distribution of snapping turtles in North Dakota, light counties have records of snapping turtle presence and dark counties have no records.

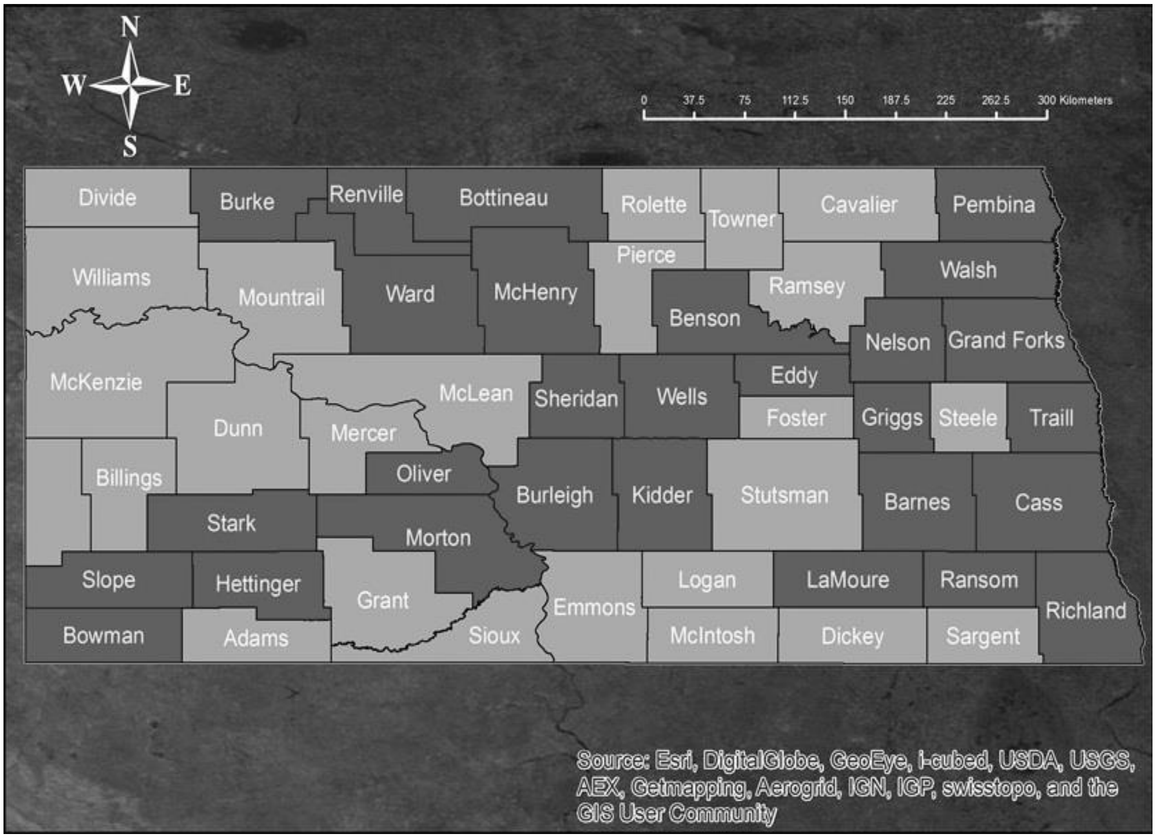


Figure 37. Snapping turtle harvest map from harvest survey, where dark counties represent counties with harvest and dark counties did not have harvest.

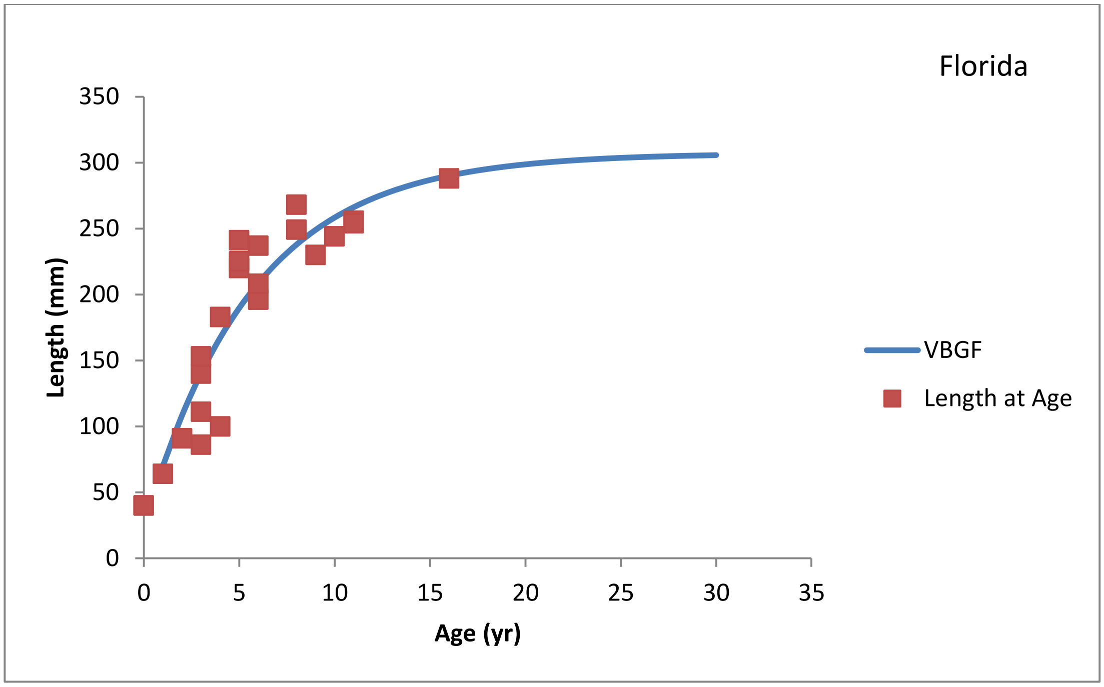


Figure 38. Von Bertalanffy growth function for length at age of turtles captured in Florida. The equation used was $L_t = 307.1[1 - e^{-0.1757(t+0.4757)}]$ (Aresco, unpublished).

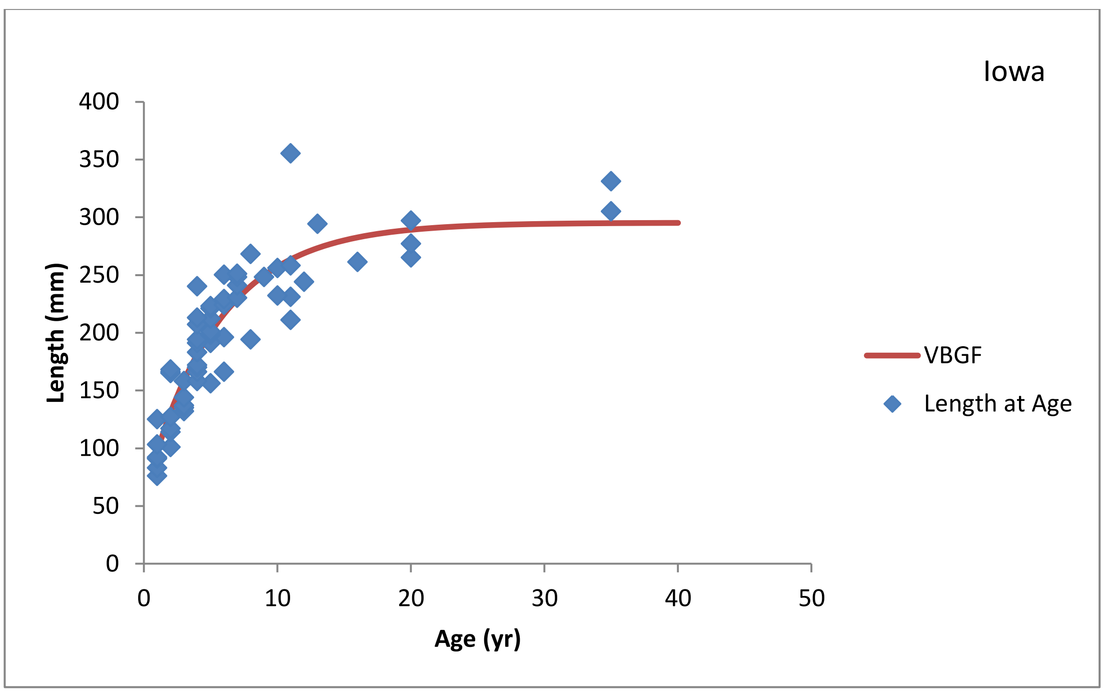


Figure 39. Von Bertalanffy growth function for length at age of turtles captured in Iowa. The equation used was $L_t = 307.1[1 - e^{-0.1757(t+0.4757)}]$ (Christiansen, 1979)

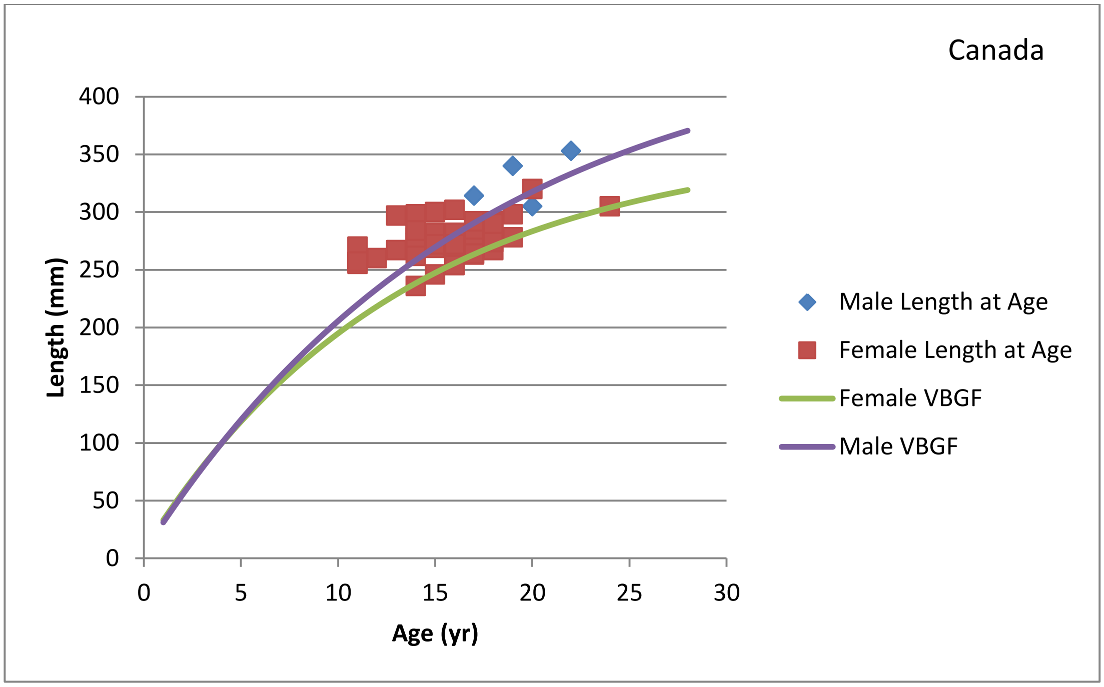


Figure 40. Von Bertalanffy growth function for length at age of turtles captured in Canada. The equation used was $L_t = 307.1[1 - e^{-0.1757(t+0.4757)}]$ (Obbard, 1983).

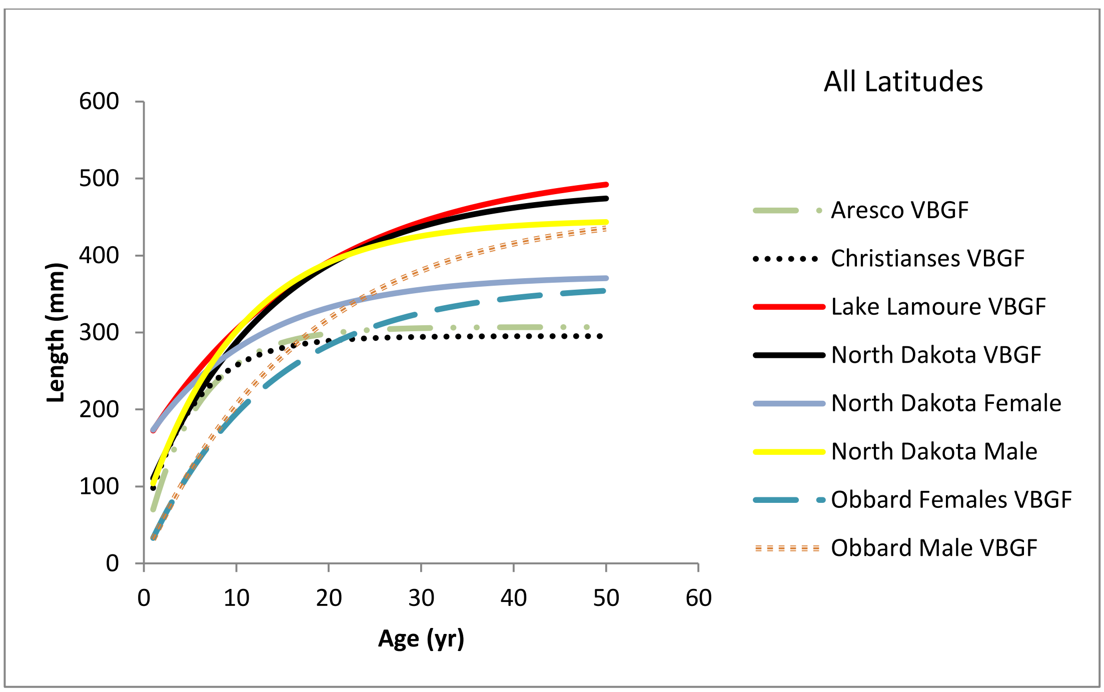
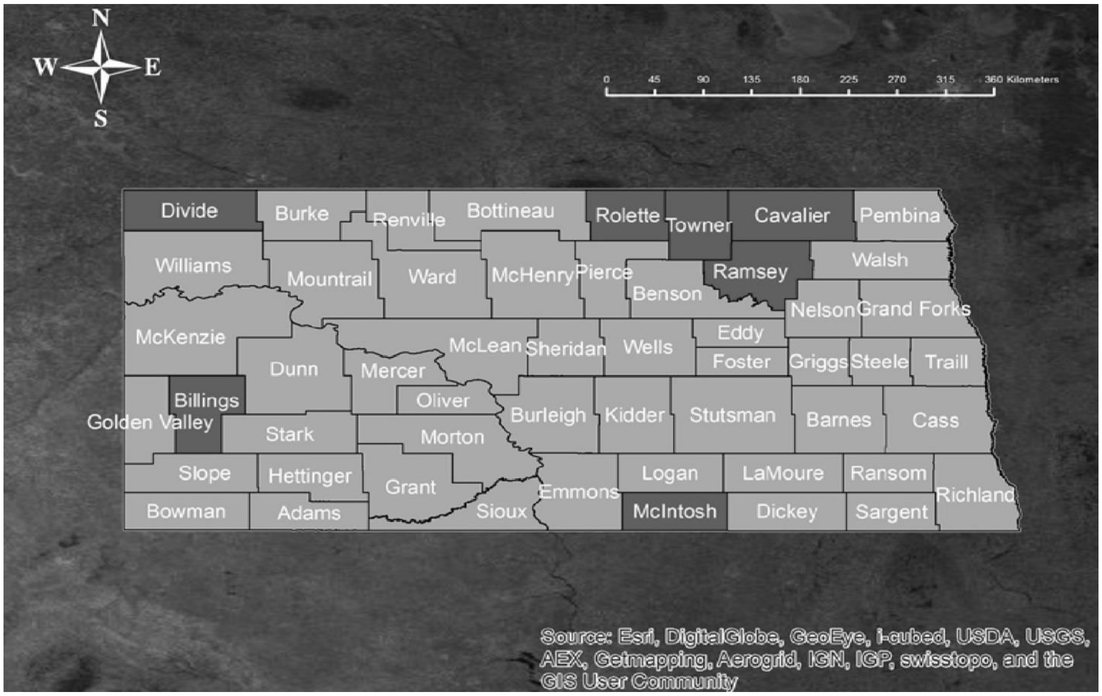
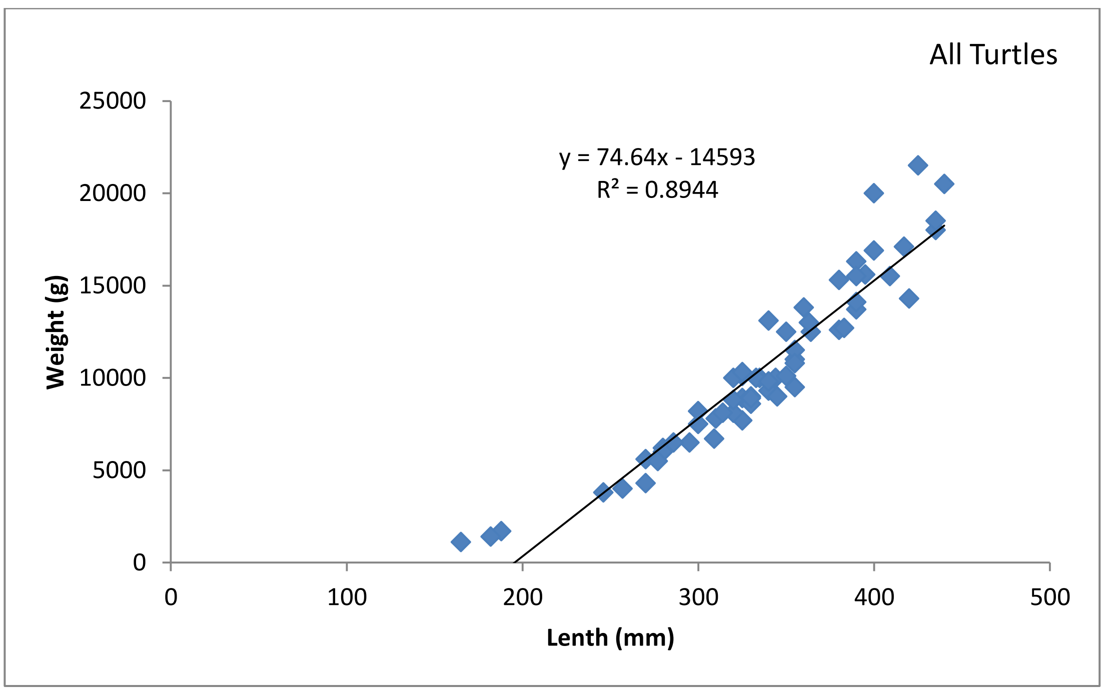


Figure 41. Von Bertalanffy growth functions for Ontario, North Dakota, Iowa, and Florida side by side for comparison (Christiansen 1979, Obbard, 1983, Aresco, unpublished data).

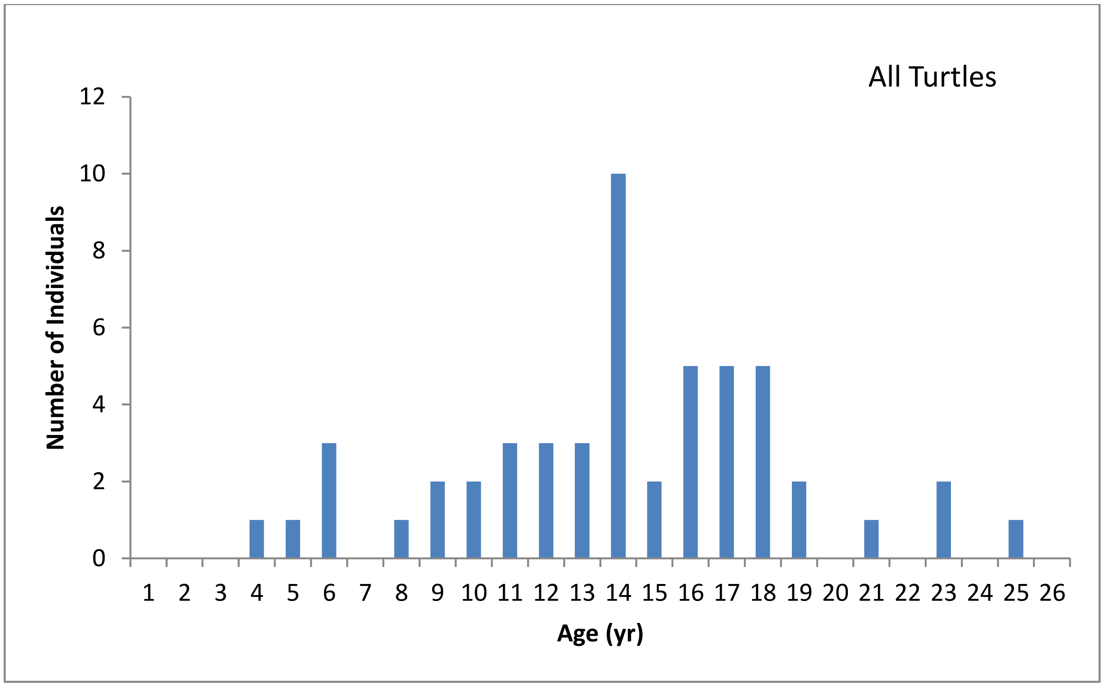
Supporting Figures



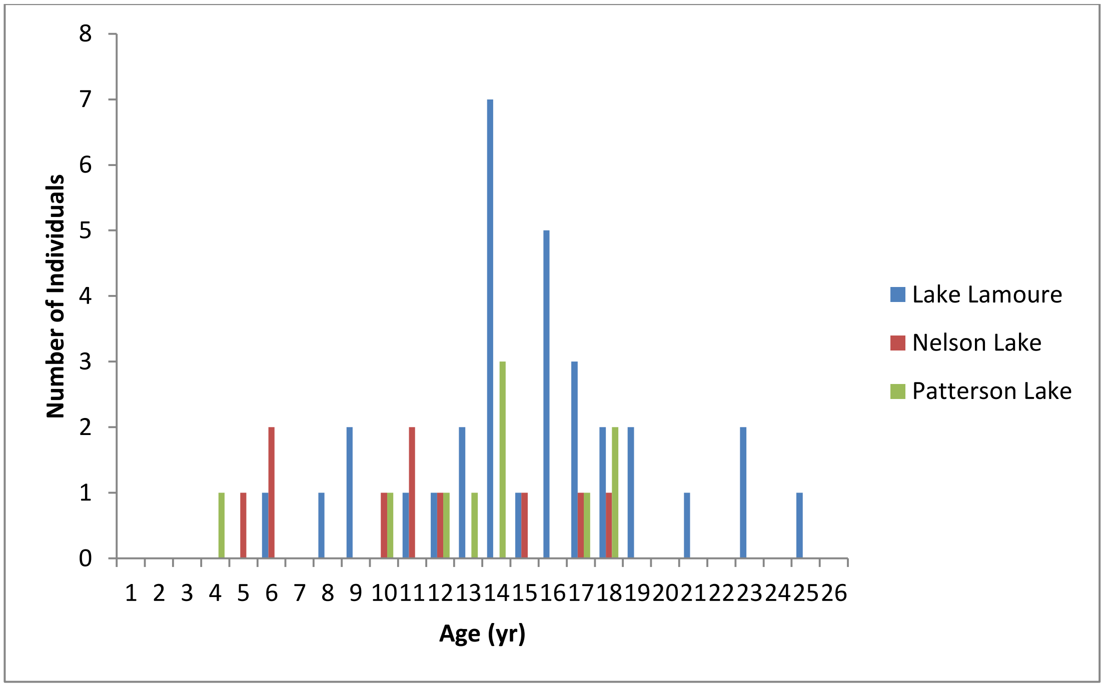
Updated statewide distribution map that includes counties represented on the harvest map. Light counties represent counties with records of snapping turtles and dark counties have no record.



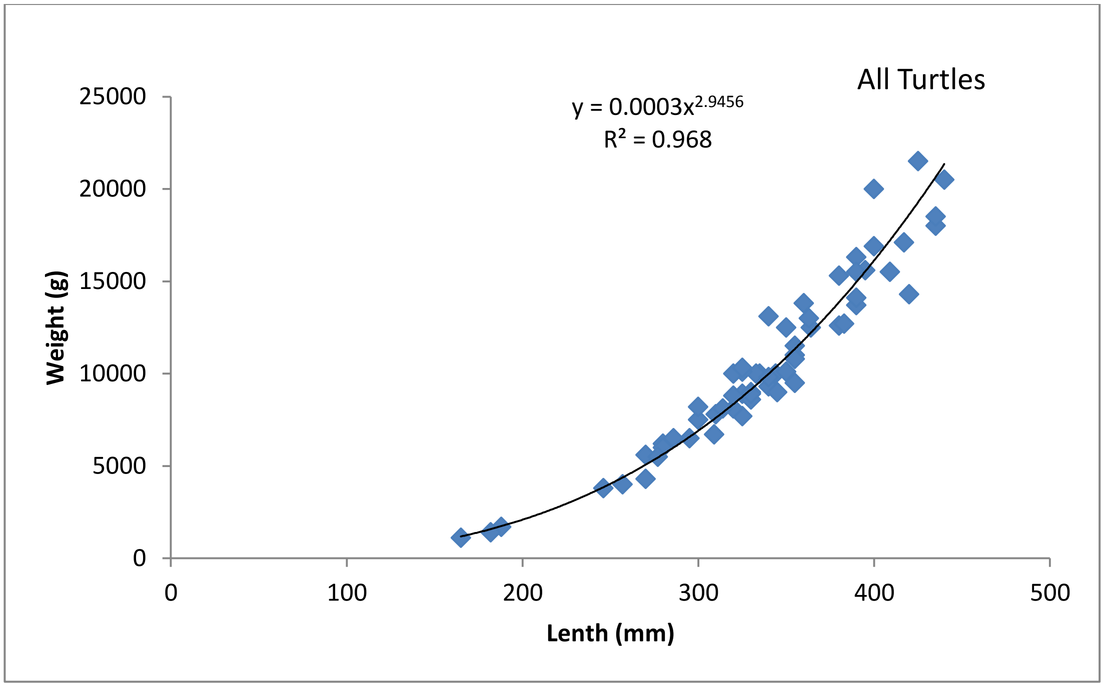
Length (L) vs. weight (W) linear regression for all snapping turtles that were captured in North Dakota. Length is along the x axis in millimeters and weight is along the y axis in grams. A linear trend line was fitted to the data and the resulting equation is shown.



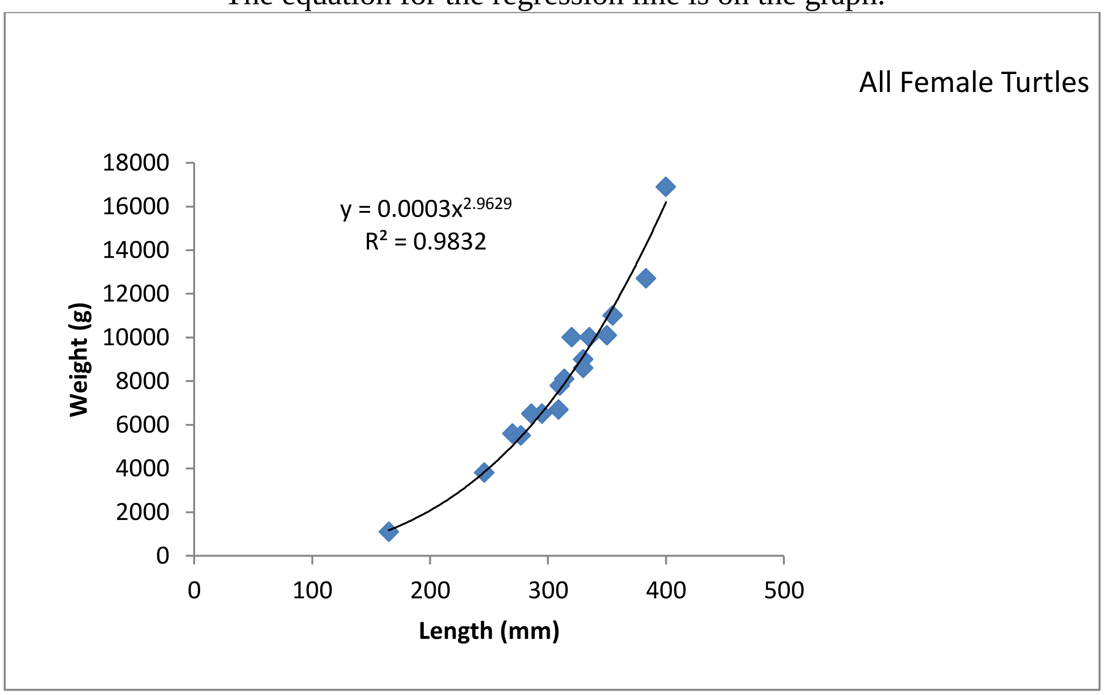
Age frequency histogram showing the number of individual in each age class. Along the x axis age is denoted and along the y axis the number of individuals in each age class is denoted.



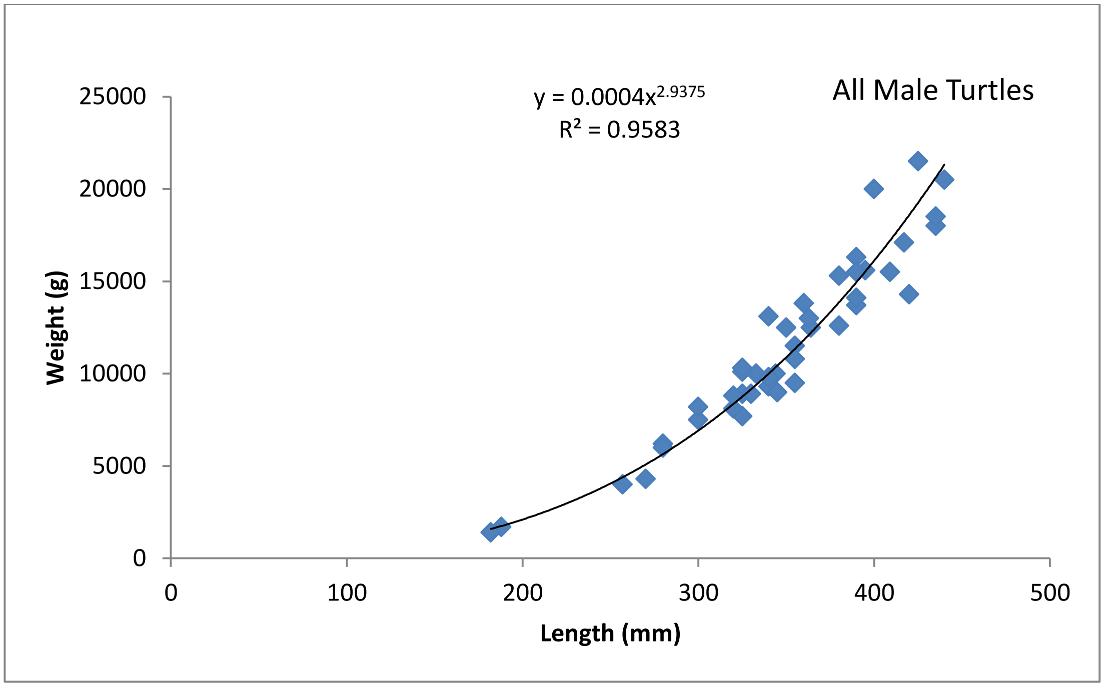
Age frequency histogram showing the number of individuals in each age class and the lake they were captured in.



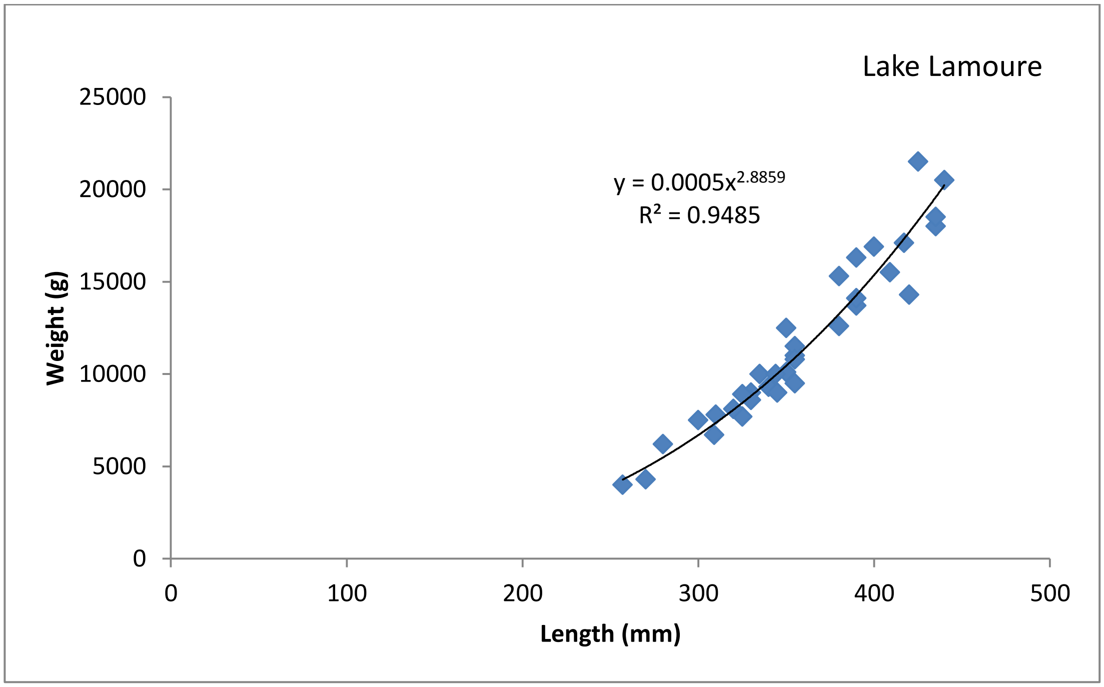
Length (L) vs. weight (W) power regression for all snapping turtles captured in North Dakota. The equation for the regression line is on the graph.



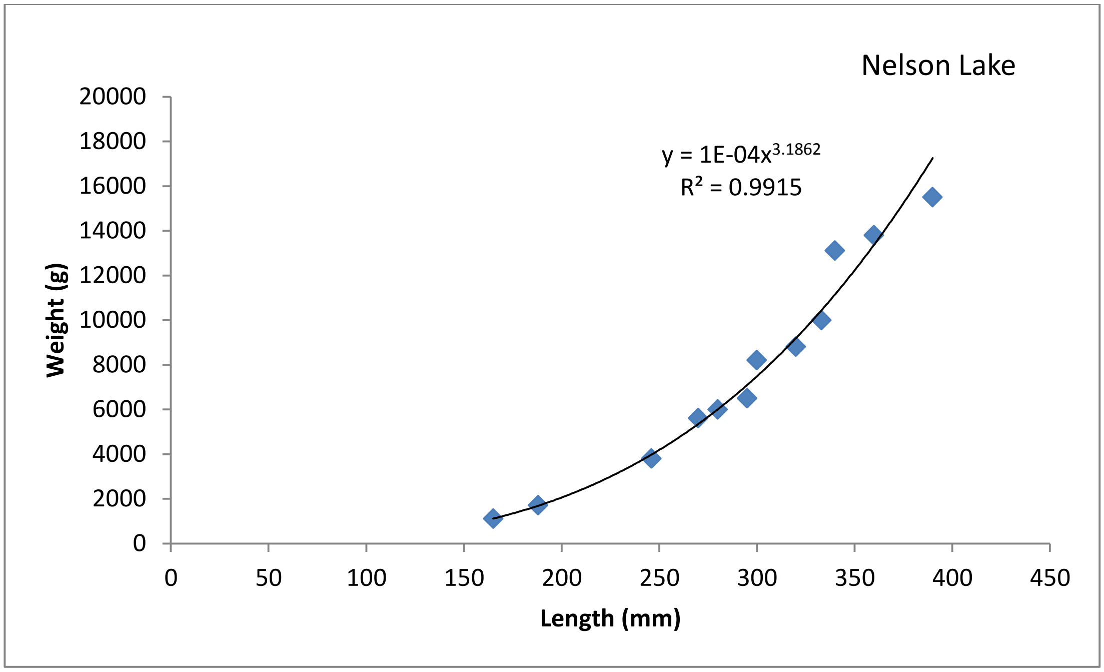
Length (L) vs. weight (W) power regression for all female snapping turtles captured in North Dakota.



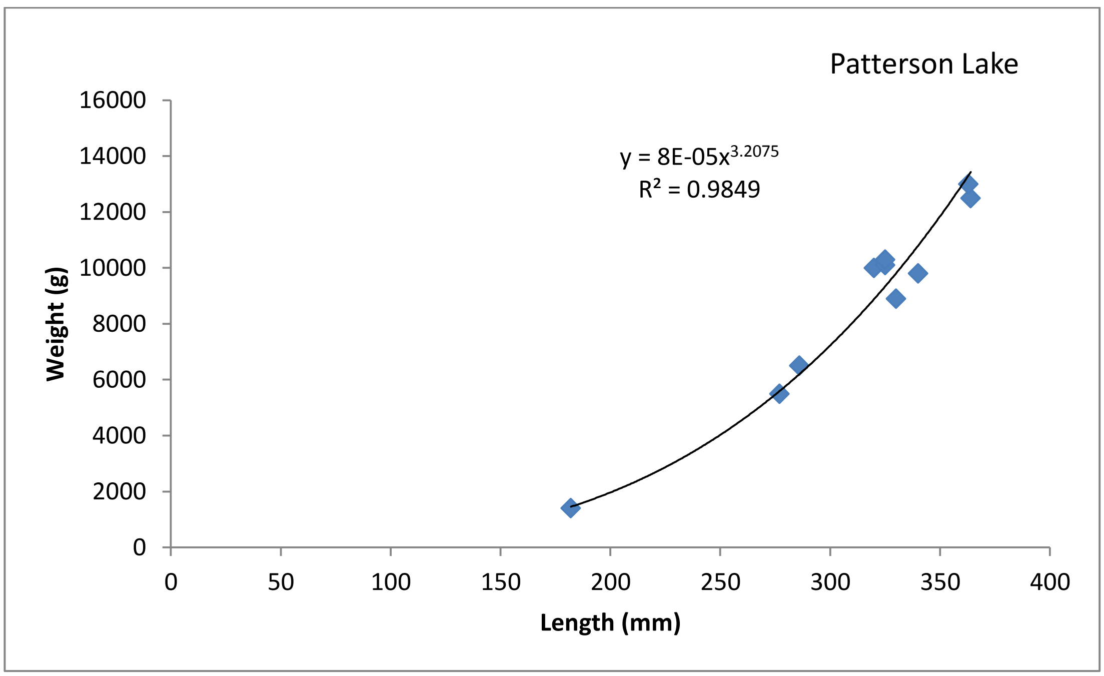
Length (L) vs. weight (W) power regression for all male snapping turtles captured in North Dakota.



Length (L) vs. weight (W) power regression for snapping turtles captured at Lake LaMoure.



Length (L) vs. weight (W) power regression for snapping turtles captured at Nelson Lake.



Length (L) vs. weight (W) power regression for snapping turtles captured at Patterson Lake.