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Age Determination of Common Snapping Turtles (Chelydra Serpentina) in West Central Minnesota

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AGE DETERMINATION OF COMMON SNAPPING TURTLES (*Chelydra serpentina)* IN WEST CENTRAL MINNESOTA

by

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This thesis submitted by Justin J. Jenniges in partial fulfillment of the requirements for the Degree of Master of Arts at St. Cloud State University are hereby approved by the final evaluation committee.

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AGE DETERMINATION OF COMMON SNAPPING TURTLES
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Common snapping turtles (*Chelydra serpentina serpentina L.*) from west central Minnesota were captured as by-catch in modified fyke nets placed in commercial fish rearing ponds during the summers of 1998-1999 (n = 111). Individuals were examined to determine sex, mass, age, circumference at midpoint, thickness at midpoint, carapace to tail tip length, cloaca to tail tip length (ct), and plastron to cloaca length (pc). Curved length and width were determined for carapace, plastron, second left anterior costal scute, and fourth posterior vertebral scute.

Sex was determined by mass, visual examination of secondary sex characteristics, and mathematically with tail measurements. Approximately 56% of individuals examined were male. Tail measurement ratios were used to predict sex with ct/pc and ct/(pc+ct) being > 90% accurate.

Snapping turtle age was determined by means of 2 methods of scute annuli analysis and 3 methods of skeletochronology, with samples prepared at St. Cloud State University (SCSU) and Matson's Laboratory, LLC. (ML; Milltown, MT). Marks of Skeletal Growth (MSGs) and annuli were used to estimate age in humerus/femur and 4th vertebral scutes, respectively.

Age estimates varied by methodology used, with old individuals showing the widest deviation in estimates while hatchling ages were always determined to be zero. Maximum age estimated was 26 for average skeletochronology, 33 for age since maturity, 63.0 for resorption estimation, 24 for scute annuli, and 91.5 for scute erosion. Unrealistic age estimates were caused by the projection of several small MSGs or annuli to the entire respective bone or scute. SCSU and ML samples were significantly similar with physical differences being cosmetic and numerical differences caused by sample location.

Regression analysis suggests that age since maturity and curved carapace length are best suited for future age determination efforts (R^2 = 0.995 and 0.955,

respectively), though all methods and features tested showed promise. Regression analysis also suggested that MN snapping turtles should be approximately 3 in. (7.5 cm) larger when harvested to assure maturity had been reached.

Future snapping turtle management efforts should be sex-based and possibly include a slot limit similar to that used for game fish species. A maximum size restriction on female harvest should be beneficial for maintaining variable popluations of common snapping turtles in Minnesota.

NOVEMBER 2001
Month Year

Approved by Research Committee:

William E. Faber
William E. Faber Chairperson

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Mike Lint and Mike Holme, owners of West Central Bait, Inc. (New London, Minnesota) supplied the equipment and water bodies used in this study and also allowed me to handle snapping turtles in a manor that was not always the most efficient from a business standpoint. Without their continuous assistance and support, this study would not have been possible. Also, my fellow employees: Joel Thompson, Justin Barber, Kraig Hanson, and occasionally even Corey Mead, made the long, windy and humid days enjoyable.

I would especially like to thank my family and friends for their understanding and support during this seemingly never-ending process. In addition, I would like to thank my fellow graduate students for being enlightening, encouraging, and entertaining … mostly entertaining.

The MN DNR Fisheries (New London–Spicer, Minnesota) and Todd Arndt of Buckstar Bait (New London, Minnesota) contributed several specimens. Gary Matson of Matson's Lab, LLC. (Box 308, Milltown, MT 59851) was responsible for off-site preparation of humerii and femurs. SCSU Department of Biological Sciences provided miscellaneous field and laboratory equipment, office space, computer access, as well as space to house my pets and specimens. The SCSU GIS Department allowed my use of the SARC Lab.

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When working on a project of this magnitude and duration, one tends to have momentary difficulties recalling the numerous parties who generously provided assistance. This does not mean their contributions, or my gratitude, are any less significant; it only brings to light a memory temporarily cluttered with 'useless' snapper information. I could not have even attempted this project without all the help. I am, and will always be, grateful.

Finally, I would above all like to thank: my patient committee members–Bill Faber, Al Grewe, Jeff Torguson, and Neal Voelz; Sharon Doucette–[this] man's best friend; and my Dad–cause of my enduring fascination with nature.

Completed at last…
In memory of Al Grewe:
A dear friend greatly missed.

"90% of everything is crap"
-George Bernard Shaw

"Of all men's miseries the bitterest is this,
to know so much and to have control over nothing."
-Herodotus

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Chapter I

INTRODUCTION

Common snapping turtles, *Chelydra serpentina serpentina* Linnaeus.*, are large, aquatic members of the Chelydridae family, which also includes two other North American species: Florida and alligator snapping turtles (Breckenridge 1944, Ernst et al. 1994, Conant and Collins 1998). Also known as mossbacks, freshwater loggerhead, or simply as snappers, they take their name from a tendency to lunge and bite, or snap, at perceived threats (Breckenridge 1944, Carr 1952, Conant and Collins 1998). To date, Minnesota snapping turtles remain under-studied and under-protected organisms.

Little is known about general snapping turtle life history and information that is available comes from regions outside of Minnesota. This study is the first of its kind completed in the state and is intended to serve as a reference for future studies and management practices (Personal Communication. Spring 2001. Roy Johannes, Commercial Fisheries Program Coordinator, and Richard Baker, Animal Research Coordinator, Minnesota Department of Natural Resources, St. Paul, Minnesota).

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* Scientific names for all species appearing in the text can be found in the appendices.

Snapping turtles have a largely ill-deserved reputation for volatile, aggressive behavior, but contrary to popular belief, an individual confronted in water will simply pull in its head or attempt to escape (Breckenridge 1944, Carr 1952, Ernst et al. 1994, Conant and Collins 1998). Their foul-tempered reputation likely comes from defensive actions of sun-warmed individuals that become cornered on land and are quick to bite anywhere they see movement (J. Jenniges, pers. obs.).

Common snapping turtles have the second largest physical size and geographical distribution of all North American turtle species. With mass and carapace length frequently exceeding 29 lb. (13 kg) and 15 in. (38 cm), respectively, and a record individual topping 86 lb. (39 kg), only the continuously feeding alligator snapping turtle of the southern United States achieves greater size or mass (Conant and Collins 1998). Snapping turtle range covers most of North America from the Rocky Mountains, east to the Atlantic Ocean, and from extreme southern Canada, south to the Gulf of Mexico, with other populations reportedly scattered throughout Central America (Ernst et al. 1994). Generally, any water body is potential snapping turtle habitat providing it continually remains wet and well stocked with food (Graves and Anderson 1987, Conant and Collins 1998).

Snapping turtle prey preferences are subject to fallacy and exaggeration. Duck hunters often believe their diet is composed solely of waterfowl, while some fishermen believe they have a strong preference for trophy size sport fish (Carr 1952). In reality, snapping turtles are opportunistic omnivores that consume large volumes of vegetable

matter and invertebrates (e.g., crayfish; Breckenridge 1944, Carr 1952, Graves and Anderson 1987, Ernst et al. 1994, Conant and Collins 1998).

River otters and alligators aside, adult snapping turtles have no natural predators, although humans now prey heavily upon them (Carr 1952, Brooks et al. 1991, Ernst et al. 1994, Conant and Collins 1998). Snapping turtles are valued for their delicious, succulent, multi-textured flesh, which makes them a favorite for soups in households and restaurants nationwide (Thrune 1976, Ernst et al. 1994). Further, their wide range of distribution has contributed to the misconception of great abundance and subsequently led to commercial harvest from [Minnesota] bodies of water at an unsustainable rate (Carr 1952, Galbraith and Brooks 1989, Brooks et al. 1991, Conant and Collins 1998).

Snapping turtles exhibit "bet-hedging" meaning they mature late in life, have relatively low reproductive effort per year, and high nest/hatchling/juvenile mortality (Galbraith and Brooks 1989, Brooks et al. 1991), but this is countered by high fecundity and longevity (Germano 1992). Past studies have indicated that "bet-hedgers" are not able to compensate for an increased loss of adults from a population and are especially vulnerable to human consumption (Galbraith and Brooks 1989, Ernst et al. 1994). For example, in a region where average age of nesting females was estimated to be 33–40 yr., a 96.6% adult survivorship rate still results in a predicted population decrease (Brooks et al. 1991).

Snapping turtles produce one clutch of eggs per year and this effort is increasingly insufficient (Carr 1952, Ernst et al. 1994, Conant and Collins 1998). An

early study determined that predators destroyed 48% of snapping turtle nests while later studies have reported 94%–100% nest destruction (Hammer 1969, Graves and Anderson 1987, Galbraith and Brooks 1989, Tyning 1990, J. Jenniges, pers. obs.). Further, less than 0.00007% of eggs laid and 1% of eggs hatched will survive to sexual maturity (Galbraith and Brooks 1989, Brooks et al. 1991). In Minnesota, typical nest predators include [native] mink and fox, [immigrant] skunk and raccoon, and [domesticated] dog and cat. With the exception of limited populations of fox and mink, these predators were not found in the state before European influences, and since establishment, their populations have increased greatly (Personal Communication. 1996–2000. Al Grewe, Professor of Wildlife Biology, St. Cloud State University, St. Cloud, Minnesota).

Unlike other commercially valuable Minnesota species, snapping turtle management plans are lacking and little is known about basic life history (R. Baker and R. Johannes, pers. comm.). Presently, it is not clear at what age or size Minnesota individuals mature. Prior research has indicated that growth rate and age/size at maturity are directly related to latitude (Frazer and Ehrhart 1985, Litzgus and Brooks 1998). For instance, females reach maturity at a minimum of 6–8 yr. in New York, 6–10 yr. in Iowa, 9 yr. in South Dakota, 12 yr. in Michigan, and 17–19 yr. in Ontario, while males generally mature 2–3 yr. prior (Christiansen and Burken 1979, Galbraith and Brooks 1989, Brooks et al. 1991, Congdon et al. 1994). It seems plausible that west central Minnesota snapping turtles mature at a time interval ranging between

Ontario and Iowa populations, possibly akin to Michigan populations (i.e., females at a minimum of 12 yr. and males 3 yr. prior).

Minnesota law encourages professional and novice snapping turtle trappers to selectively remove the most fecund (i.e., largest) members of a population (Conant 1958, Brooks et al. 1991, Dickson 2001). Any Minnesota resident with a valid angling license may have up to 3 snapping turtles in possession provided that they have a curved carapace width (CCW) of at least 10 in. (25.4 cm). A recent restriction suspending all harvest during May and June is intended to permit gravid females to lay eggs, but this restriction is often unknown or altogether ignored (Dickson 2001, R. Johannes, pers. comm., J. Jenniges, pers. obs.). Commercial turtle trappers must possess a Minnesota commercial turtle license and also comply with several additional regulations.

There is general agreement that snapping turtle numbers range-wide are declining at a rate that merits concern and has led to their discontinued harvest in some regions (e.g., Wisconsin; R. Johannes, pers. comm.). If this decline continues, snapping turtles could be threatened with commercial or ecological extinction throughout their distribution (Conant 1958, Brooks et al. 1991, Ernst et al. 1994, A. Grewe, pers. comm.). For snapping turtles to remain a part of our cultural and natural heritage, information on age structure is necessary to better comprehend their population dynamics and to develop advanced management and conservation strategies (Germano 1992, Congdon et al. 1994, Brooks et al. 1997).

Determining the age of a turtle, regardless of species, is a difficult task. Mark-recapture studies are ideal for determining age/length relationships but remain time and labor intensive over both the short- and long-term (Frazer and Ehrhart 1985, Zug et al. 1986, Galbraith and Brooks 1989, Murphy and Willis 1996, Litzgus and Brooks 1998). Unfortunately, one cannot utilize captive-reared turtles for predicting wild population maturity patterns because captive turtles grow and mature more rapidly than their wild counterparts (Zug et al. 1986). More favorable methods for temperate, non-pelagic turtle age determination include scute annuli analysis and skeletochronology.

Scute annuli analysis has been used since the 1800's to estimate age for turtle species found in areas with defined seasons (Galbraith and Brooks 1989, Germano and Bury 1998). Hatchling scutes never increase in size but rather new growth is added underneath and around them in an annual manner (i.e., one annulus/year; Galbraith and Brooks 1989, Germano 1992, Castanet 1994, Ernst et al. 1994, Germano and Bury 1998, Litzgus and Brooks 1998). The onset of sexual maturity is marked by diminished growth but additional annuli continue to be added as evident by increasing scute margin (seam) depth (Galbraith and Brooks 1989, Germano 1992, Congdon et al. 1994).

There are several key advantages for using scutes to study age. Scute analysis is convenient and purportedly can be performed in the field by anyone with a minimum amount of experience, equipment, or time (Galbraith and Brooks 1989, Castanet 1994, Germano 1994, Brooks et al. 1997, Germano and Bury 1998, Litzgus

and Brooks 1998). In addition, plastic impressions or photos of scute annuli can be prepared in the field for subsequent analysis under laboratory conditions (Brooks et al. 1997, Galbraith and Brooks 1989). Most importantly, scute analysis is non-destructive which means specimens can be examined alive and do not need to be removed from a population (Brooks et al. 1997). However, since growth is reduced after maturity and early annuli become less conspicuous over time, it is important to treat these age estimates as a minimum (Galbraith and Brooks 1989, Germano 1992, Castanet 1994, Ernst et al. 1994, Brooks et al. 1997).

Skeletochronology is similar to scute annuli analysis and analogous to dendrochronology used to count annual rings in trees, and has been used to age reptiles and amphibians worldwide (Zug et al. 1986, 1997, Castanet 1994, Guarino et al. 1998). This procedure involves sectioning and staining decalcified bone taken from the structure with the highest number of growth marks and lowest level of remodeling (Castanet 1994). Preferred bones vary by species, but generally the femur or humerus is used (Hammer 1969, Zug et al. 1986, Bjorndal et al. 1998). As with scute analysis, each year of life a new annulus, or mark of skeletal growth (MSG), is deposited on the external bone surface (Zug et al. 1986). Each MSG is composed of a light staining band (zone), and a dark staining band (line of arrested growth or LAG; Castanet 1985, 1994, Zug et al. 1986).

Skeletochronology is preferable in areas with seasonal fluctuations of biotic and abiotic factors (e.g., testosterone, temperature, light; Guarino 1998). Tetracycline, which fluoresces under UV light, has been used to label bone layers in mark-recapture

studies which confirmed the annual nature of MSGs (Hemelarr and van Gelder 1980, Frazer 1985, Castanet 1994). Unfortunately, as with scute annuli analysis, skeletochronology is not 100% accurate because of the gradual degradation of early MSGs though resorption and redeposition, and thus provides a minimum age estimate and not an actual age (Hemelarr and van Gelder 1980, Patnaik and Behera 1981, Zug et al. 1986, 1997, Galbraith and Brooks 1989, Castanet 1994, Wake and Castanet 1995, Zug and Parham 1996, Parham and Zug 1997, Bjorndal et al. 1998, Guarino et al. 1998, Zug and Glor 1998, de Buffrenil and Castanet 2000).

Recovery of depleted snapping turtle populations will be slow due to a lack of rapid density dependent responses in reproduction and recruitment (Brooks et al. 1991). The aforementioned intensification of nest depredation and human consumption will only serve to compound this effect. Therefore, the present study was undertaken with one goal being to increase current scientific understanding of common snapping turtles by examining age and maturity in a previously unstudied region of North America, i.e., west central Minnesota. Currently, Minnesota turtle harvest laws are being revised based upon studies completed in other regions of the continent without actually studying Minnesota populations (R. Baker and R. Johannes, pers. comm.). This study will help guide management plans in Minnesota and serve as a foundation for future studies. It is possible that with this valuable information, combined with previous and future studies, snapping turtle protection and management may be scientifically based on the Minnesota population(s) being regulated.

The primary objectives of this study were to: 1) further develop mathematical methods for determining snapping turtle sex, 2) develop methodologies for determining snapping turtle age which are less expensive and equipment-intensive than current methods, 3) determine snapping turtle age through the use of skeletochronology, scute annuli analysis, and several projective methods, and 4) correlate estimated snapping turtle age to an external feature such as curved carapace width (CCW). Based upon information and insight gained, suggestions are made for future study and also for future management strategies aimed at maintaining viable populations of common snapping turtles in Minnesota.

Chapter II

STUDY AREA

The study area was comprised of 16 study sites (13 water bodies and 3 land locations) in portions of 5 counties in west central Minnesota (Figures 1–3, Table 1). The bulk of study sites (13) are concentrated within 10 mi. (16 km) of New London, Minnesota in Kandiyohi County. Remaining sites were located in Grant (1), Swift (1), Pope and Stevens (1) counties. Most lakes and wetlands used in this study are privately owned and free of game, rough, and nuisance fish species, which makes them desirable to commercial minnow trappers who stock them with baitfish.

Water bodies used in this study are generally small and shallow. Surface area for the study sites range from approximately 4–120 acres (1.6–48.6 ha), with approximately 15–20 acres (6.1–8.1 ha) being typical. Depths range from approximately 2–20 ft (0.6–6.1 m) but 6–8 ft (1.8–2.4 m) is most common (Personal Communication. 1994–2001. Mike Holme, Co-owner, West Central Bait, New London, Minnesota).

Due to their relatively small, shallow nature, water bodies used for baitfish production have water temperatures that vary greatly depending upon depth, season, and water clarity. Summertime water temperatures can exceed 70° F (21° C) near the

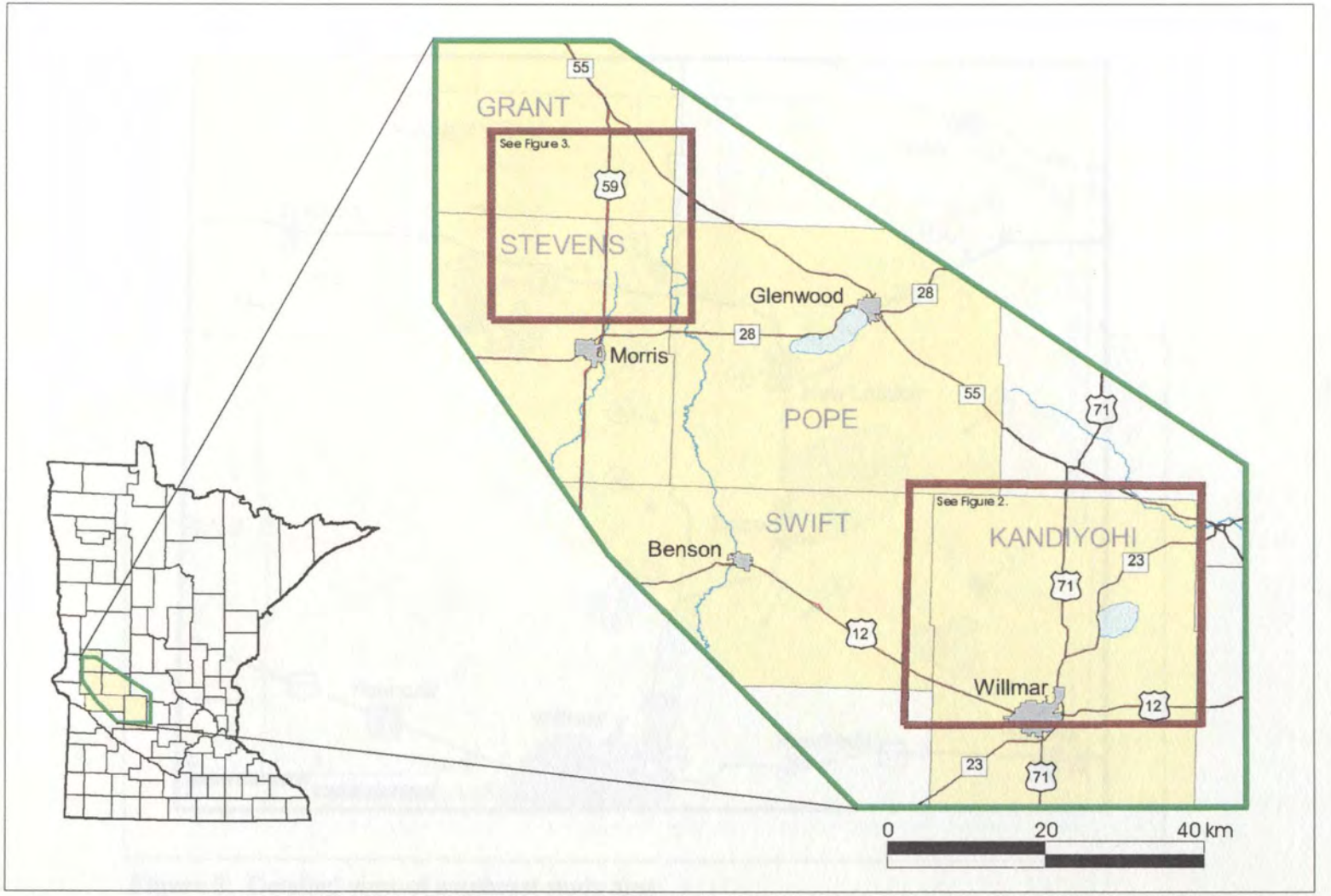

Figure 1. Common snapping turtle study area in west central Minnesota, during summers of 1998 – 1999.

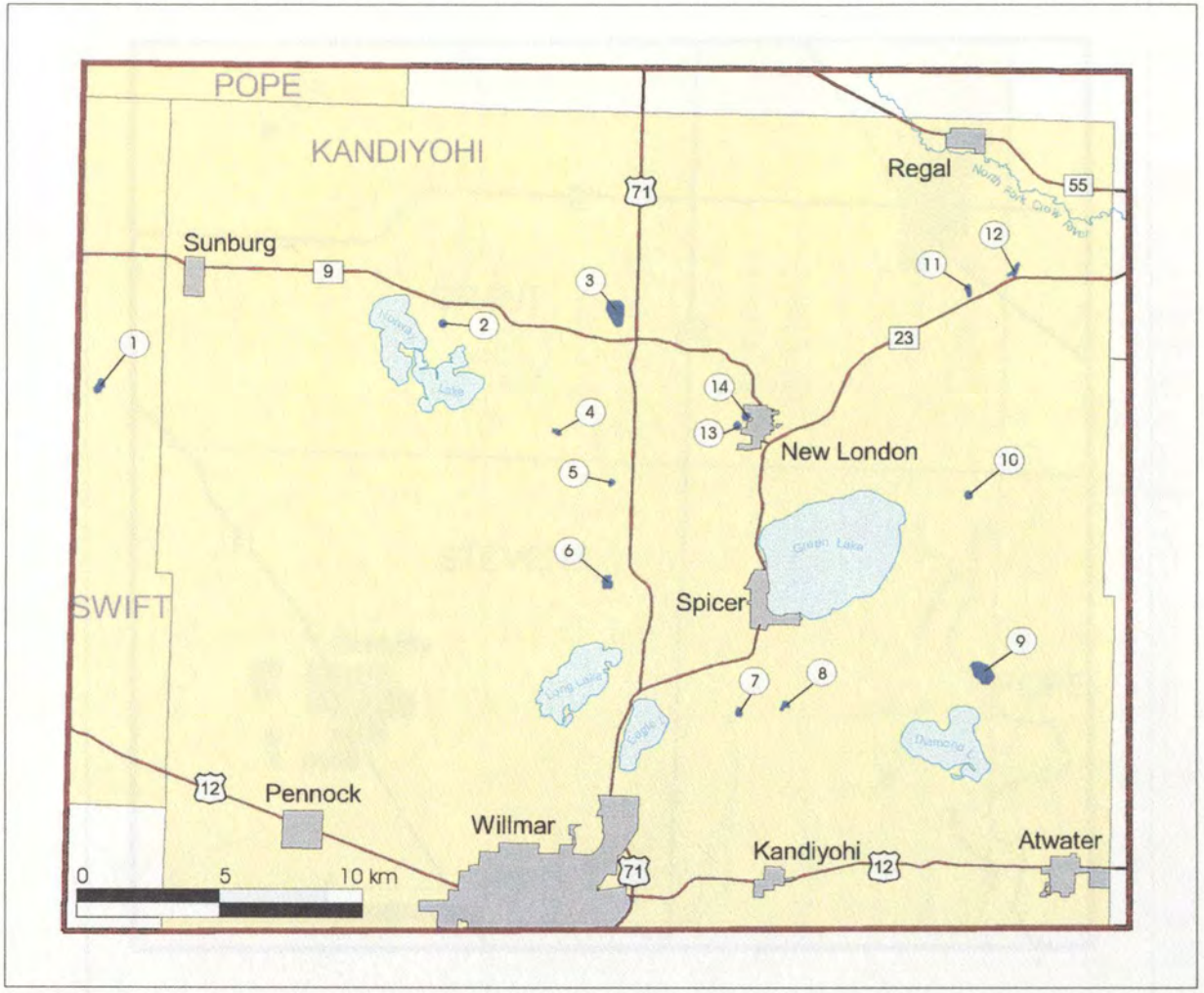

Figure 2. Detailed view of southeast study area.

Figure 3. Detailed view of northwest study area.

Table 1. Names and locations of study sites used summers of 1998–1999 and referred to in Figures 1–3.

Location ID	Location name (if named)	Location – Legal (Twnshp, Rng, Sec)
1	———	121N 37W 12
2	Games Lake	121N 35W 31 – 33
3	———	122N 35W 26
4	———	121N 36W 26
5	———	121N 35W 24
6	Carlson Lake	121N 35W 36
7	———	120N 34W 16
8	———	120N 34W 22
9	Sperry Lake	120N 33W 9,16
10	Calhoun Lake	121N 33W 21,22,27,28
11	———	122N 33W 29
12	———	122N 33W 22
13	West Central Bait	121N 34W 9
14	MN DNR NLFH*	121N 34W 9
15	———	125N 40W 32,33
16	Otter Lake	125N 41W 12

* New London Fish Hatchery

lake bottom and winter may cover lakes with more than 3 ft (0.9 m) of ice (Personal Communication. 1994–2001. Mike Lint, Co-owner, West Central Bait, New London, Minnesota).

Thick ice and snow cover coupled with low water volume cause oxygen levels to decrease during winter months, often killing fish. Aerators are used to keep oxygen levels at a point that will support aquatic life. Historically, all ice has melted by March 15–April 1 (M. Lint, pers. comm.).

Most of the area surrounding the study water bodies has been converted from native prairie to agricultural activities. Typical crops include corn, soybeans, small grain, and alfalfa. Livestock in areas immediate to study sites include cattle, pigs, and turkeys. Agricultural lands are extensively tiled (i.e., drained) and any moisture is often directed into the nearest water body, likely affecting water quality.

Chapter III

MATERIALS AND METHODS

TURTLE CAPTURE

Four methods were used for snapping turtle collection. Most individuals were captured as by-catch in modified fyke nets (Figure 4; see Murphy and Willis 1996) placed in privately owned lakes leased by a commercial bait operation (West Central Bait, Inc., New London, Minnesota) for the express purpose of collecting planted stocks of white sucker minnows. Employees of the Minnesota Department of Natural Resources New London Fish Hatchery also collected several specimens during early autumn draw down of fish rearing ponds. Other individuals were captured while they were traversing the countryside (e.g., crossing a road), which is behavior typical of gravid females in search of suitable nesting habitat or individuals moving from an unsatisfactory water body to an improved one. Finally, hatchlings that died of exposure were collected from the gutters of several New London municipal streets.

Modified Fyke Nets

Modified fyke nets (traps) used were of similar design to those illustrated and described in Murphy and Willis (1996; see Figure 4). Trap specifications used in the

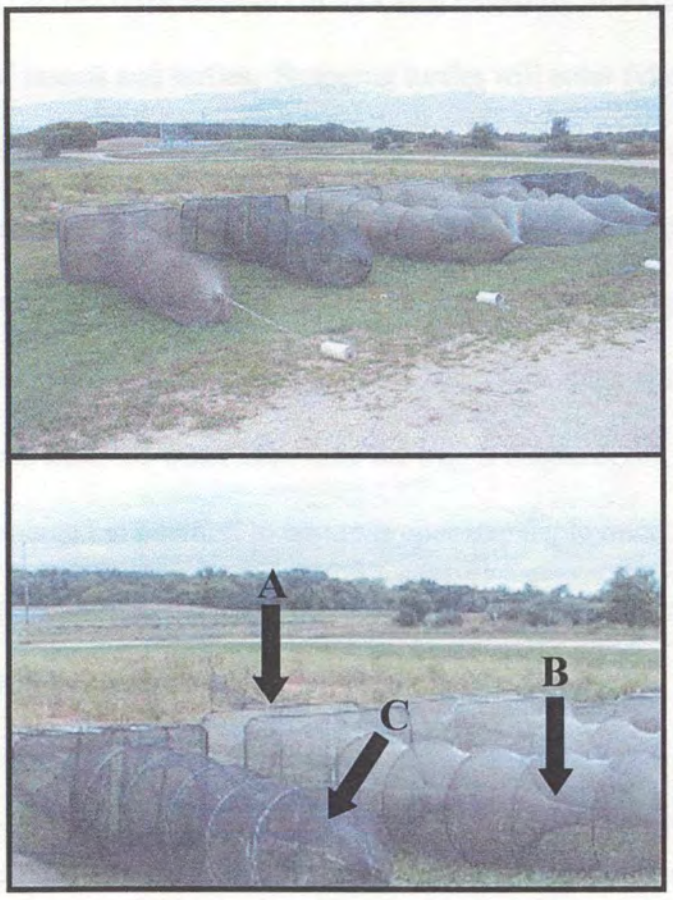

Figure 4. Modified fyke nets for commercial fish harvest, which occasionally capture snapping turtles. Note trap mouth (A), throat (B), and bag (C). (Photography: Jeff Gunderson)

current study include: 5/8 in. (1.6 cm) mesh, 30 x 3 ft (9.1 x 0.9 m) lead, a rectangular 3 x 6 ft (0.9 x 1.8 m) steel-framed trap entrance (mouth), and two cylindrical funnels with an opening (throat) of approximately 4-6 in. (10.1–15.2 cm).

Fyke nets can capture large amounts of by-catch including muskrats, crayfish, and various species of insects and turtles. Snapping turtles will enter fyke nets when they have their progress impeded or are attempting to feed upon concentrated numbers of prey species (J. Jenniges, pers. obs.). Captured animals will concentrate escape efforts in the trap's corners, but eventually smaller creatures travel through the series of funnel like throats and become concentrated in the bag. This is the only portion of the trap that is removed from the water each time the trap is checked; the remainder stays completely submerged in position to ensure proper trap deployment. Large turtles are unable to pass through the trap's smaller, second throat and are not likely to be discovered until they have drowned.

Respiratory Status

Traps were usually checked on a daily basis and most snapping turtles were discovered alive. Initially, several inactive individuals were found that had eyes that appeared cloudy. These individuals would remain motionless until their carapace was tapped, at which time they would retract their head and/or inhale. In all instances, individuals that displayed these symptoms died after being placed in a dry location near a water body, and therefore future turtles found in this condition were considered to be dead and kept for further study.

TURTLE PROCESSING

Live and dead snapping turtles were initially processed in a similar fashion. Sex of each individual was determined through the visual inspection of secondary sex characteristics (Breckenridge 1944, Tyning 1990, Ernst et al. 1994), and then mass was measured in kg using a spring scale. Straight-line measurements were determined with a caliper (cm) while curved lengths were acquired with a tape measure (cm). Data were collected on straight-line carapace length (SCL), curved carapace length (CCL), straight-line carapace width (SCW), curved carapace width (CCW), plastron length (PL), plastron width (PW), thickness at midpoint, and circumference at midpoint (waist). Further, curved and straight-line length/width of the 2nd left anterior costal and 4th vertebral scutes were recorded, as well as tail length (cm) from carapace to tip (t), from cloaca to tip (ct), and from plastron to cloaca (pc).

Scute Annuli Analysis

Annuli analysis was attempted on the 4th vertebral scute using methods similar to those suggested in previous studies (Galbraith and Brooks 1989, Galbraith, et al. 1991, Germano 1992, Germano and Bury 1998). Scutes were scrubbed with a wire bristle brush to remove their characteristically thick algal growth and then annuli were repeatedly counted under ambient light conditions until a satisfactory count of the visible annuli was determined. Distance between each annulus was measured using a caliper accurate to 0.0004 in. (0.01 mm) or a drafting compass and ruler. Eroded

annuli were calculated by projecting width of an average annulus to the entire scute length minus the length of an average hatchling scute (0.53 cm; Figure 5).

Turtle Release

After initial analysis, live turtles were transported to suitable habitats outside the study area and released. This eliminated any possibility of recapture which could adversely affect an individual, as well as have negative consequences for the current study. Dead individuals were labeled, sealed in a plastic bag, and frozen for future analysis.

LABORATORY PROCEDURES

In the laboratory, flesh and viscera were removed from thawed snapping turtles. Articulated bones and other hard parts, excluding the plastron, were air-dried and then skeletonized with dermestid beetle larvae. Humerus and femur pairs were removed, weighed successively on a single arm balance, and then averaged to determine individual mass (g). Measurements in cm were recorded on thickness of shell, length of humerus, width of humerus at diaphysis, length of femur, width of femur at diaphysis, and width of head. Right humerus and femur for each turtle specimen were delivered to Matson's Laboratory, LLC. (ML; Milltown, Montana) for off-site preparation.

Left humerus and femur were kept for on-site preparation at St. Cloud State University (SCSU). Techniques used in preparation of bones and subsequent age

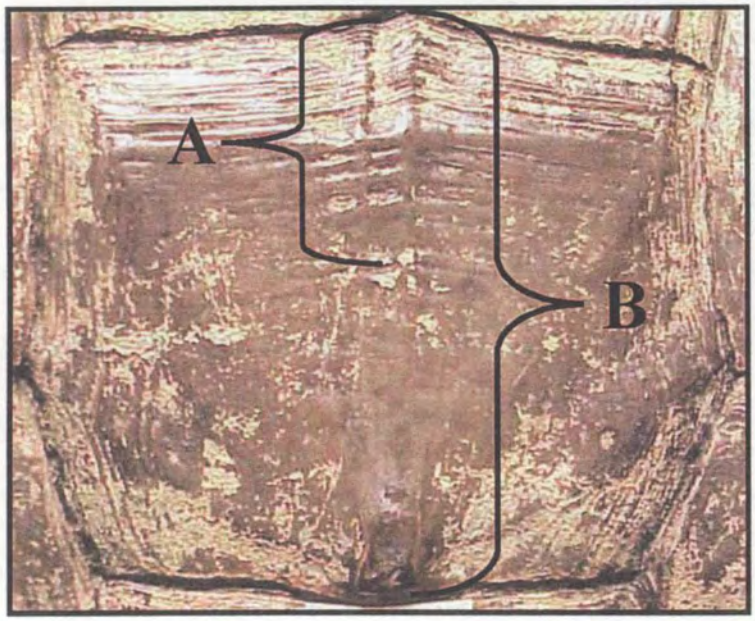

Figure 5. The 4th vertebral scute depicting how age was estimated from erosion of scute annuli. Number of annuli and total distance covered by these annuli was measured (A). Length of scute was measured (B) and then average annuli distance was applied to entire scute length minus the length of a hatchling scute (0.21 in. or 0.53 cm).

analysis were modified from standard paraffin histotechniques described in Zug et al. (1986). A band saw was used to remove a 1 in. (2.5 cm) section from the humerus and femur just distal to the proximal end at the diaphysis (Figures 6 and 7).

Decalcification

Bone samples were macerated in tap water and then hydrated in a 4% formalin solution for 24 hr. Hydrated samples were placed in a solution composed of equal parts of 8% formic acid and 8% hydrochloric acid for 3–7 days pending complete decalcification. A Thelco Model 19 vacuum oven (GCA/Precision Scientific, Chicago, Illinois), with an attached Disto-Pump Model 1399 (The Welch Scientific Company, Skokie, Illinois) and 1/3 HP GE Motor (General Electric, Ft. Wayne, Indiana), was briefly used to apply vacuum pressure which ensured absolute penetration of the acid solution. Decalcification was deemed complete when bones became rubbery and bubbles no longer formed when placed under vacuum.

Decalcified bones were thoroughly rinsed in tap water, trimmed with a utility knife to a point near where thin sections would be removed, and dehydrated with increasing concentrations of ethyl alcohol. Initially, samples were placed in 95% ethyl alcohol for 12 hr, transferred to fresh solution, and then soaked for an additional 12 hr with the final 8 hr under vacuum. Next, samples were placed in 100% ethyl alcohol for 12 hr, transferred to fresh solution, and then soaked for an additional 12 hr under vacuum. Finally, samples were clarified in xylene under vacuum for 6 hr, transferred to fresh solution, and then returned to vacuum for an additional 6 hr.

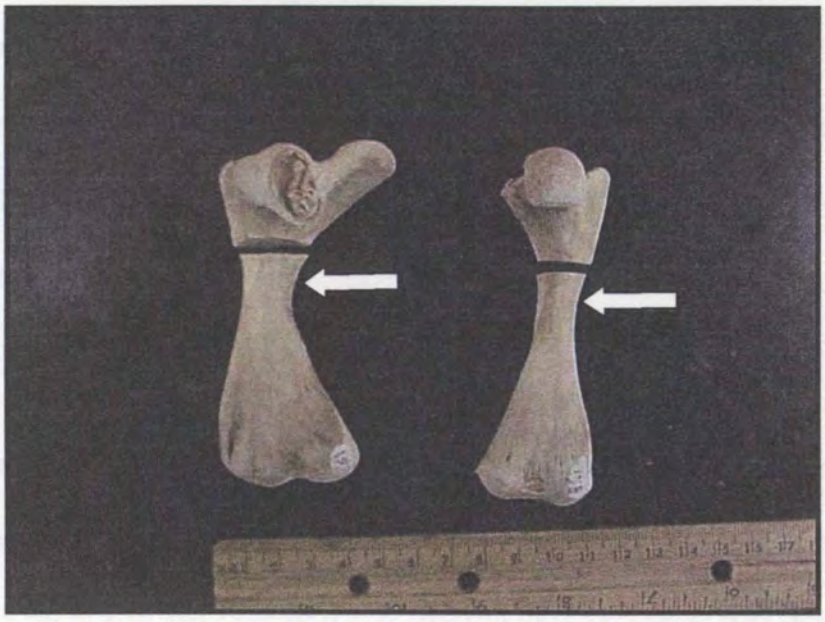

Figure 6. Snapping turtle humerus (left) and femur (right) displaying sample region. Diaphysis is located near arrow. (Photography: Dennis Sjogren)

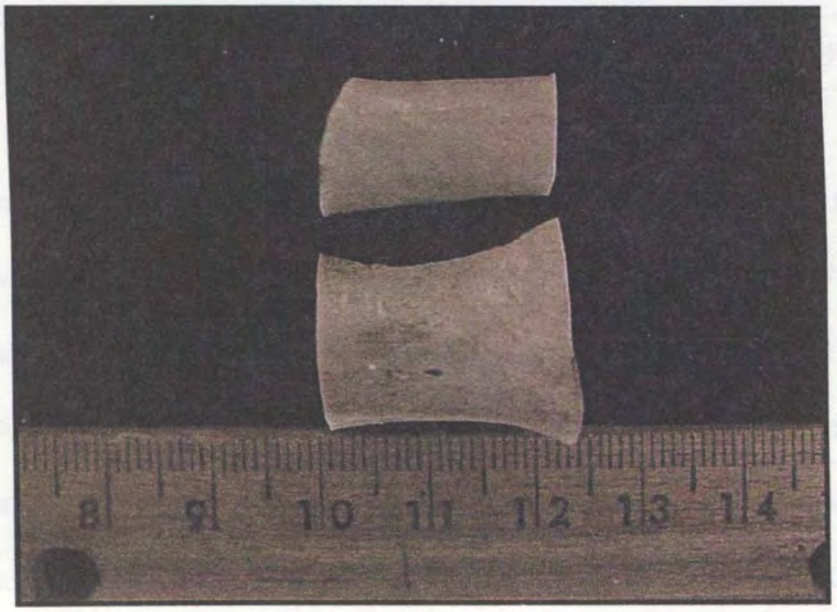

Figure 7. Portions of undecalcified snapping turtle femur (top) and humerus (bottom) which will be processed to produce thin sections. (Photography: Dennis Sjogren)

Prior to thin sectioning, decalcified humerus and femur samples were stored in two ways. Some samples were kept in xylene until ready for use. Most samples were allowed to dry and then stored until they were rehydrated in xylene with no readily apparent ill-effects on structure, although it is possible that these bones were denser than samples not allowed to dry.

Mounting

Paraplast® Plus Tissue Embedding Medium (Sherwood Medical Industries, St. Louis, Missouri) was used to mount samples for thin sectioning. Samples were labeled and placed in size S22 Peel-A-Way® paraffin molds (Peel-A-Way Scientific, South El Monte, California) on a 140° F (60° C) slide warmer used to keep Paraplast® mellifluous. Liquid Paraplast® was added and then the Peel-A-Way® molds were transferred to the oven and kept at 136°–140° F (58°–60° C) until all Paraplast® was liquid.

Vacuum was induced with temperatures of 136°–140° F (58°–60° C) for 12 hrs. Molds were removed from vacuum pressure and then placed upon a 140° F (60° C) slide warmer where samples were transferred to fresh Paraplast®, and then returned to a 136°–140° F (58°–60° C) vacuum for 12 additional hrs. Samples were removed from the oven and allowed to cool. Blocks containing Paraplast® impregnated decalcified bone samples were removed from the Peel-A-Way® molds and stored until sectioning.

Sectioning

Initial sectioning attempts were made with a rotary microtome that used a thin razorblade, but this method was abandoned because hard, thick samples damaged the cutting blade and did not produce usable sections. It was determined that relatively uniform sections of approximately 0.0059 in. (150 μm) could be made by using consistent pressures to draw a thick, hand-held, single-edged razorblade across a sample surface.

It was unreasonable to anticipate complete sections when cutting large, dense samples with a hand-held razorblade. However, since marks of skeletal growth (MSGs) are visible throughout the entire bone (Zug et al. 1986, 1997, Zug and Parham 1996, Guarino et al. 1998), sections need only contain a complete radius to assure accurate MSG representation. In addition, multiple thin sections were made to help eliminate possible location bias.

Staining and Slide Preparation

Sections were deparaffinized and hydrated in a 136° F (58° C) hot water bath and then submersed in Harris Hematoxilin stain for 30–60 min. Stained sections were rinsed in tap water before an acid differentiation step was used to enhance appearance of MSGs. Sections were differentiated in a 2% hydrochloric acid -2% formic acid solution for approximately 5–15 sec., depending upon thickness of section, and then

transferred to tap water and stirred to halt the differentiation process. Tap water was changed several times and sections remained in water until they no longer bled any stain.

Stained sections were examined with an Olympus SH2 Stereozoom microscope (Olympus Optical Co, Ltd., Tokyo, Japan) and those with the most inclusive representations of MSGs were set aside. Poor sections (e.g., too thick, over-differentiated, over-stained, incorrect region of bone) were discarded. The best 10–20 sections were blotted of excess water, placed on a glass slide, covered in Permount™ (Fisher Scientific Company, Fair Lawn, New Jersey), and sealed with a glass coverslip.

Off-site Preparation

Techniques used in ML preparation of right humerii and femurs were also similar to those described in Zug et al. (1986; Personal Communication. Fall 2000–Summer 2001. Gary Matson, Owner, Matson's Laboratory, LLC., Milltown, Montana). Bones were trimmed, decalcified using a hydrochloric acid solution, mounted in paraffin, and sectioned in 0.00055 in. (14 μm) intervals using a rotary microtome. Thin sections were stained using Harris Hematoxilin, placed on a glass slide, and sealed with a glass coverslip. Prepared slides were returned to SCSU where MSGs were counted.

Counting MSGs

Slides were examined with bright and dark fields while continuously varying magnification between 7.5–64x. MSGs were counted from the section outer edge inward and repeated with other sections for a minimum of 10 observations per turtle. The tightest MSGs, which are indicative of maturity, were also repeatedly counted until a minimum of 10 observations were made. Sections had varying levels of resorption and redepostion (the process by which MSGs are eroded), hence likely failing to yield counts of all MSG present, and therefore age was considered to be the highest count that had been repeated in more than one section.

When sections prepared at SCSU and ML were examined for MSGs, great care was taken to avoid sequentially counting humerus and femur from the same individual; also, counts were not reviewed until all samples were examined. This was done in an effort to avoid any observer bias which would tend to occur when multiple samples from the same individual are examined consecutively.

Digital images of representative samples for each bone were made at various levels of magnification with a microscope mounted Javelin Smart Cam Model JE3762DSP (Javelin Systems, Torrance, California). Digital images of complete sections were also made at 7.5x magnification and then printed on a laser printer. Prints were cut out and reassembled so that a scale model was made and then each was examined for MSGs.

Reassembled scale photographs of humerii were used to measure bone diameter and distance to earliest observable MSG (cm) near the widest point of the

bone, and then average distance for each MSG deposited was projected to the entire bone radius (Figure 8; see Zug et al. 1986, 1997, Zug and Parham 1996, Parham and Zug 1997); this was repeated near the widest point 90° from the first measurement. The two estimates were averaged to obtain an age estimate which included years lost to resorption.

Microsoft® Excel (Microsoft Corporation, Redmond, Washington) was used for data storage and statistical analysis. A paired t-test for means was used to examine statistical differences among age estimates. Attempts were made to correlate age estimates to an external feature so that snapping turtles need not be sacrificed in future age determination studies.

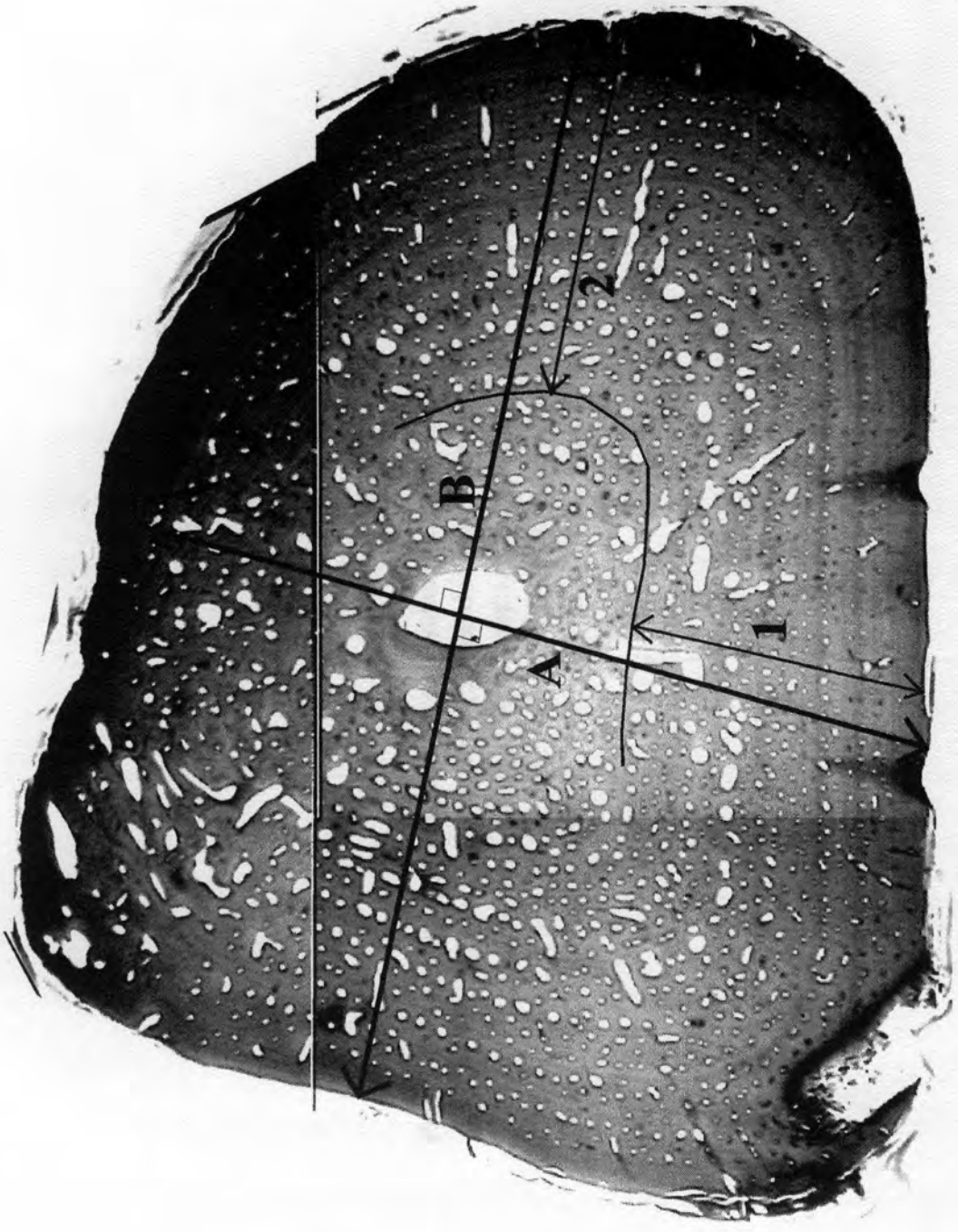
2
B
A
1

Figure 8. Reassembled digital images of a humerus used for estimating MSGs lost to resorption. Bone diameter (B) and distance to earliest observable MSG (2) were measured near the widest point and then average distance for each MSG was applied to the bone radius (0.5 B). This was then repeated 90° from the first measurement near the widest point (A & 1) and the two estimates were averaged.

Chapter IV

RESULTS AND DISCUSSION

SEX DETERMINATION

A total of 111 wild and 53 hatchling snapping turtles were examined during the summers of 1998–1999. Of 66 wild individuals sexed, 37 males and 29 females were represented. Traps used in this study are unlikely to be sex selective, although this was not tested, and therefore populations within the study area are thought to be comparable to this ratio.

Snapping turtles are sexually dimorphic with males attaining larger sizes than females (Carr 1952, Conant 1958, Tyning 1990, Ernst et al. 1994, Conant and Collins 1998). Free ranging individuals (n = 60) had respective average mass, curved carapace length (CCL), and curved carapace width (CCW) of 7.6 ± 0.52 (SE) kg, 30.4 ± 0.80 (SE) cm, and 34.2 ± 0.95 (SE) cm, with males being significantly larger than females (Table 2; t-test: paired two sample for means).

Correctly determining sex of snapping turtles will likely play an important role in future management plans because animal populations are commonly managed by controlling female harvest (Bookhout 1996). Prior research has indicated that sex can

Table 2. Comparison of mass, curved carapace length (CCL), and curved carapace width (CCW) of snapping turtle sexes using a paired two sample t-test for means.

	Mass (kg)	CCL (cm)	CCW (cm)
	t = -2.96 df = 58 P = 0.002	t = -2.30 df = 58 P = 0.010	t = -2.03 df = 58 P = 0.023
Average:			
Male	8.0 ± 0.75 (SE)	31.9 ± 1.14 (SE)	35.8 ± 1.34 (SE)
Female	5.8 ± 0.53 (SE)	28.3 ± 0.95 (SE)	31.9 ± 1.18 (SE)

be visually determined based upon secondary sex characteristics such as cloaca location in relation to carapace rim (Breckenridge 1944, Oliver 1965, Tyning 1990, Ernst et al. 1994). The female cloaca is located directly below the posterior most edge of the carapace while the male cloaca is located posterior to the carapace. In the present study, this method was utilized in 59 instances and, upon dissection of 24 dead individuals, was found to be 100% accurate. Still, less experienced turtle trappers or the general public may have difficulty accurately distinguishing male and female snapping turtles without the assistance of an explicit mathematical methodology.

Mass

In general, mass serves as a simple sex determinant because males are usually larger (Carr 1952, Conant 1958, Tyning 1990, Ernst et al. 1994, Conant and Collins 1998). When sex of west central Minnesota snapping turtles was determined, 55.9% (33/59) were male. All individuals >25 lb. (11.3 kg) were male (10/10), while 82.6% (19/23) >18 lb. (8.2 kg) were also male (Figure 9). Accuracy of sex predictions decreases as mass decreases. Of those 10–18 lb. (4.5–8.2 kg), 64% (16/25) were female while 54.5% (6/11) of 1.5–10 lb. (0.7–4.5 kg) individuals were male.

Tail Measurements

Tail length (ct), the distance from cloaca to tip of tail, is particularly useful for sex determination. Visual comparison of cloaca to tail tip lengths and overall tail length yields a quick, accurate sex determination, although this method is inaccurate

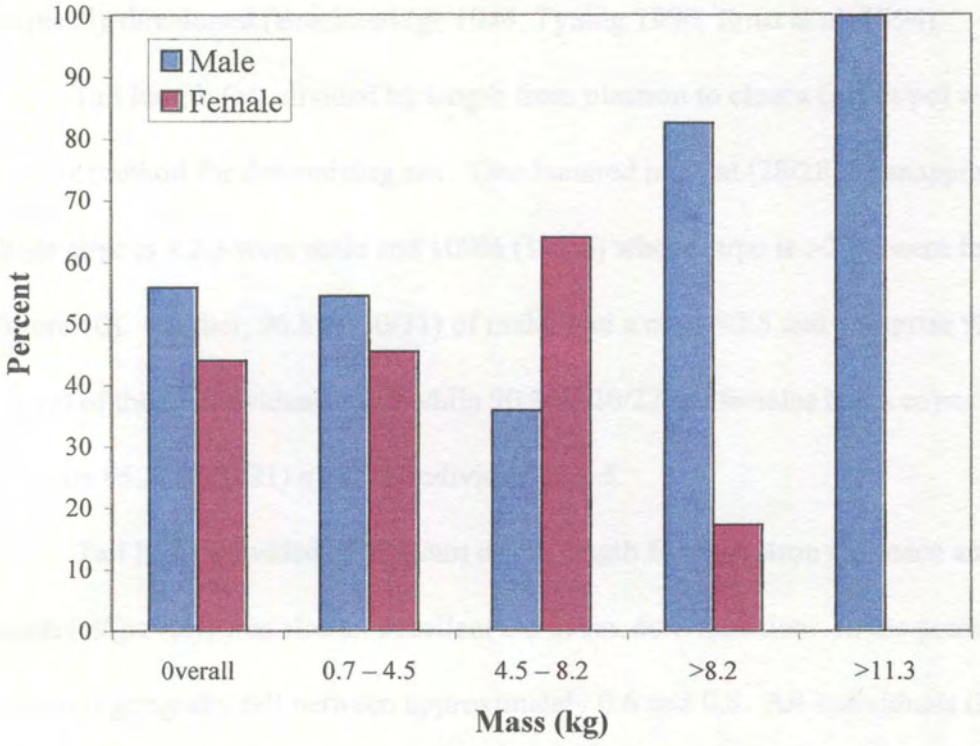

Figure 9. Sex of west central Minnesota snapping turtles (n = 61) by mass (kg).

among small individuals because these secondary sex characteristics are not yet adequately developed (Breckenridge 1944, Tyning 1990, Ernst et al. 1994).

Tail length (ct), divided by length from plastron to cloaca (pc; ct/pc) was a very accurate method for determining sex. One hundred percent (28/28) of snapping turtles whose ct/pc is <2.3 were male and 100% (18/18) whose ct/pc is >2.84 were female (Figure 10). Further, 96.8% (30/31) of males had a ct/pc <2.5 and comprise 93.8% (30/32) of those individuals <2.5 while 90.9% (20/22) of females had a ct/pc >2.5 and comprise 95.2% (20/21) of those individuals >2.5.

Tail length divided by the sum of the length from plastron to cloaca and tail length (ct/(pc+ct)) was also an excellent aid in sex determination. In the present study, ct/(pc+ct) generally fell between approximately 0.6 and 0.8. All individuals (28/28) <0.7 were male and they comprised 90.3% (28/31) of individuals <0.7 while all females (22/22) were >0.7 and comprised 88.0% (22/25) of the total >0.7 (Figure 11).

Tail length divided by dorsal tail length from carapace to tip (t; ct/t), tail length minus plastron to cloaca length divided by plastron to cloaca length ((ct-pc)/pc), and tail length minus plastron to cloaca length divided by dorsal tail length ((ct-pc)/t) all adequately determined sex but were to some extent less precise than methods already described.

AGE ESTIMATIONS

Information on age structure should lead to a better understanding of snapping turtle population dynamics and aid in the development of successful management and

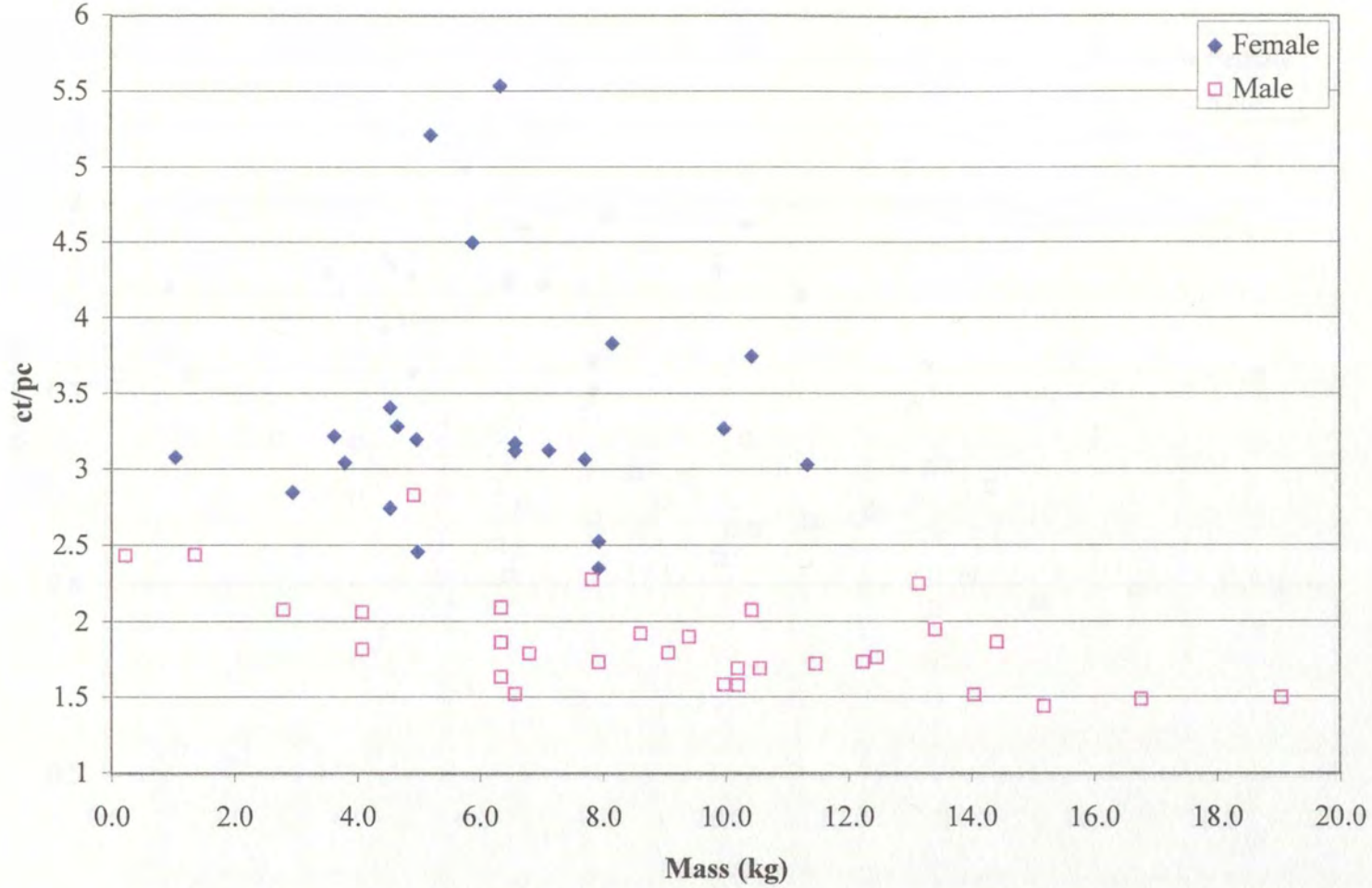

Figure 10. Relationship of snapping turtle ct/pc and mass (ct = length of tail from cloaca to tip and pc = length from plastron to cloaca, in cm).

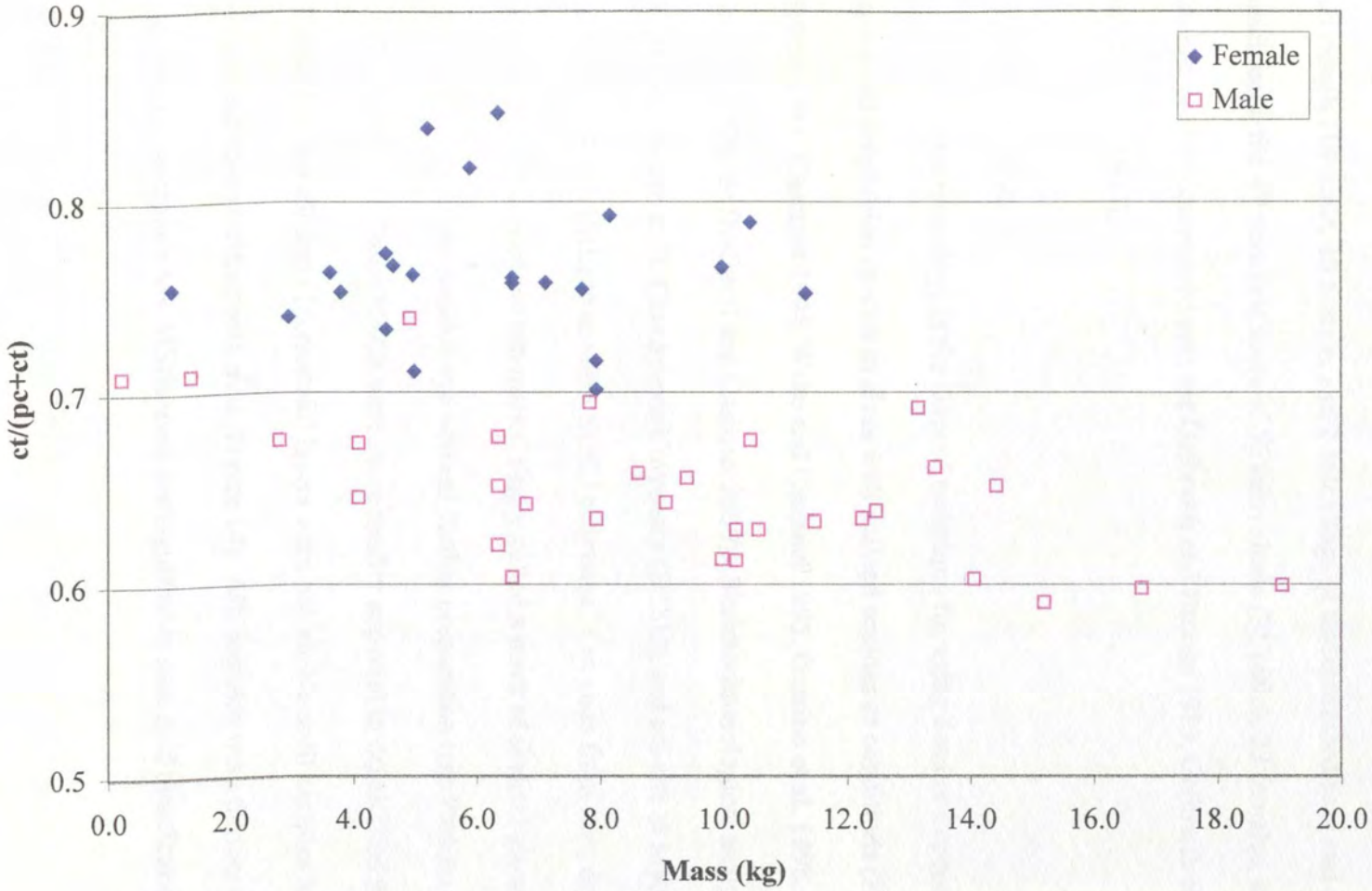

Figure 11. Relationship of snapping turtle ct/(pc+ct) and mass (ct = length of tail from cloaca to tip and pc = length from plastron to cloaca, in cm).

conservation strategies (Germano 1992, Congdon et al. 1994, Brooks et al. 1997). In the present study, age was estimated through the skeletochronological analysis of 26 individuals (14 male, 10 female, and 2 hatchlings of undetermined sex) and analysis of annuli upon the 4th vertebral scute of 56 individuals (31 males, 23 females, and 2 hatchlings of undetermined sex; see Galbraith and Brooks 1989, Galbraith et al. 1989, Brooks et al. 1997).

Skeletochronology

Skeletochronology is the favored technique for aging dead or expendable reptile and amphibian species in areas with defined seasons or conditions (Patnaik and Behera 1981, Castanet 1994, Wake and Castanet 1995, Guarino et al. 1998, Waye and Gregory 1998, de Buffrenil and Castanet 2000). Skeletochronological analysis was performed on-site at St. Cloud State University (SCSU), and off-site at Matson's Laboratory, LLC. (ML) to confirm SCSU estimates. Cut ends from raw, dry, SCSU bones displayed annual growth marks, singly called a mark of skeletal growth (MSG), that were visible to an unaided eye without further preparation (see Parham and Zug 1997; Figure 12). These MSGs were more readily apparent in decalcified thin sections (Figure 13), but all outer [periosteal] layers were not visible until samples had been stained and then clarified with acid (Figure 14). ML samples were thinner than SCSU samples and therefore ML MSGs were distinguishable sans acid clarification (Figure 15).

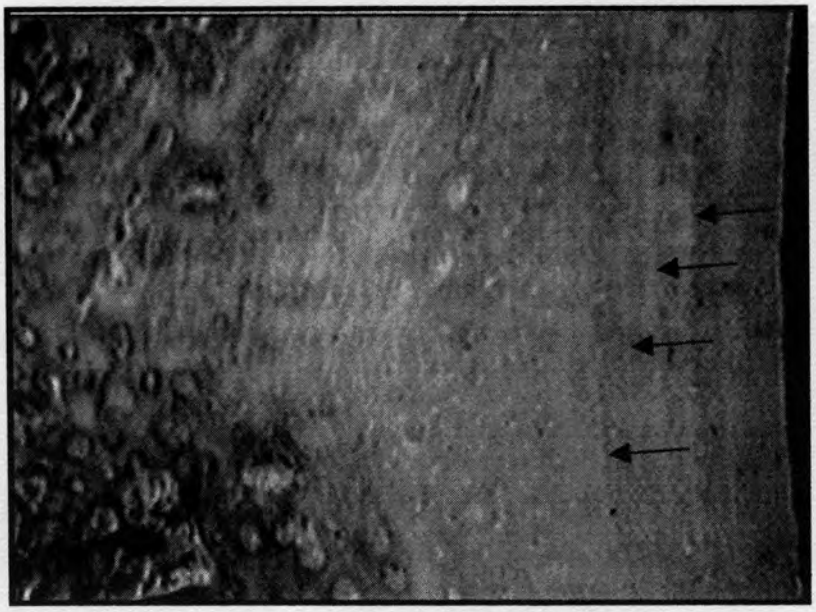

Figure 12. Raw humerus, with proximal end removed, displaying signs of MSGs.

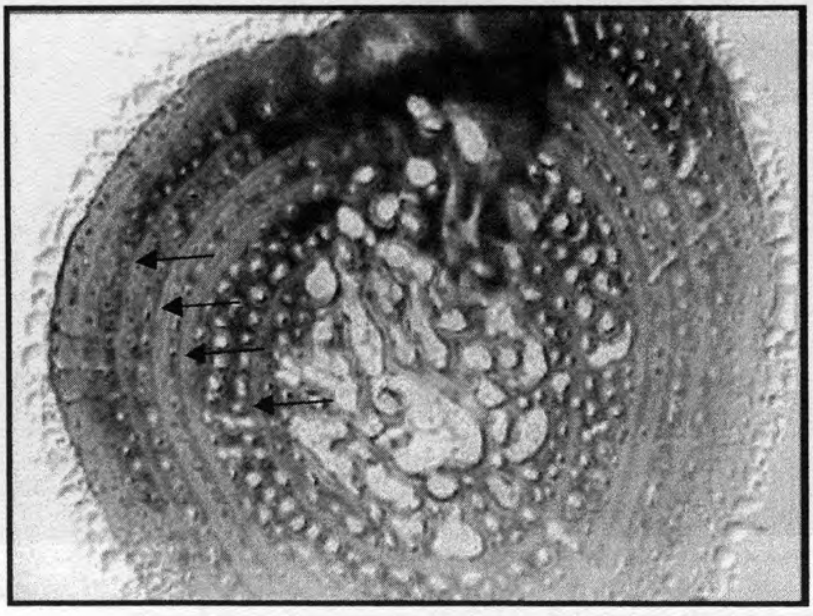

Figure 13. Thin section of femur prior to staining. A minimum of 4 MSGs are visible.

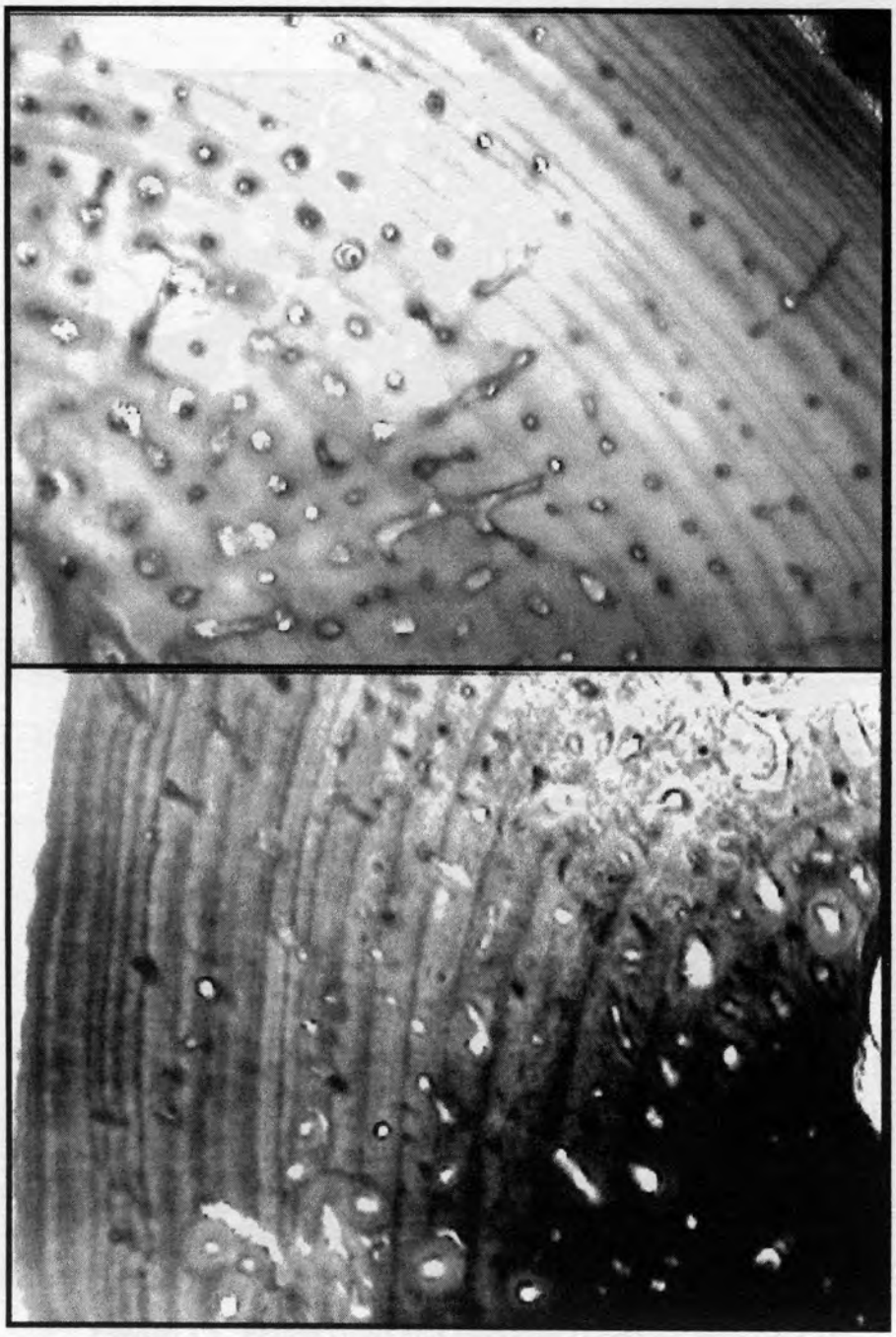

Figure 14. Femur (top) and humerus (bottom), prepared at St. Cloud State University (SCSU), following staining and acid clarification. Note visible MSGs, most of which likely would not have been visible prior to staining.

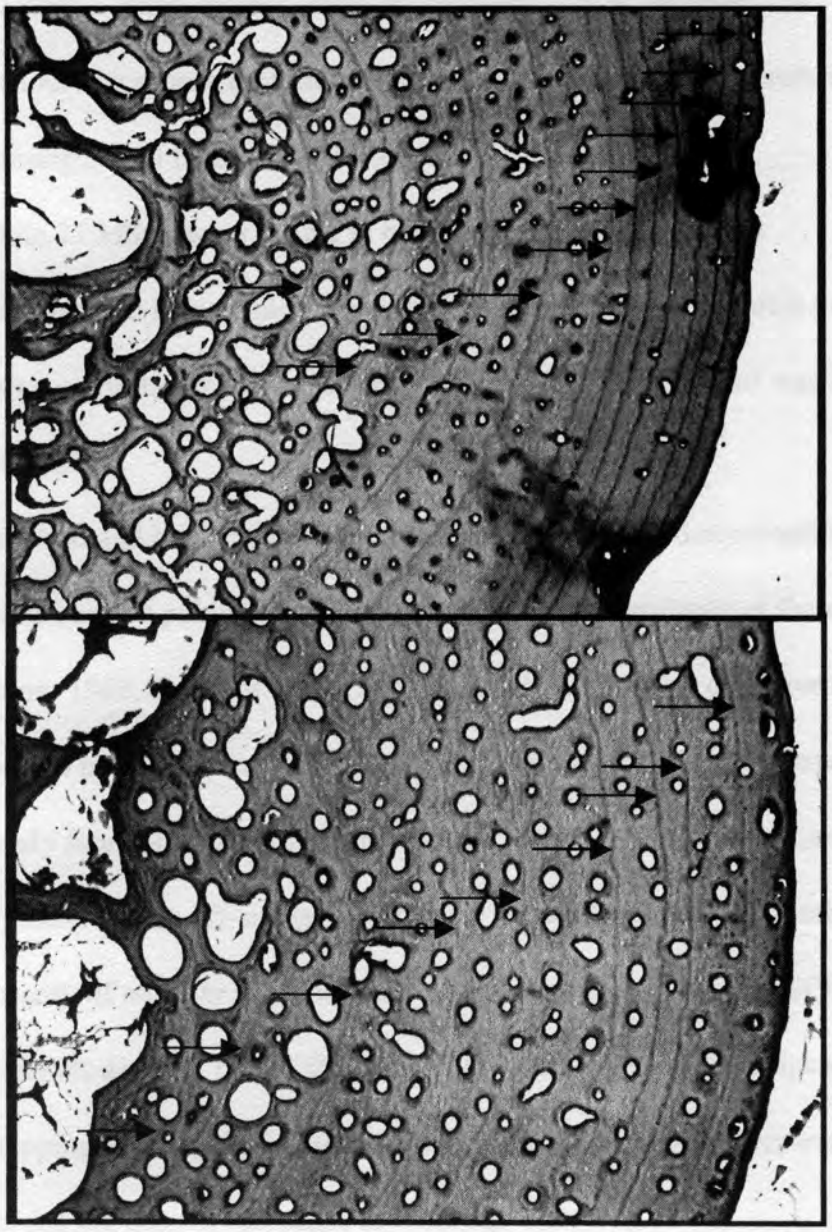

Figure 15. Femur (top) and humerus (bottom), prepared at Matson's Laboratory, LLC. (ML), with 11 and 9 MSGs visible, respectively.

Generally, age estimates among femur and humerus were similar regardless of method of preparation. Hatchling bones did not have any MSGs, regardless of preparation, as should be expected of individuals of age zero. Maximum number of MSGs visible among SCSU femurs was 28 and 25 for males and females, respectively, while 27 MSGs were visible in both male and female humerii (Figure 16). ML prepared femurs had a maximum of 26 and 25 MSGs visible in males and females, respectively, while maximum visible MSGs in humerii was 26 in males and 27 in females.

Though femur and humerus have been used in previous age determination studies, there have been no published attempts to establish the similarity of these age estimates (Hammer 1969, Zug et al. 1986, Bjorndal et al. 1998). One objective of the present study was to perform skeletochronological analysis by utilizing less expensive equipment, already found in many small laboratories, instead of more specialized and expensive equipment used in off-site laboratories. It is hoped that this will establish the significant parity of not only humerus and femur age estimates, but also SCSU and ML prepared samples as well. Establishment of these significant relationships should allow future snapping turtle age estimation studies to use either bone or preparatory method without fearing bone or technique specific age bias.

MSG appearance and age estimates, among femurs and humerii prepared at SCSU and ML, were generally similar (Figures 17 and 18; see Figure 16). The congruence of age estimates from ML samples were statistically significant, but age estimates from SCSU samples were not (t-test: paired two sample for means; Table 3).

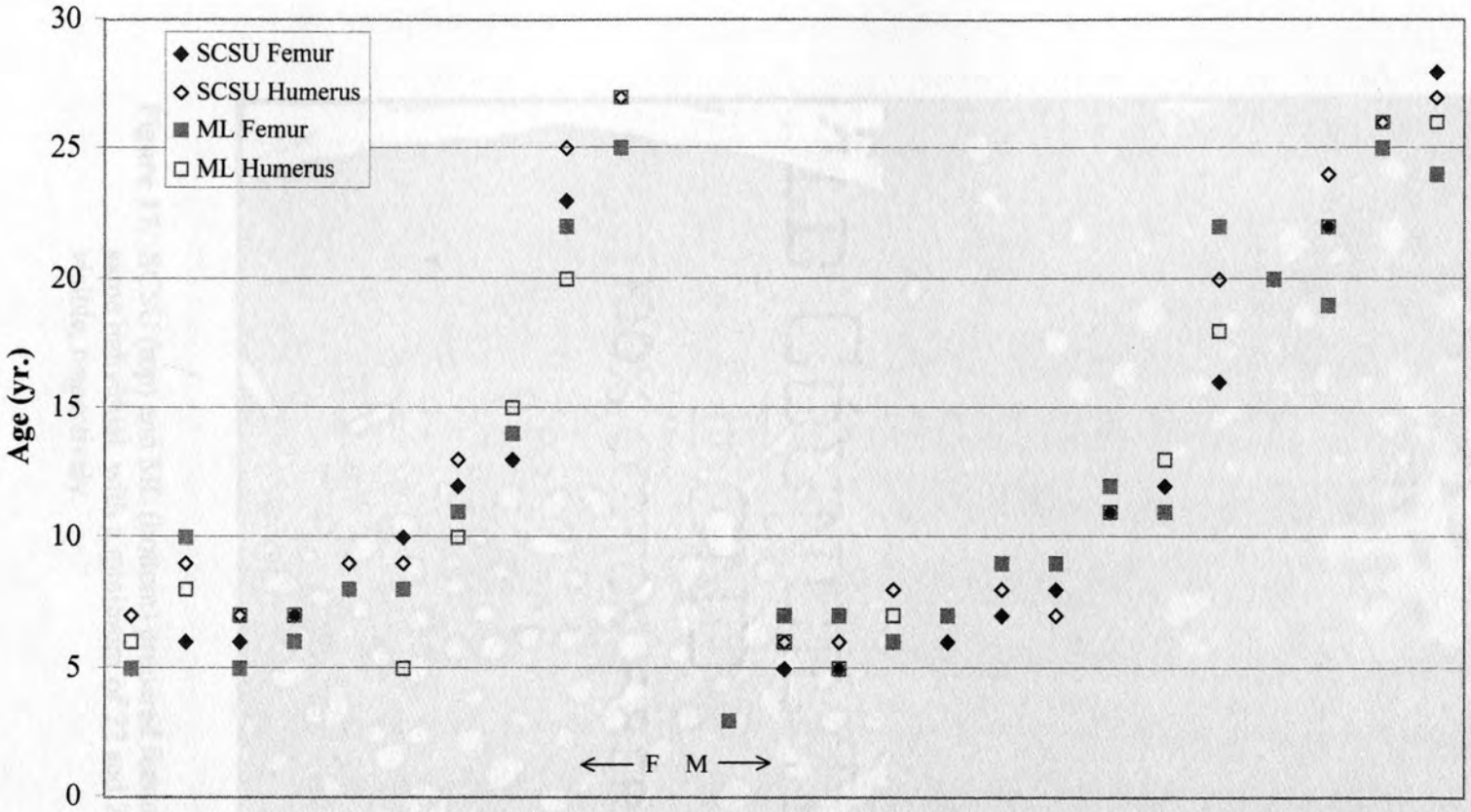

Figure 16. Estimated age (yr.) from skeletochronological analysis of SCSU and ML prepared snapping turtle femurs and humerii (n = 26). Females are on the left of the figure and males are on the right.

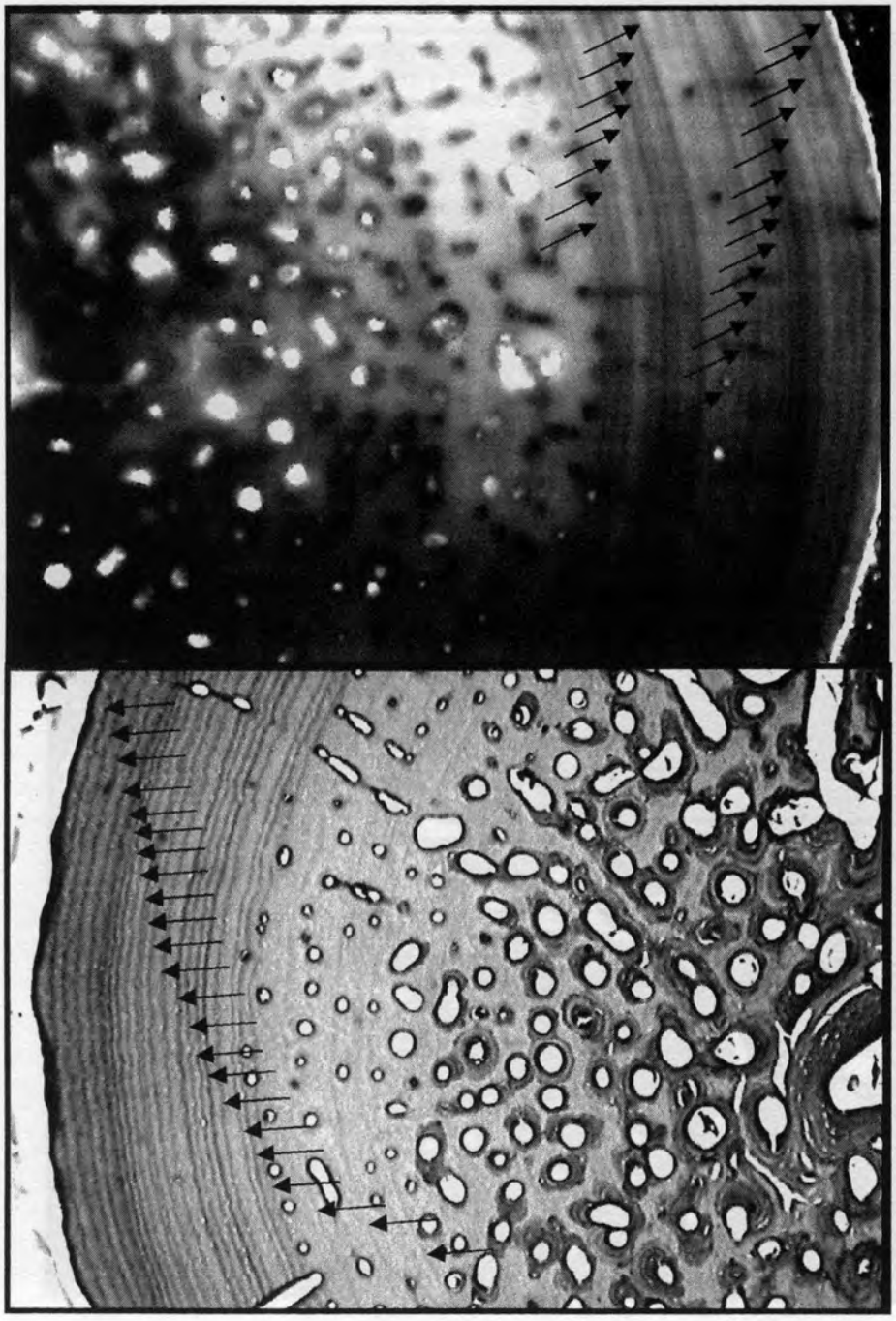

Figure 17. SCSU (top) and ML (bottom) prepared femur from the same individual, with a minimum of 22 and 23 MSGs visible, respectively.

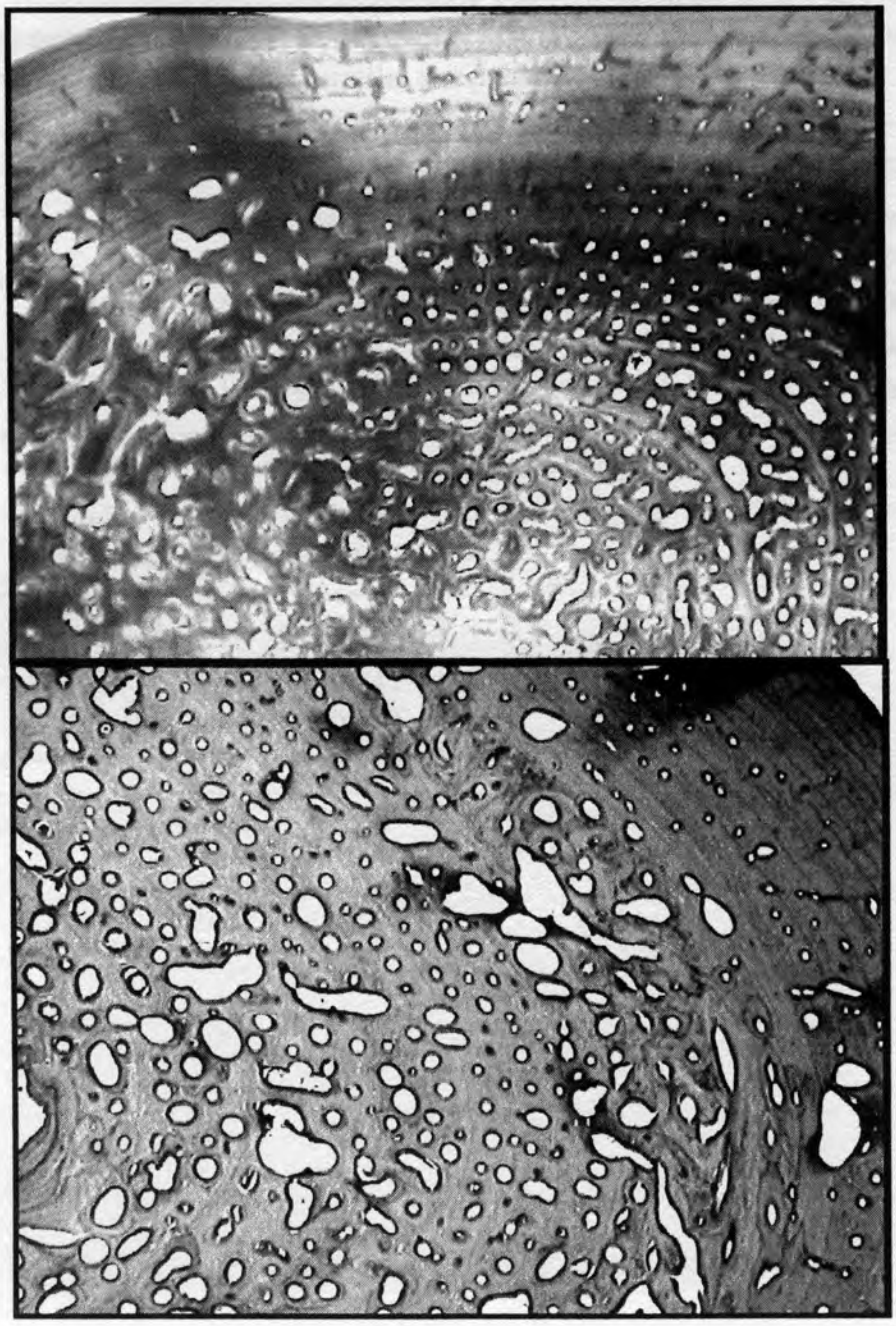

Figure 18. Humerus prepared at SCSU (top) and ML (bottom) with approximately 20 and 18 MSGs visible, respectively.

Table 3. Comparisons of statistical significance and correlation for SCSU and ML prepared femur and humerus using a paired two sample t-test for means. Note the figure functions similar to a punnet square.

		ML Femur			ML Humerus			SCSU Humerus		
		t	df	P	t	df	P	t	df	P
SCSU Femur	Overall	0.59	25	0.281	-0.71	25	0.242	-3.53	25	0.001 *
	Male	0.79	13	0.223	2.10	13	0.028 *	-2.24	13	0.022 *
	Female	-0.19	9	0.427	-0.26	9	0.399	-2.91	9	0.009 *
SCSU Humerus	Overall	-1.85	25	0.038 *	-1.96	25	0.031 *			
	Male	-0.54	13	0.299	-0.72	13	0.244			
	Female	-2.88	9	0.009 *	-1.95	9	0.042 *			
ML Humerus	Overall	0	25	0.500						
	Male	1.51	13	0.441						
	Female	0.18	9	0.432						

* Indicates where a significant difference exists

The lack of statistical significance in SCSU samples is likely partially attributable to the thicker sections produced with SCSU techniques (approximately 0.0059 in. [150 μm] vs. 0.00055 in. [14 μm] for ML sections), which tended to be blurry and thus hinder consistent MSG identification (see Figures 14–15).

Samples prepared at SCSU and ML were also generally significantly similar and the sexes were as well (Figure 16, Table 3). Age estimates from femurs were significant in all categories and humerii were significant in 1 category. SCSU femur and ML humerus were significant in 2 categories while ML femur and SCSU humerus were significant in 1 category. Age estimates from femurs prepared at SCSU were statistically significant when compared to either bone prepared at ML while humerus prepared at SCSU were less significant when compared to either bone prepared at ML.

The significance of age estimates suggests that the relatively simple, inexpensive skeletochronological methods used at SCSU will yield age estimates which are comparable to those prepared at ML. Physical differences among samples produced by the two methods are generally cosmetic with samples prepared at SCSU being smaller (i.e., a radius vs. complete diameter) and thicker (approximately 10x) than those prepared at ML (see Figures 17 and 18). Small discrepancies among age estimates are likely due to a variance in resorption levels among sections being observed, caused by the location within the diaphysis where the sample was taken (G. Matson, pers. comm.). Further, uneven section thickness could affect visible resorption levels by obscuring MSGs in one area of the section while allowing excessive acid clarification of another area. Also, the small number of samples used

for sex-specific skeletochronological analysis (14 male, 10 female) tends to intensify any minor differences in age estimates. In spite of these slight differences, most methods of standard skeletochronological preparation produced sections with significantly similar MSG counts and therefore an average age from skeletochronology was used as a standard of comparison for further aging techniques.

Resorption estimation. Resorption and redeposition cause the deterioration of MSGs over time and occur among the samples of nearly all adult reptilian skeletochronological studies (Castanet 1985, Zug et al. 1986). The development of additional aging methodologies to compensate for lost years will form the foundation of future studies and management alike. In the present study, redeposition was rare but resorption was common with levels varying somewhat by individual and largely by region of bone sampled (Figures 19–22; G. Matson, pers. comm.). Sections displaying MSGs to a radius much closer in size to a hatchling bone (e.g., Figure 19) were apt to produce more accurate age estimates. Overall, first visible MSGs are located at a radius much greater than that of a hatchling femur or humerus (Figure 23), suggesting the resorption of several MSGs (Zug et al. 1986, Patnaik 1994, Bjorndal et al. 1998, G. Matson, pers. comm.).

Age projections from resorption ranged from 6–63 yr. and averaged 22.8 ± 3.3 (SE) yr. with males averaging 22.7 ± 4.0 (SE) yr. and females averaging 22.8 ± 5.8 (SE) yr. (Figure 24). Several high age estimates (>60 yr., see Figure 24) were likely caused by elevated resorption of juvenile MSGs, possibly from sections taken from

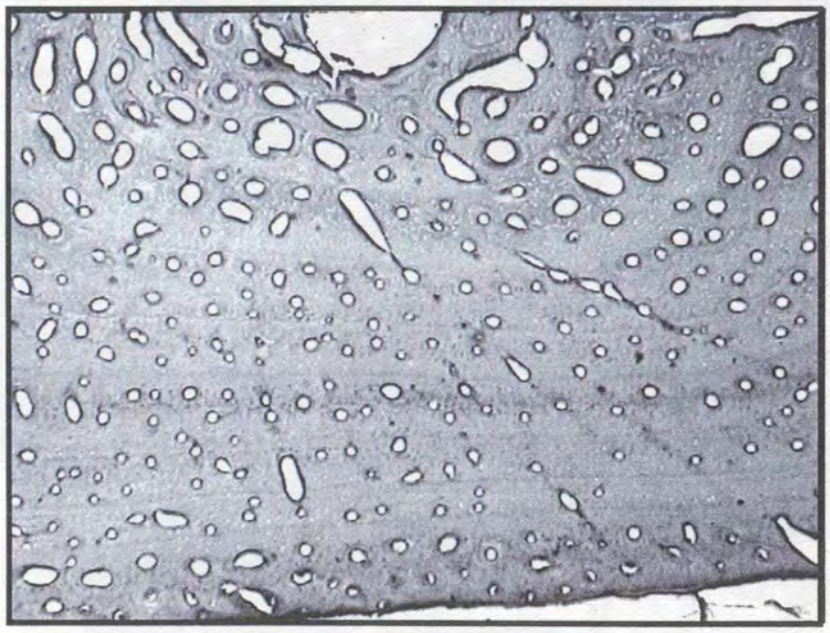

Figure 19. Humerus displaying 7 MSGs and little evidence of resorption.

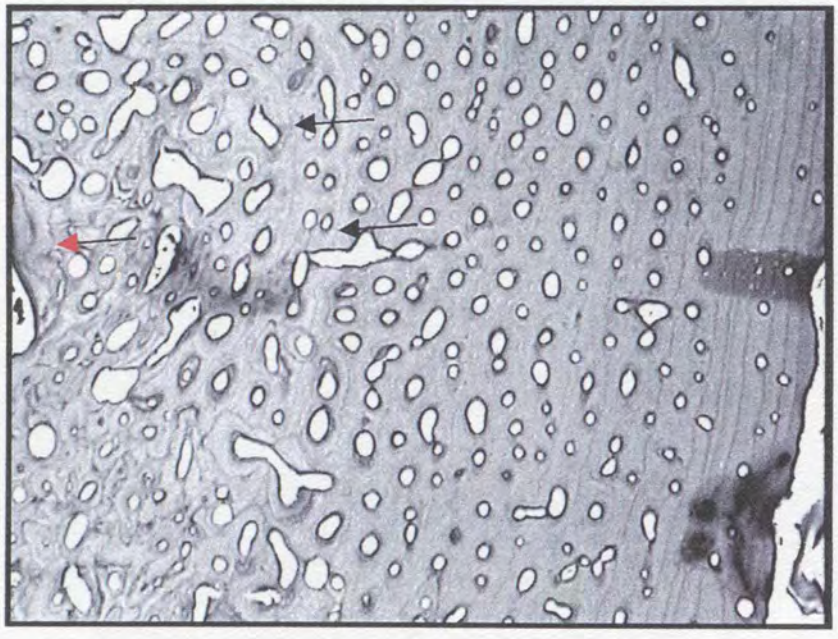

Figure 20. Femur showing two MSGs being erased through the process of resorption (black arrows). Redeposition is visible at the center left margin of the photo (red arrow).

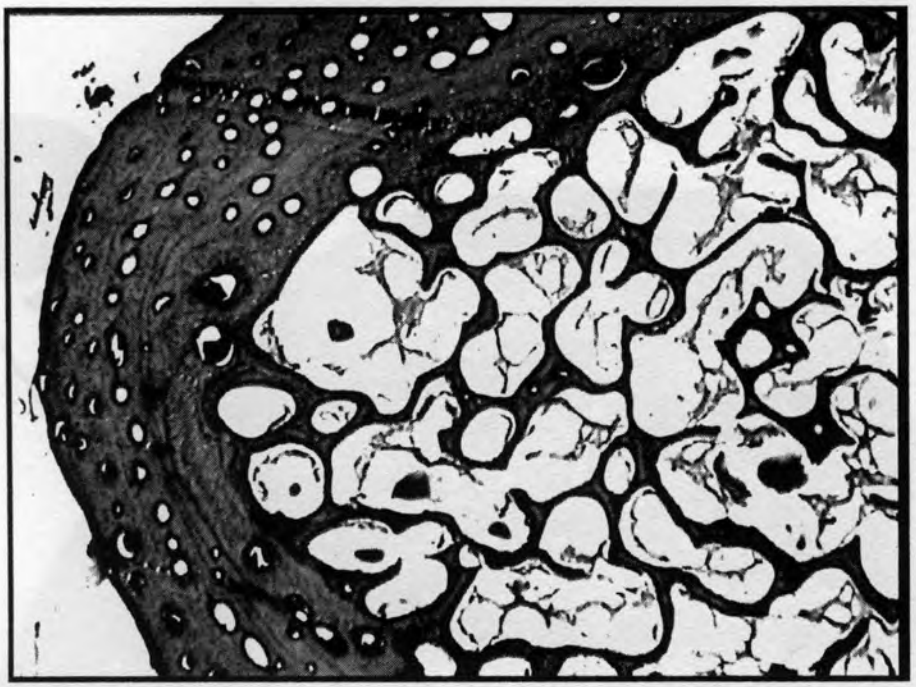

Figure 21. Humerus section from a point outside the diaphysis. Note a general lack of MSGs due to the extensive regions of porous (cancellous) bone.

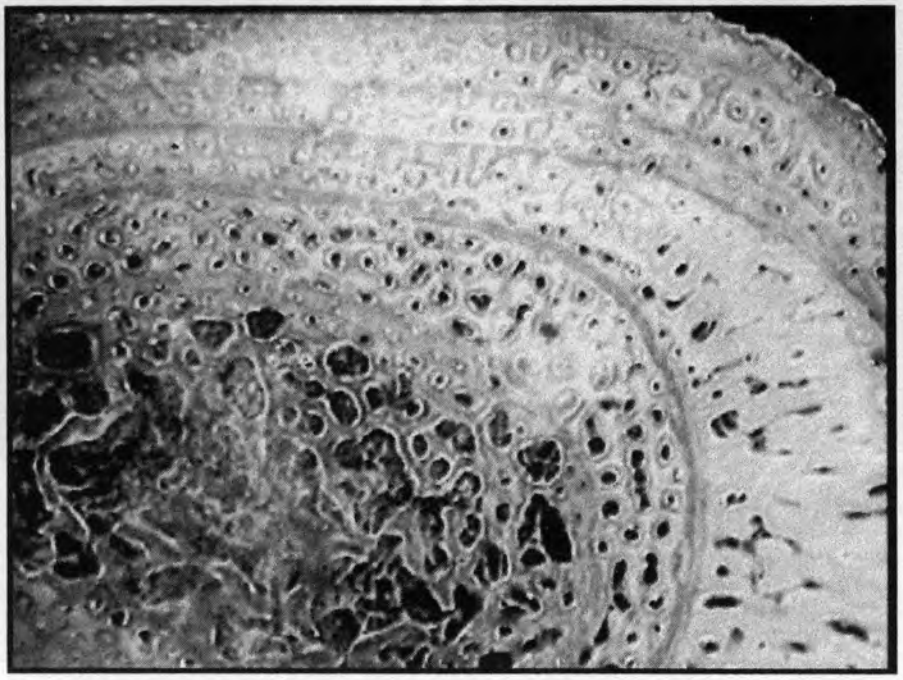

Figure 22. Humerus section from individual in Figure 21, taken from a point closer to the diaphysis, displaying MSGs nearer the center.


A
C
B

Figure 23. Comparison of hatchling humerus (A) to adult humerus (B). Red circle indicates hatchling humerus at same scale as adult humerus. First MSG has been accentuated with a line for visibility purposes (C) and is visible at a radius much greater than that of a hatchling humerus, which indicates that resorption is likely.

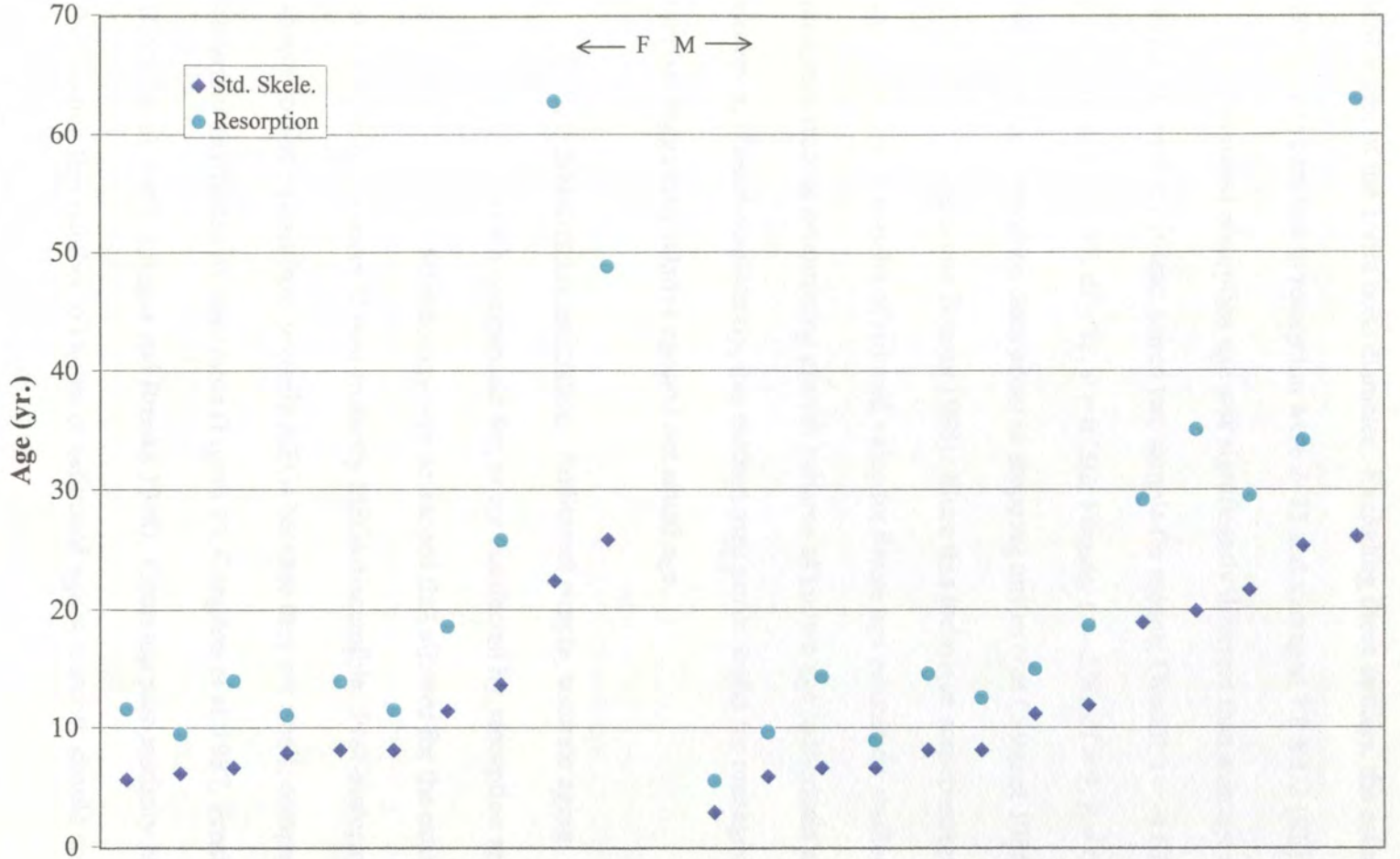

Figure 24. Comparison of snapping turtle age estimates (yr.) obtained from standard skeletochronological analysis (Std. Skele.) and resorption estimation (Resorption).

outside the diaphysis (see Figure 21), and projection of the resultant smaller average MSGs size to the entire bone diameter. Excluding these outliers, the estimated number of years lost to resorption were 2–23 and averaged 7.8 ± 1.2 (SE) yr.

Estimated resorption age was significantly different than average age from skeletochronology (t-test: paired two sample for means; Overall: $t = -4.67$, $df = 22$, $P < 0.001$; Male: $t = -3.57$, $df = 12$, $P = 0.002$; Female: $t = -2.96$, $df = 9$, $P = 0.008$), which indicates that resorption does occur in snapping turtles (see Castanet 1985, Zug et al. 1986, 1997, Litzgus and Brooks 1998). Since this technique sometimes produces high age estimates, it may be of reduced value for future age estimation studies until mark recapture studies determining growth patterns of known age individuals are completed. However, if used consistently, this method may prove useful for managers as an index number suggesting relative age and not actual age.

Post-maturity age estimation. Additional simple, accurate aging methodologies, which compensate for, or are unaffected by, resorption are needed. In the present study, a methodology was developed that allowed for the estimation of age based upon the number of post-maturity MSGs discernible. Post-maturity MSGs are simple to distinguish from juvenile MSGs because they are small, compact, and generally unaffected by resorption (Figure 25; Congdon et al. 1987, Ernst et al. 1994, Brooks et al. 1997, Litzgus and Brooks 1998). Counting post-maturity MSGs and then adding this number to known or estimated age at maturity should accurately indicate actual age.

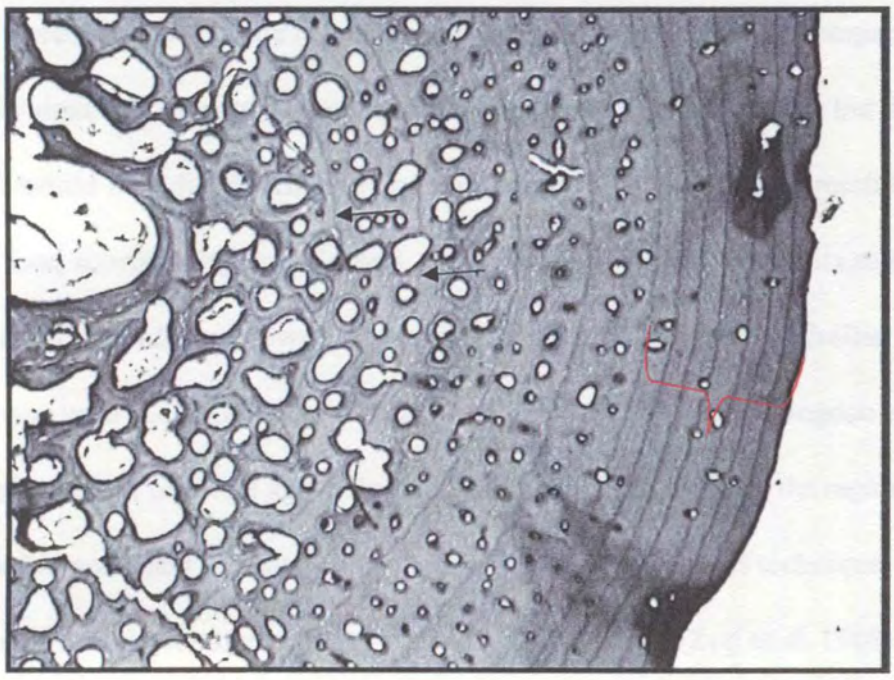

Figure 25. ML prepared femur section displaying 7 MSGs deposited after maturity was reached (brackets) and two MSGs being eroded through resorption (arrows).

Since this method is not currently represented in the scientific literature, several assumptions and advantages require explanation. First, to assure maturity, individuals were considered to be immature until they displayed multiple compact MSGs. Individuals with a single compact MSG could be entering maturity, but this single MSG would be indistinguishable from one caused by a temporary stressful event (e.g., food shortage, injury). Second, since the age at which Minnesota snapping turtles mature is currently unknown, age at maturity for a geographically similar population was used (i.e., Michigan: female 12 yr. and male 9 yr.; see Congdon et al. 1987). Establishment of actual age at maturity for turtle populations in the region being studied is necessary to assure the precision and accuracy of this technique. Finally, standard skeletochronology is a minimum age estimate (Zug et al. 1986, 1997, Patnaik 1994, Bjorndal et al. 1998, G. Matson, pers. comm.) and resorption estimation is more likely a maximum age estimate. If age at maturity is known, post-maturity age estimation should indicate an individual's actual age.

Appearance of MSGs among SCSU and ML prepared samples was similar, with mature individuals displaying post-maturity MSGs in both femur and humerus, and immature individuals not displaying post-maturity MSGs in either bone (Figures 26 and 27). Nearly half of individuals sampled (12 of 26) were considered immature because they lacked compact, maturity-indicating MSGs. The same individuals were determined to be mature for both the SCSU and ML prepared samples. In SCSU samples, half of mature individuals (7 of 14) had identical estimates for each bone, while six of the remaining samples differed by only 1 yr. and the last differed by 2 yr.

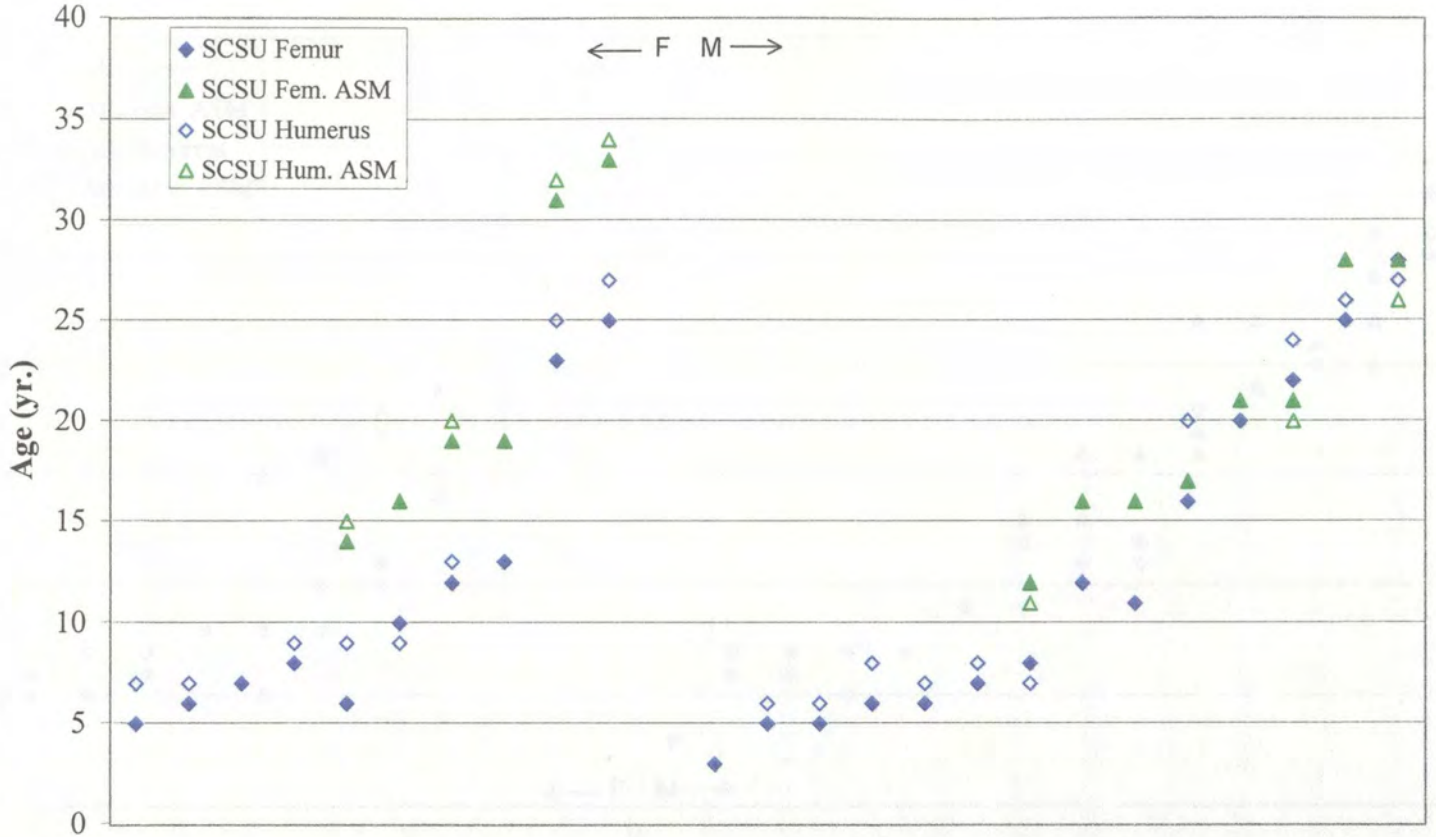

Figure 26. Snapping turtle age (yr.) as estimated through skeletochronological age and post-maturity MSGs (ASM) in SCSU prepared femur and humerus. Age since maturity is the sum of post-maturity MSGs and average age at maturity, assumed to be 12 yr. for females and 9 yr. for males (see Congdon et al. 1987).

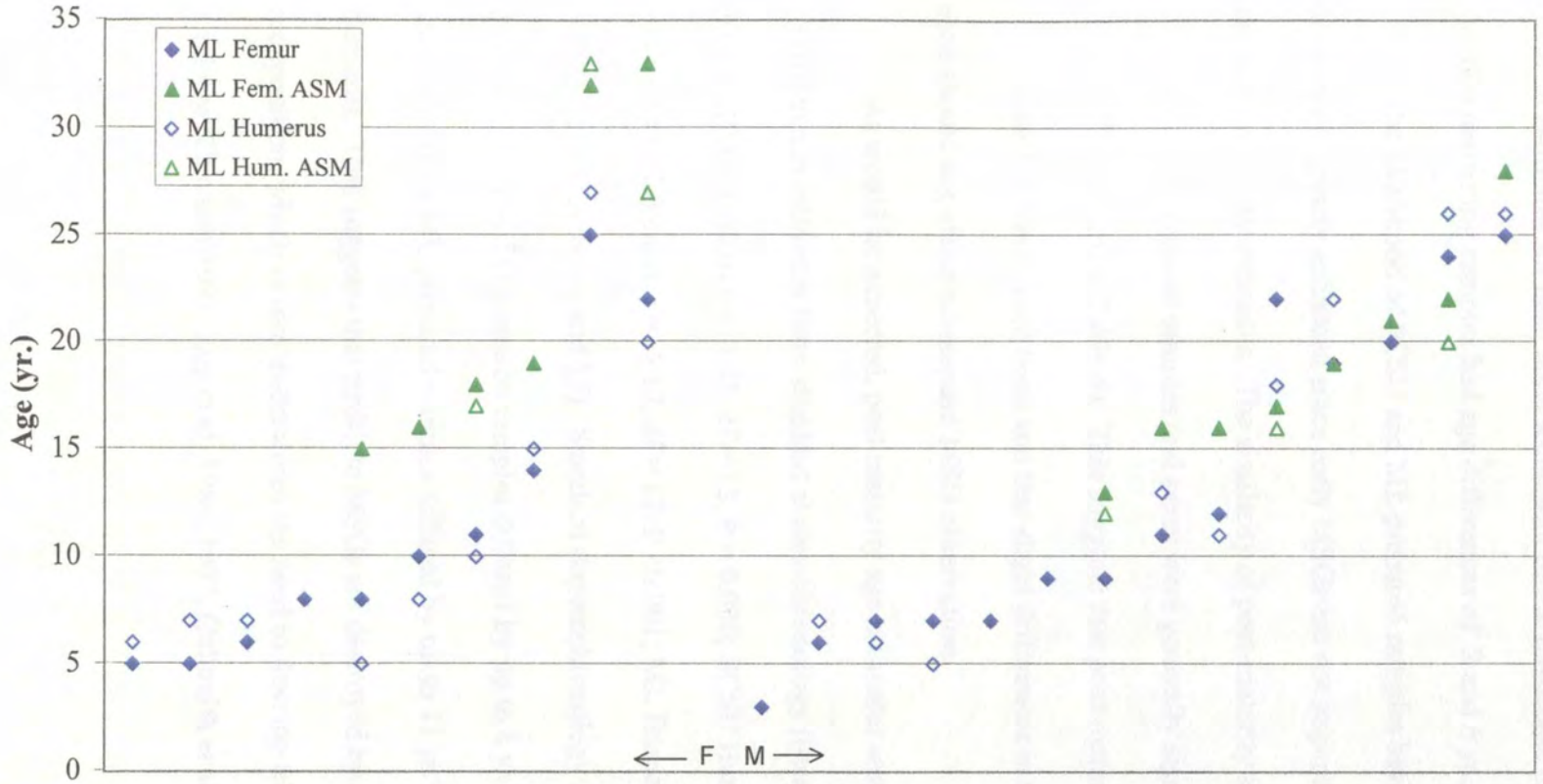

Figure 27. Snapping turtle age (yr.) as estimated through skeletochronological age and post-maturity MSGs in ML prepared femur and humerus.

In ML samples, more than half of those displaying post-maturity MSGs (8 of 14) had identical estimates for each bone while four of the remainder differed by only 1 yr. The two remaining samples had age differences of 2 and 6 yr., respectively.

The likelihood of SCSU and ML prepared samples having similar age estimates is greatly enhanced since early MSGs are not imperative to the accuracy of age since maturity estimates. The similarity of post-maturity age estimates from SCSU and ML prepared samples and sexes were generally significant (t-test: paired two sample for means; Table 4). This suggests that post-maturity MSGs are deposited in a similar fashion in each bone and that slight differences in the preparatory methods used should not affect subsequent MSG observation.

As would be expected, post-maturity age estimates were not significantly related to age estimates from standard skeletochronology (t-test: paired two sample for means; SCSU Femur: $t = -3.41$, $df = 13$, $P = 0.020$; SCSU Humerus: $t = -2.66$, $df = 13$, $P = 0.020$; ML Femur: $t = -5.17$, $df = 13$, $P < 0.001$; ML Humerus: $t = -3.34$, $df = 13$, $P = 0.003$; see Figures 26 and 27). Standard skeletochronology and post-maturity age estimates from SCSU prepared samples differed by up to 8 yr. for femur and 7 yr. for humerus, while ML prepared samples differed by up to 11 yr. in femur and 10 yr. in humerus. This suggests that multiple MSGs are destroyed by resorption or redeposition, which in turn underscores the need to develop techniques to determine total age (Castanet 1985, Zug et al. 1986, 1997, Galbraith et al. 1989, Bjorndal et al.

Table 4. Comparisons of statistical significance and correlation for SCSU and ML prepared femur and humerus using a paired two sample t-test for means.

		ML Femur			ML Humerus			SCSU Humerus		
		t	df	P	t	df	P	t	df	P
SCSU Femur	Overall	-0.82	13	0.21	-1.77	13	0.05 *	0	13	0.50
	Male	-1.10	7	0.15	-1.40	7	0.10	1.87	7	0.05 *
	Female	0.28	5	0.40	-1.00	5	0.18	-3.16	5	0.01 *
SCSU Humerus	Overall	-1.07	13	0.15	-2.03	13	0.03 *			
	Male	-0.63	7	0.27	-1.14	7	0.15			
	Female	-0.89	5	0.21	-1.69	5	0.08 *			
ML Humerus	Overall	1.59	13	0.07 *						
	Male	1.87	7	0.05 *						
	Female	0.97	5	0.19						

* Indicates where a significant difference exists

1995, 1998, Zug and Parham 1996, Klinger et al. 1997, Parham and Zug 1997, Litzgus and Brooks 1998).

Standard skeletochronology yields a minimum age (Castanet 1985, Zug et al. 1986, 1997, G. Matson, pers. comm.). Among samples prepared at SCSU and ML, three males had post-maturity age estimates less than or equal to standard skeletochronological age (SCSU- 2 femur and 3 humerus, ML- 3 humerus and 3 femur; Figures 26 and 27) and the youngest of these individuals was 16 yr. Assuming there were no miscounted or accessory MSGs, then some male Minnesota snapping turtles seem to mature later than those in the Michigan study. Additional maturity studies within Minnesota are needed to establish the exact age at maturity so that the accuracy of this method can be assured.

Scute Annuli Analysis

Scute analysis is a non-destructive age determination technique that is generally accurate among young turtles (e.g., <10 yr.), but accuracy decreases as age and size increases (Figure 28; Galbraith and Brooks 1989, Galbraith et al. 1989, Brooks et al. 1997, Germano and Bury 1998, Litzgus and Brooks 1998). Male annuli counts ranged from 4–24, averaging 10.9 ± 1.7 (SE), while female counts ranged from 3–22, averaging 10.0 ± 1.8 (SE). No annuli were observed in hatchlings (Figure 29).

Counts of scute annuli were significantly different from average standard skeletochronological age (t-test: paired two sample for means; Overall: $t = -3.53$, $df =$

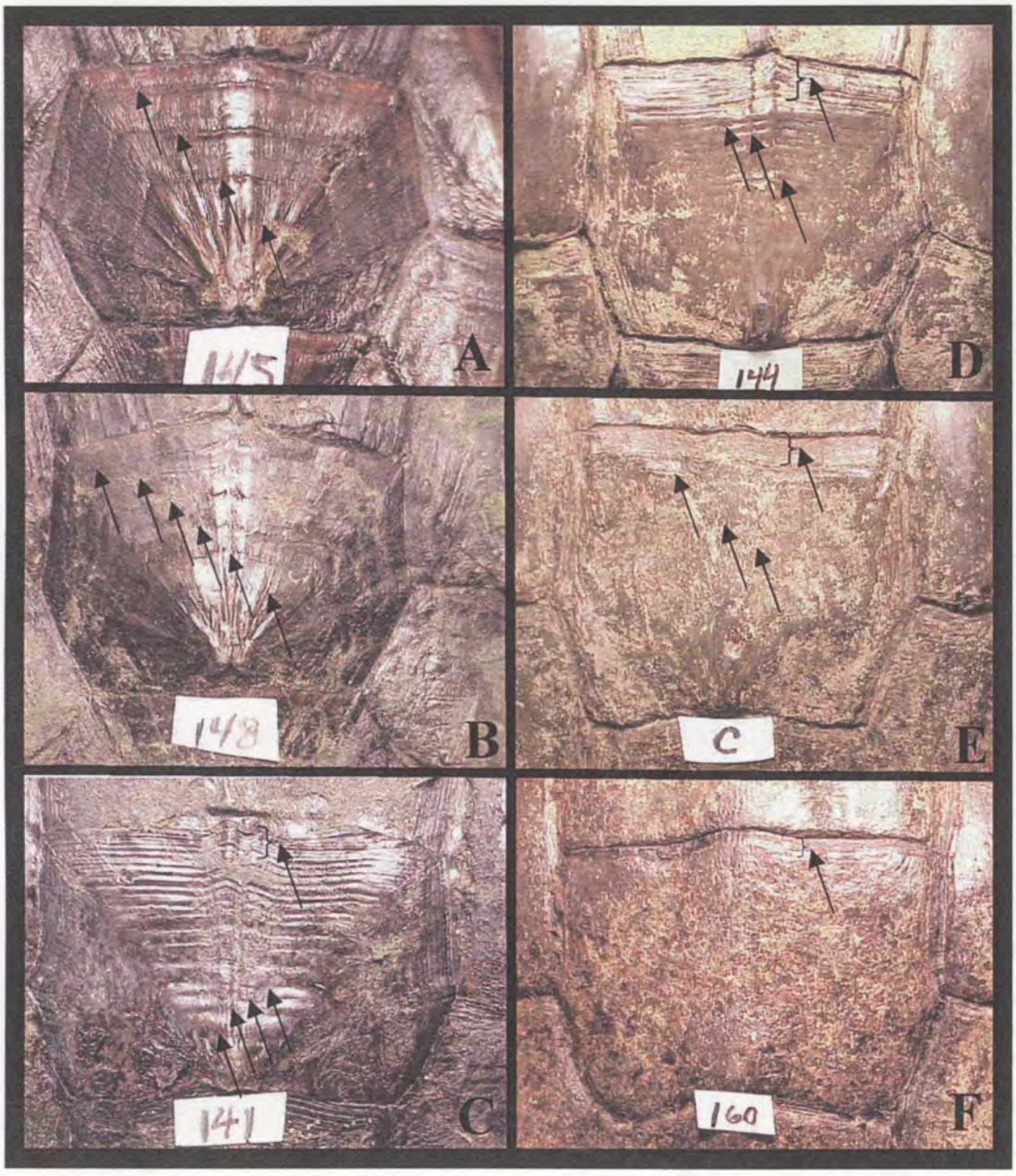

Figure 28. Annuli from fourth vertebral scutes. Note increasing difficulty distinguishing annuli in the progression from A – F. Brackets indicate regions of extremely tight annuli, typical of mature snappers, which are very difficult to distinguish with a naked eye. (Photography: Jorge Arriagada)

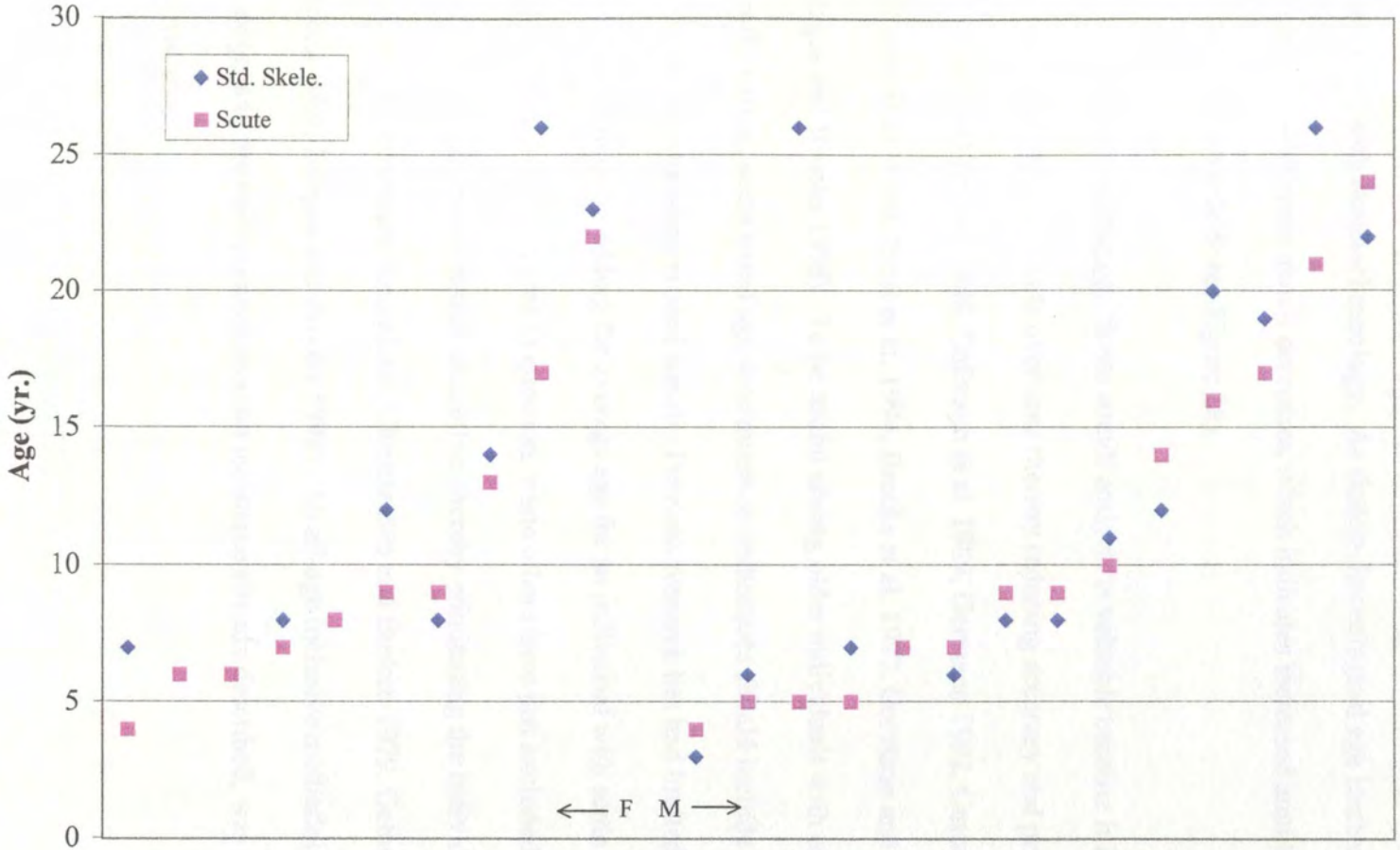

Figure 29. Comparison of snapping turtle age estimates (yr.) determined by scute analysis and standard skeletochronology.

25, P = 0.038; Male: t = -1.25, df = 13, P = 0.116; Female: t = -1.78, df = 9, P = 0.054). Half of individuals (13/26) had scute estimates less than average age determined with skeletochronology. As skeletochronological age increases, congruence with scute annuli decreases, which indicates increased annuli erosion as age increases (Table 5: see Figure 28).

Erosion estimation. Scute annuli analysis is valuable because it is non-destructive, but scutes erode over time thereby reducing accuracy and practicality (Galbraith and Brooks 1989, Galbraith et al. 1989, Germano 1992, Castanet 1994, Congdon et al. 1994, Ernst et al. 1994, Brooks et al. 1997, Germano and Bury 1998, Litzgus and Brooks 1998). To be useful among older individuals with extensive annuli erosion, scute based age determination techniques should include projective methods for estimating eroded annuli. Previous research has had limited success aging individuals by adding the average age for an individual with scute length the same size as the eroded area in question, while others have just excluded individuals with incomplete sets of annuli altogether, thereby eliminating the individuals most in need of age estimation (i.e., oldest; Christiansen and Burken 1979, Galbraith and Brooks 1989, Litzgus and Brooks 1998). An all-age inclusive methodology, analogous to the resorption estimation technique already described, was used in the current study.

Table 5. Correlation of scute age and average bone age as age increases, using a paired two sample t-test for means.

	t	df	P	P. Cor[1]
Overall	-1.89	25	0.035	0.810
<10 years	-0.60	14	0.278	0.957
>10 years	-1.90	10	0.043	0.378
>20 years	-1.82	5	0.065	-0.441

[1] Pearson Correlation

Age estimates were obtained by projecting average annulus distance to the entire scute length minus hatchling scute length. Excluding hatchlings, projected scute age ranged from 5.6–91.5 yr. for males and 3.3–38.8 yr. for females (Figure 30). The exaggerated male age estimate of 91.5 yr. was the result of projecting the average width of several small, post-maturity annuli to the entire scute. Without this individual, male age estimates ranged up to 34.3 yr. Overall average projected age from scute annuli was 16.0 ± 0.97 (SE) yr., with males averaging 16.9 ± 1.30 (SE) yr. and females averaging 14.8 ± 1.43 (SE) yr., which is significantly different than scute annuli analysis (t-test: paired two sample for means; Overall: $t = -12.86$, $df = 51$, $P < 0.001$; Male: $t = -10.02$, $df = 29$, $P < 0.001$; Female: $t = -8.30$, $df = 21$, $P < 0.001$). The estimated number of eroded annuli ranged from approximately 1–11 yr. and average 4.59 ± 0.36 (SE) yr., with males averaging 5.02 ± 0.50 (SE) yr. and females averaging 4.02 ± 0.48 (SE) yr. Differences in these two age estimates are an indicator of universal scute erosion and therefore support the need for development of further techniques to estimate these eroded annuli.

Projected scute age was also significantly different than average bone age from skeletochronology (Figure 31; t-test: paired two sample for means; Overall: $t = 4.70$, $df = 23$, $P < 0.001$; Male: $t = -4.14$, $df = 11$, $P < 0.001$; Female: $t = 2.68$, $df = 9$, $P = 0.010$). Average difference in age estimates from scute annuli and bone age was 2.8 ± 0.65 (SE) yr., with 62.5% (15 of 24) differing by <3 yr. and 4 estimates less than or equal to average bone age estimates. These estimates were more similar than the

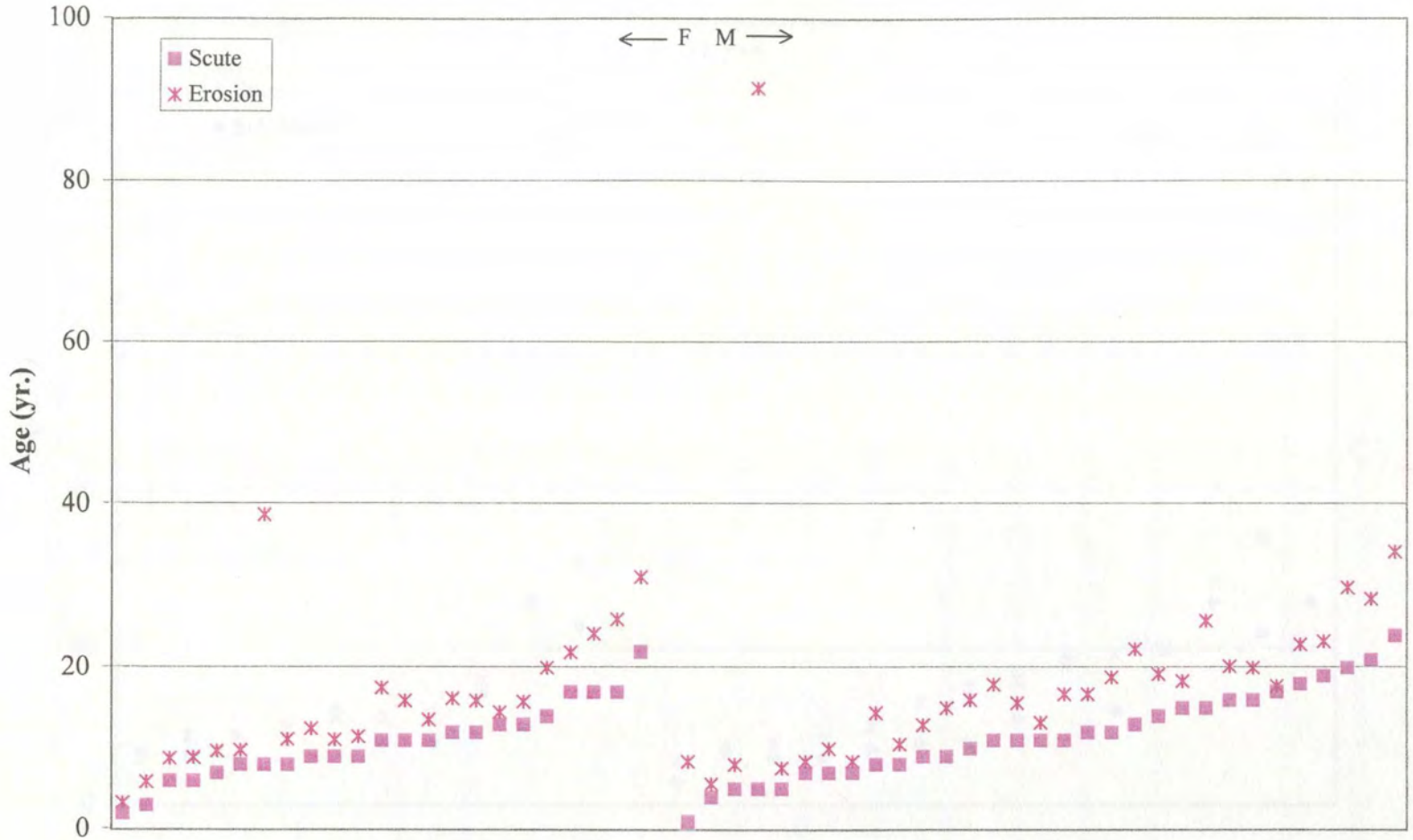

Figure 30. Scute age (yr.) and estimated age from scute erosion (yr.; Erosion) for west central Minnesota snapping turtles.

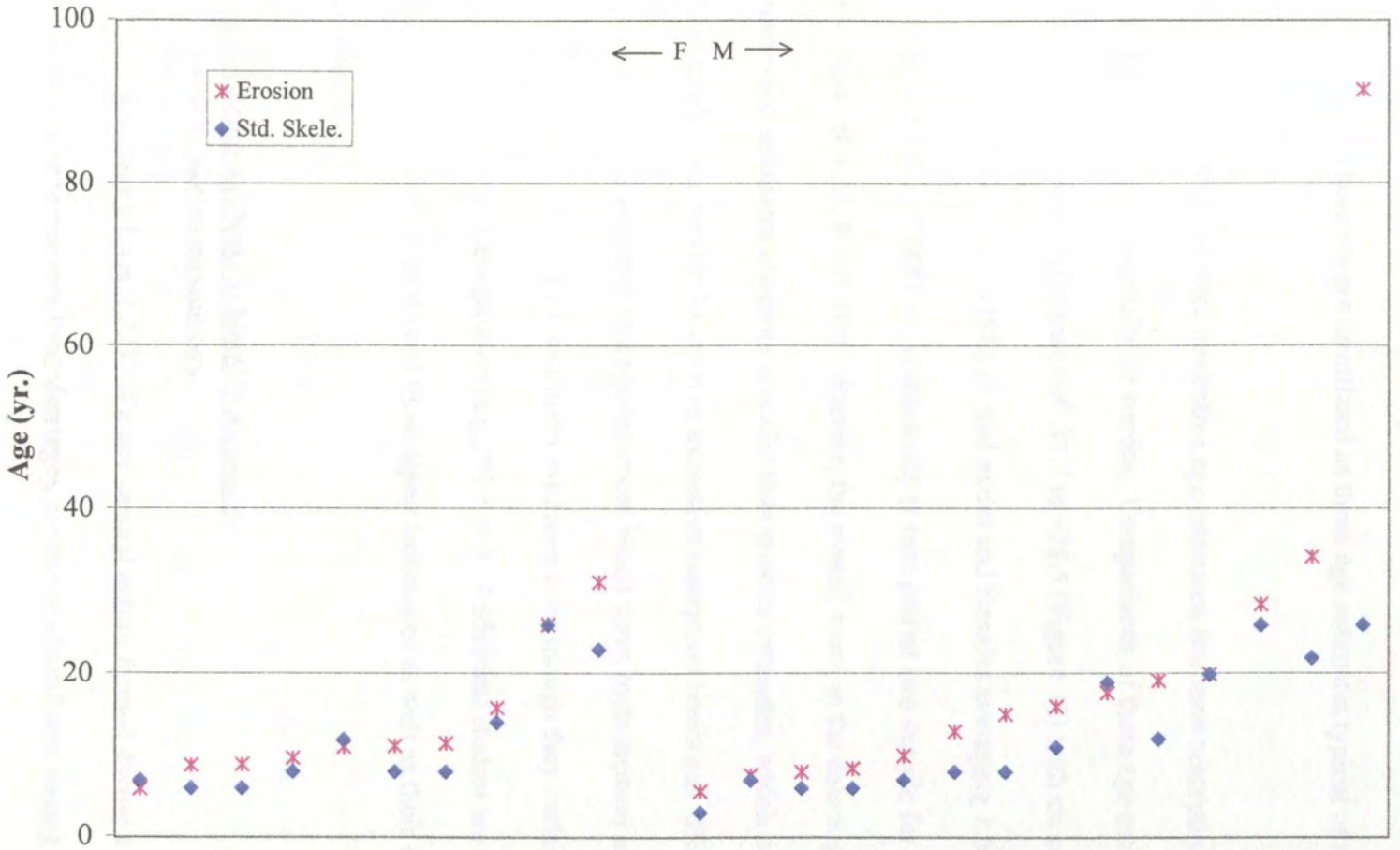

Figure 31. Comparison of estimated age from scute erosion (yr.; Erosion) and average bone age (yr.) for west central Minnesota snapping turtles.

difference between scute annuli and projected scute annuli, which had an average difference of 4.59 ± 0.36 (SE) yr., suggesting that age estimates based upon scute erosion as a whole are not as inflated as those age estimates typical of resorption estimates.

Since they are both projective age estimates, humerus resorption age and scute erosion age could potentially be similar. Comparisons of these age estimates revealed significant estimate differences of -31.7 to +28.5 (Figure 32) with an average difference of 4.65 ± 2.28 (SE) yr. and males and females averaging 1.66 ± 2.93 (SE) yr. and 8.84 ± 3.32 (SE) yr., respectively (t-test: paired two sample for means; Overall: $t = -2.04$, $df = 23$, $P = 0.026$). Further, the overall trend in the data suggests that resorption estimates are more sporadic than erosion estimates, which demonstrates how easily poor section location or excessive resorption levels can affect age estimates. This suggests that age estimates based upon scute erosion are not as inflated as those typical of resorption estimates even though they certainly have the same potential for exaggeration (e.g., 91.5 yr.). Additional studies are needed to further establish the validity of these aging techniques as well as their exact relationship.

Use of Scute Analysis to Identify Accessory Lines in Skeletochronology

Accessory lines, LAGs of a non-annual nature formed during a stressful event (e.g., injury or temporary food shortage), are easily identifiable among juvenile MSGs

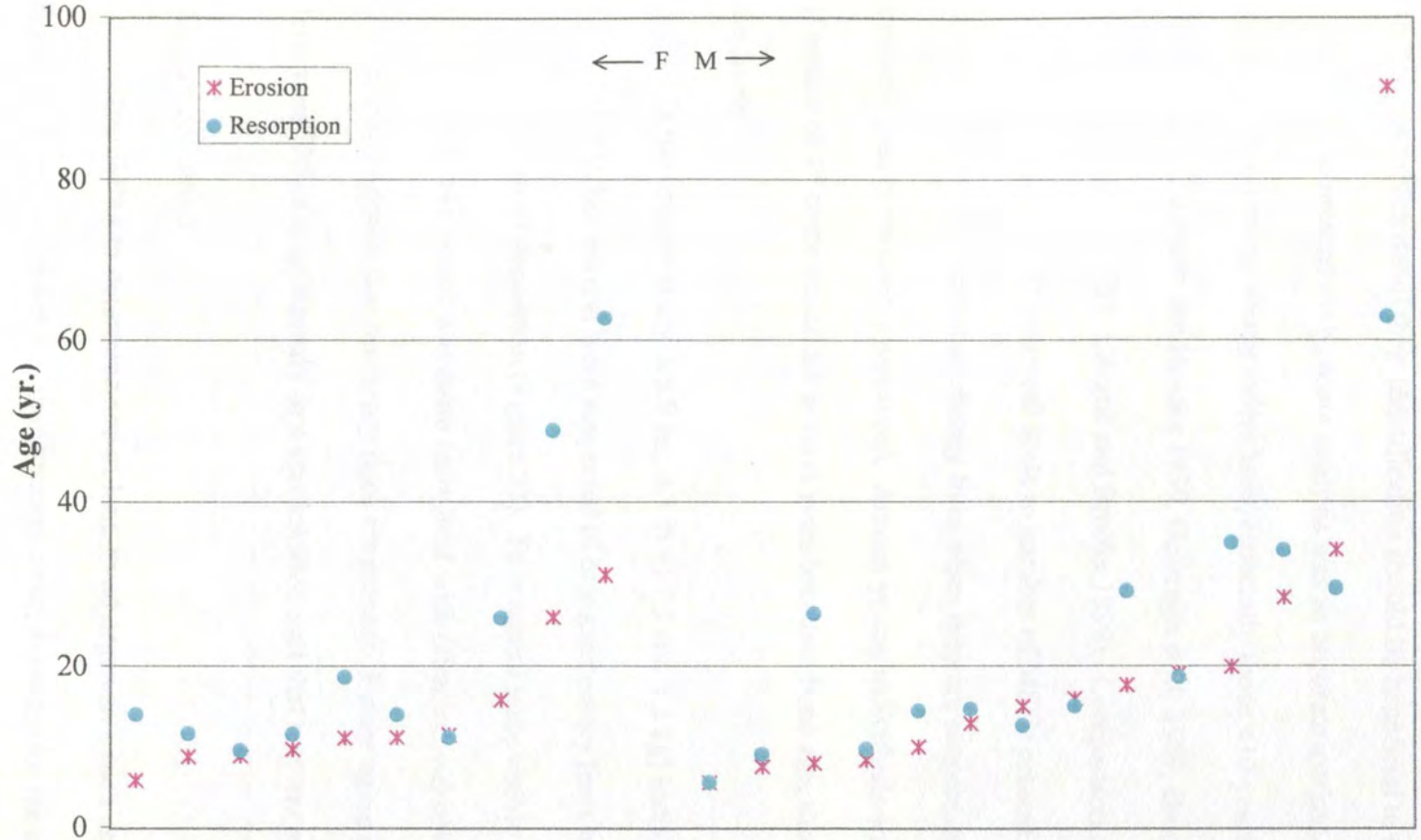

Figure 32. Comparison of estimated scute age (yr.; Erosion) and age estimated from humerus resorption (yr; Resorption) for west central Minnesota snapping turtles.

but are difficult to distinguish among compact post-maturity MSGs (Castanet 1985, Zug et al. 1986). Methods for identification of accessory lines are scarce, so additional techniques which detail their identification should be beneficial to future aging studies.

In the present study, scute analysis was an accurate method of age determination among young individuals, especially those <10 years of age (see Table 5; see Galbraith and Brooks 1989, Galbraith et al. 1989, Brooks et al. 1997, Germano and Bury 1998, Litzgus and Brooks 1998). Comparison of the number of annuli visible on the 4th vertebral scute to number of MSGs present in humerus or femur should help confirm accessory lines when they are suspect, especially when a multiple year difference is perceived. Among young individuals with complete annuli, if counts of 4th scute annuli are several years less than bone age, then accessory lines are likely.

In the present study, a 6.9 in., 2.3 lb. (17.5 cm, 1.1 kg) individual appeared to have 7 MSGs, but several were suspected of being accessory lines because of their atypical pattern of deposition (Figure 33). Four annuli were visible on the 4th vertebral scute (Figure 34), which was more consistent with other individuals of similar size, and thereby suggests that accessory lines are present. Future aging studies may help to determine if this is an anomaly or a species wide trait that requires additional attention.

All Age Estimates

The ability to determine age of long-lived organisms such as snapping turtles is important to future studies and management alike, allowing for the establishment of

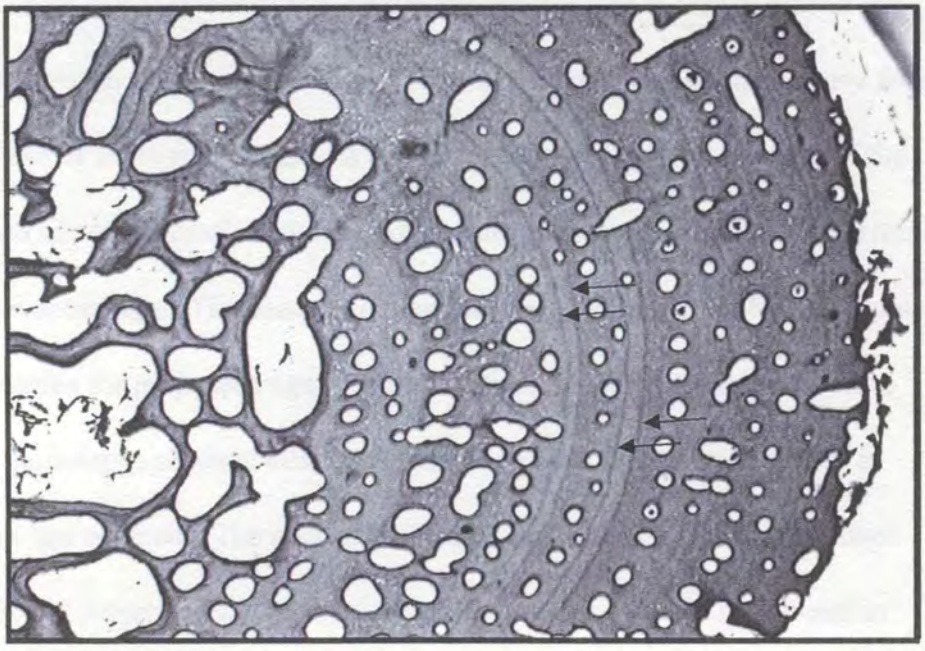

Figure 33. Humerus with accessory lines.

Figure 34. Fourth vertebral scute from individual in Figure 27. Note only 4 annuli are visible. (Photography: Jorge Arriagada)

factors such as age at maturity and maximum lifespan that in turn assists in the development of management practices. Prior age determination efforts have focused upon the use of scute annuli analysis and skeletochronology, but because of the destruction of early annual marks these estimates must be considered an age minimum rather than actual age. The need for determining actual age led to the development of methodologies for projecting age based upon erosion and resorption, but these methods sometimes produce inflated estimates so they should be treated as a maximum age estimate. The present study utilized each of the aforementioned minimum and projective age estimation methodologies and also developed an additional technique that could determine the age of a mature individual without the pitfalls of the other techniques (i.e., age since maturity). It was hoped that age could then be related to an external feature to allow quick, accurate, non-lethal age determination.

Age estimates varied by age determination method used (Figure 35). Minimum age estimates ranged from 3–5.6, maximum age estimates ranged from 24–91.5, and hatchling age was always zero. Significant statistical differences existed among age estimates from all methodologies used, but the overall trend in the data is the same. In general, scute annuli analysis and skeletochronology are the most comparable aging methods, with erosion estimation mirroring these estimates for all but the oldest individuals. Exceptions in the data trend are usually found among projective age estimates and especially among individuals >20 yr. These individuals demonstrate that samples with high numbers of destroyed annual marks not only

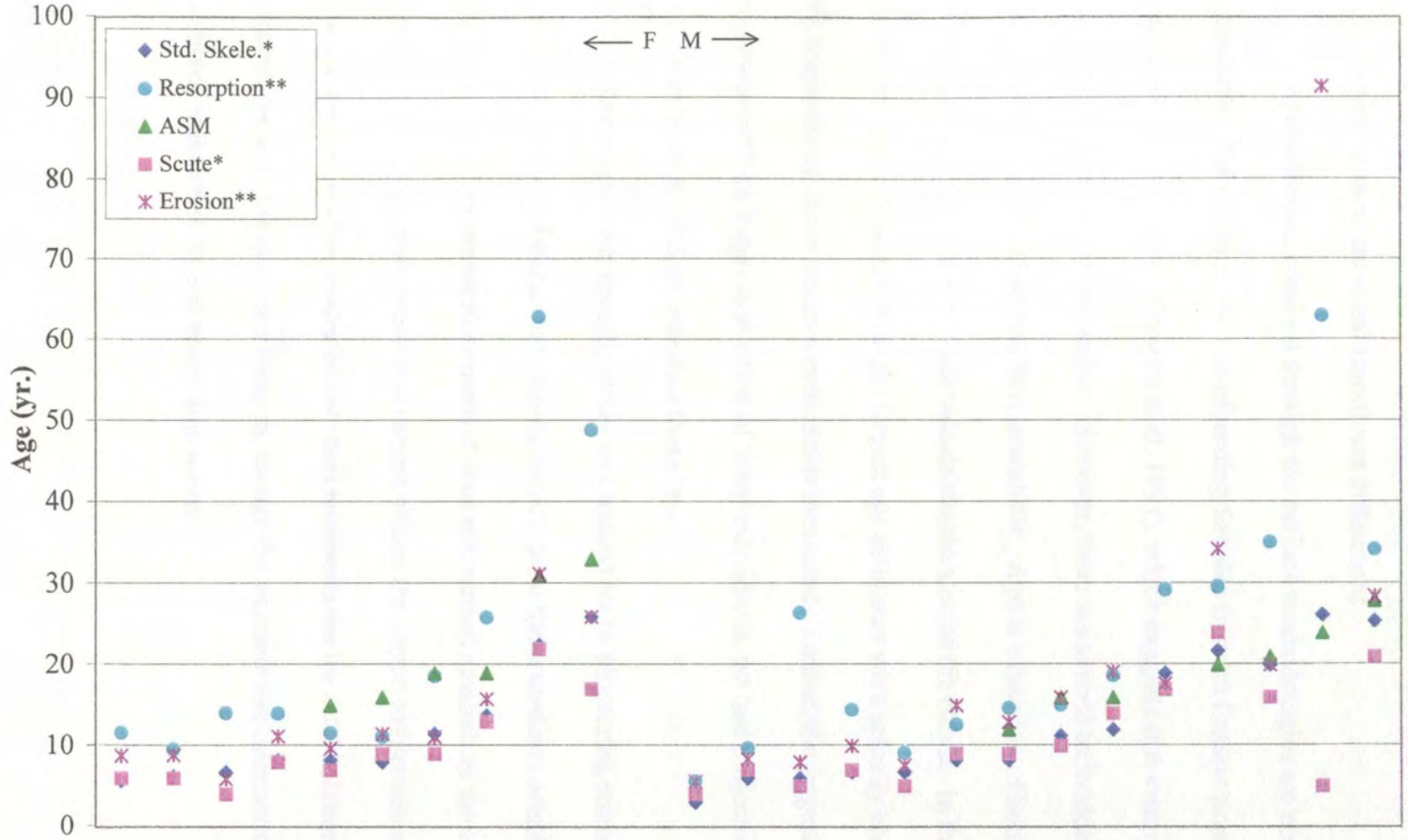

Figure 35. Comparisons of minimum and projective age estimates obtained through skeletochronology and scute annuli analysis.

* indicates minimum age estimate ** indicates projective age estimate

produce inflated age estimates, but also disrupt the trend of the data thereby contributing to their universal significant differences.

Age estimates obtained through the various methodologies are not, as a whole, unrealistic. For instance, the age of nesting females from an Ontario population was estimated to be 33–40 yr. (Brooks et al. 1991), which suggests that estimates >30 yr. in the present study are reasonable. However, there are several individuals with estimates that are, in all probability, unrealistic. Age is a function of body size, so it follows that the most massive individuals should also be the oldest. In the current study, the two individuals with the largest age estimates were actually only the 4th and 6th, respectively, most massive individuals measured. Further, the largest individual mass was >4.3 kg larger than either of these individuals, yet had projective age estimates of 26.8–71.5 yr. less than these two.

The present sex-specific study was limited by its pioneering nature and small sample size. Future researchers should benefit from the precedents established (e.g., humerus, femur, or preparatory method does not matter) as much as the age estimates determined. Additional research is needed within the region to increase sample size. Mark-recapture studies would be the most beneficial for the establishment of age at maturity as well as maximum lifespan, though the expense and time commitment involved makes this type of study impractical.

PRELIMINARY USE OF EXTERNAL FEATURES IN AGE ESTIMATION

Since skeletochronology requires dead individuals, the ability to use a living individual's external features for age determination is an exciting prospect (Bjorndal et al. 1998). Scute annuli would be the most convenient choice but they are of diminished value among older turtles (Klinger et al. 1997, Litzgus and Brooks 1998). Additional methodologies establishing a relationship between age and size of an external feature need to be developed so that snapping turtles need not be sacrificed for future aging studies. To be practical, these correlative methods should be sex-specific and use measurements that are relatively simple to obtain in the field from large and aggressive individuals.

Prior attempts at feature based age estimation of turtle species have used variations of elaborate growth models (e.g., von Bertalanffy, Gompertz, and logistic) that were developed by fisheries managers to predict age at a given size (Frazer and Ehrhart 1985, Galbraith et al. 1989, Cox et al. 1991, Ehrhart and Witham 1992, Murphy and Willis 1996, Zug and Parham 1996, Parham and Zug 1997, Zug et al. 1997, Litzgus and Brooks 1998). These methods would be feasible for large-scale studies but had to be abandoned in the current, sex-specific study due to the small sample sizes involved.

Preliminary Regression Analysis

Regression analysis of sex-specific age and feature size data (e.g., mass, length, width, circumference, etc.) can be used to aid in the formation of growth models (see Ehrhart and Witham 1992, Germano 1992, Litzgus and Brooks 1998). In the current study, size data were plotted against age for each sex, using an identical hatchling age. Since many types of regression cannot be performed with a zero value in the data set, hatchling age was considered to be 0.001 yr. because they died less than a day after hatching. A power curve represented the best fit to the data, as indicated by the R^2 value, and all regressions appeared similar to Figure 36. Age/size regressions indicate that males were larger than females throughout life as suggested by prior studies (see Carr 1952, Conant 1958, Tyning 1990, Ernst et al. 1994, Conant and Collins 1998).

The R^2 values ranged from 0.735–0.998 (Table 6), which suggests that all aging methods and features tested are potentially useful as age indicators. Age since maturity yields the highest average R^2 value for both males and females (0.995 and 0.996, respectively) and the highest average R^2 value for features measured was CCL (curved carapace length) and 2CSL (curved scute length of the second left anterior costal) in males (0.955) and plastron width in females (0.963). These R^2 values indicate promising combinations of features and aging methods for future research efforts.

Regression equations and graphs can also be utilized to predict age or size for an individual. For example, using CCW (curved carapace width) data and average

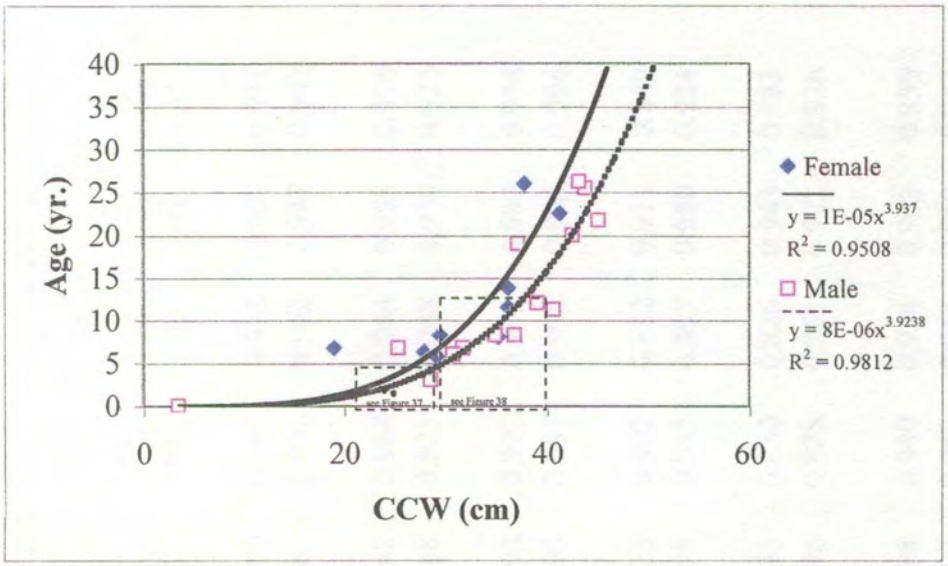

Figure 36. Curved carapace width (CCW; cm) vs. age from standard skeletochronology (yr.) for snapping turtle sexes. R^2 values indicate how well an equation (regression) describes the data.

Table 6. R^2 values from regression analysis of graphs of various physical features and aging techniques.

	Weight	CCL*	CCW*	Head W.	Tail	Plastron L.	Plastron W.	2CSL*	2CSW*	Average
Bone Average										
Male	0.979	0.982	0.981	0.977	0.970	0.985	0.985	0.968	0.971	0.977
Female	0.943	0.950	0.951	0.943	0.883	0.936	0.962	0.947	0.942	0.940
Resorption Age										
Male	0.978	0.977	0.978	0.970	0.968	0.984	0.984	0.958	0.996	0.977
Female	0.932	0.938	0.940	0.934	0.868	0.923	0.948	0.939	0.926	0.928
Maturity										
Male	0.996	0.994	0.996	0.992	0.992	0.997	0.995	0.993	0.998	0.995
Female	0.997	0.997	0.994	0.998	0.995	0.997	0.998	0.995	0.996	0.996
Scute Age										
Male	0.884	0.899	0.981	0.909	0.823	0.902	0.882	0.911	0.849	0.893
Female	0.928	0.936	0.931	0.938	0.895	0.945	0.957	0.950	0.924	0.934
Scute Estimate										
Male	0.810	0.921	0.822	0.908	0.735	0.830	0.826	0.943	0.883	0.853
Female	0.918	0.832	0.925	0.934	0.896	0.935	0.951	0.922	0.926	0.915
Average Male	0.929	0.955	0.952	0.951	0.898	0.940	0.934	0.955	0.939	
Average Female	0.944	0.931	0.948	0.949	0.907	0.947	0.963	0.950	0.943	

* CCL: curved carapace length, CCW: curved carapace width, 2CSL: curved scute length of second left costal scute, 2CSW: curved scute length of second left costal scute

skeletochronological age from the current study to predict age at the current minimum size of harvest in Minnesota (10 in. or 25.4 cm), indicates that these individuals would be approximately 3 yr. (Figure 37). Snapping turtles in northern latitudes are not mature at any of the ages predicted by regression analyses used in the present study (Christiansen and Burken 1979, Galbraith and Brooks 1989, Brooks et al. 1991, Congdon et al. 1994). Assuming age at maturity of 9 and 12 yr. for males and females, respectively, this regression predicts that both sexes mature at approximately 13 in. (34 cm) CCW (Figure 38). Responsible management practices should allow for reproductive sizes to be met, and therefore it will be important to consider increasing the minimum size for which harvest is allowed. Further research is needed to further refine regressions, determine the extent of all age/size relationships, and to gain additional data on small snapping turtles which were scarce in the present study.

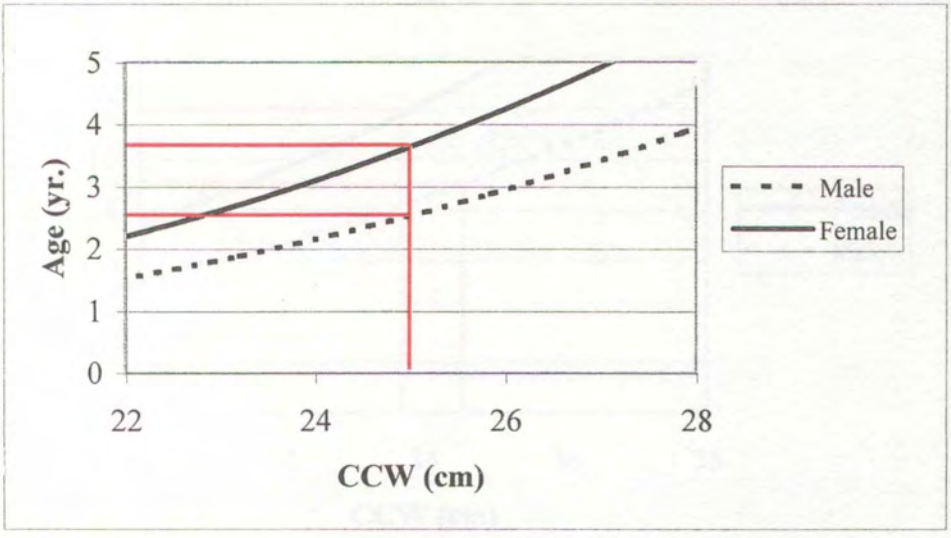

Figure 37. Average skeletochronological age of snapping turtles at a CCW of 10 in. (25.4 cm), the minimum size harvestable under Minnesota law. Age is approximately 3 yr. at this size, which is still immature.

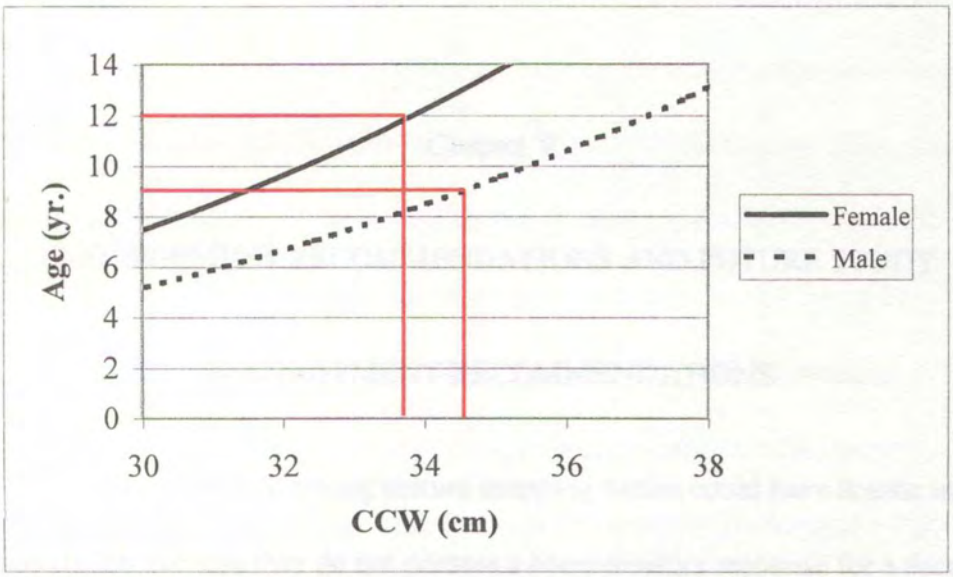

Figure 38. Use of regression analysis to predict size at a particular age. In this instance, males and females were considered to be mature at 9 and 12 yr., respectively. Individuals maturing at this age are approximately 13.4 in. (34 cm) in curved carapace width (CCW), which is more than 3 in. (7.6 cm) larger than the minimum harvestable snapping turtle in Minnesota (10 in. or 25.4 cm).

Chapter V

MANAGEMENT RECOMMENDATIONS AND FUTURE STUDY

MANAGEMENT RECOMMENDATIONS

Increased mortality among mature snapping turtles could have drastic impacts on a population because they do not possess a compensatory response for a decrease in population density (Galbraith and Brooks 1989, Congdon et al. 1994). Populations within Minnesota are likely to be declining due to years of exploitation of juveniles and adults by the general public and commercial trappers alike. Until further broad-range, landmark studies (e.g., age, population, and maturity) utilizing larger sample sizes can be completed, it is strongly recommended that snapping turtle harvest should be eliminated, reduced (enforced or voluntary), or at least frozen at current levels, to ensure a viable population.

Sex Restriction

Because of the sexually dimorphic nature of snapping turtles, responsible management should be sex-based. As with most animal species, male snapping turtles are more expendable than females for several reasons (Bookhout 1996). First, the current study suggests that males constitute a majority (55.9%) of a west central

Minnesota population, which could be indicative of populations throughout the state. Second, female snapping turtles are promiscuous and store viable sperm for several years, possibly eliminating the need for annual mating (Breckenridge 1944, Carr 1952, Conant and Collins 1998). Finally, among promiscuous species, males provide no purpose beyond sperm production, yet they consume resources that could be used to produce more fecund individuals (i.e., large females). In addition, elevated male:female ratios will reduce or maintain population numbers, while lower male:female ratios will lead to increased population numbers (Bookhout 1996).

Identification of female snapping turtles is simple, and restriction of their harvest would be beneficial to a population (Bookhout 1996). To increase the likelihood of accurate sex determination among the public, it is strongly recommended that illustrations highlighting the differences in cloaca location should be included in future editions of Minnesota fishing regulations (see Dickson 2001). Also, to further reduce the possibility of sex misidentification, mathematical sex determination methods should be included.

The present study has included accurate mathematical methodologies for sex determination using pre- and post-cloaca measurements. These methods can be further simplified by converting them into chart form, such as depicted in Figure 39. To use this figure, one only needs to plot ct vs. pc [length from cloaca to tail tip vs. length from plastron to cloaca]. Points above the diagonal line representing the 0.7 division between the sexes are male while those below the line are female. The dashed line delineates small individuals that are difficult to accurately sex because

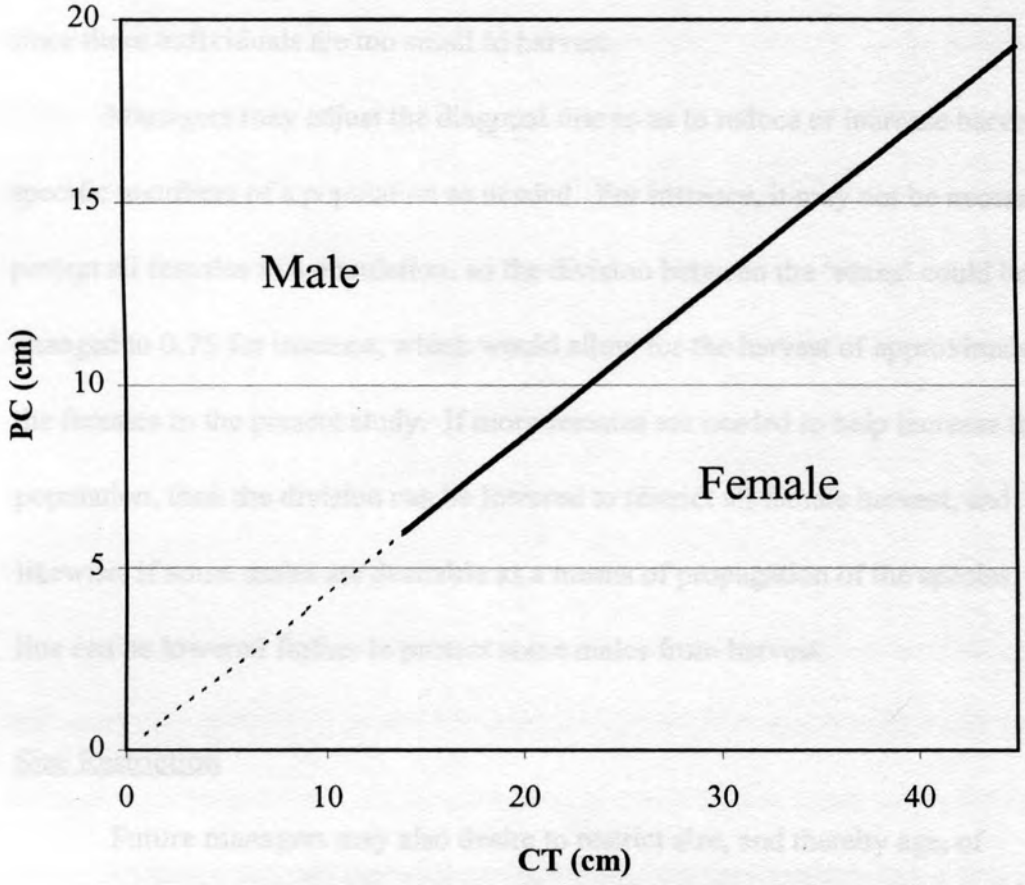

Figure 39. Possible chart of ct/(pc+ct) to be distributed to the general public to help determine sex of Minnesota snapping turtles. The diagonal line represents a ct/(pc+ct) of 0.7, the division between the sexes. Individuals falling below the line are female while those above the line are male. The dashed line indicates small snapping turtles, with cloaca to tail tip lengths (ct) less than 5.5 in. (14 cm), which are difficult to sex, regardless of method used.

secondary sex characteristics are not adequately developed, but this is unimportant since these individuals are too small to harvest.

Managers may adjust the diagonal line so as to reduce or increase harvest of specific members of a population as needed. For instance, it may not be necessary to protect all females in a population, so the division between the 'sexes' could be changed to 0.75 for instance, which would allow for the harvest of approximately half the females in the present study. If more females are needed to help increase the population, then the division can be lowered to restrict all female harvest, and likewise, if some males are desirable as a means of propagation of the species, then the line can be lowered further to protect some males from harvest.

Size Restriction

Future managers may also desire to restrict size, and thereby age, of individuals harvested. In long-lived, slow growing reptile populations such as Minnesota snapping turtles, old [large] individuals display elevated fecundity but still cannot compensate for an increase in their mortality (Brooks et al. 1991). A slot limit similar to those in place for some game fish species, could serve as an important compromise between those interested in consumption and conservation (Murphy and Willis 1996, Dickson 2001).

Minnesota law allows the harvest of immature and adult snapping turtles alike, which arguably has already adversely affected population numbers. A minimum size restriction should allow sufficient time for individuals to mature and reproduce.

Current regulations allow the harvest of snapping turtles >10 in. (25.4 cm) in curved carapace width (CCW; Dickson 2001, R. Johannes, pers. comm.). In the present study, analysis of post-maturity MSGs indicated that the smallest individual of either sex that could be confirmed mature had a CCW of 11.6 in. (29.5 cm), while the largest immature individual was 14.5 in. (36.8 cm). Further, regression analysis indicates that 10 in. (25.4 cm) individuals are <6 yr. of age while mature individuals (9 yr. male and 12 yr. female) were approximately 13 in. (34 cm) in CCW, thereby suggesting an additional 3 in. (8 cm) restriction would be necessary to assure maturity had been reached prior to harvest.

A maximum size restriction could be implemented instead of increasing the minimum size restriction, so that some large individuals remain to propagate the species. This restriction could be sex based, in that it only protects large, highly fecund females which are especially valuable because they produce larger clutch, egg, and hatchling sizes more likely to survive (Brooks et al. 1991).

FUTURE STUDY

Minnesota snapping turtles remain rarely studied and often misunderstood organisms, with even the most basic information necessary for responsible management practices lacking (e.g., current/historical population level, sex ratio, age/size at maturity). Since most of the techniques used in this study are unprecedented within this state, considerable effort is needed to further establish their effectiveness. Of particular interest is estimation of age by counting MSGs deposited

since maturity and estimation of age based upon an external feature (regression analysis).

Commercial snapping turtle trappers and processors represent a currently untapped source for the rapid collection of large amounts of data. Without affecting production or profit, a researcher working in association with one of these individuals could garner information such as sex, ct, pc, mass, CCL, CCW, scute length, and number of scute annuli from each turtle prior to their harvest. In addition, a humerus or femur could be collected following harvest, for future skeletochronological analysis. This information could allow the assessment of individual age and size with a minimal time and labor investment. Samples could possibly be collected during the course of a single season, with processing and analyzing being completed during winter months. In this manner, in-depth analysis of Minnesota snapping turtle populations may be possible in as few as 1–2 years.

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LITERATURE CITED

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APPENDICIES

APPENDIX A

Scientific Names of Plants and Animals Cited in the Text

Scientific Names of Plants and Animals Cited in the Test

Common name	Scientific name
Plants	
Alfalfa	*Medicago sativa*
Corn	*Zea maize*
Soybeans	*Glycine max*
Animals	
Alligator Snapping Turtle	*Macroclemys temminckii*
American Alligator	*Alligator mississippiensis*
Cat	*Felis catus*
Cattle	*Bos taurus*
Common Snapping Turtle	*Chelydra serpentina serpentina*
Crayfish	*Cambarus* spp.
Dermestid	*Dermestes maculatus*
Dog	*Canis familiaris*
Florida Snapping Turtle	*Chelydra serpentina osceola*
Fox	*Vulpes vulpes*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethicus*
Painted Turtle	*Chrysemys picta* spp.
Pig	*Sus scrofa*
Raccoon	*Procyon lotor*
River Otter	*Lutra canadensis*
Striped Skunk	*Mephitis mephitis*
Turkey	*Meleagris gallopavo*
White Sucker	*Catostomus commersoni*

APPENDIX B

Age Estimates For Snapping Turtles Examined 1998–2000

Age estimates of common snapping turtles sampled summers of 1998 – 1999.

Turtle ID	Sex*	ABA[1]	HRA[2]	ASM	SA[4]	ESA[5]
140	F	8	14.0	I	8	11.2
141	M	19	29.3	17	17	17.7
142	M	8	14.7	12	9	12.9
143	M	8	12.6	I	9	15.0
144	M	26	34.3	28	21	28.5
145	M	3	5.6	I	4	5.6
146	F	8	11.6	15	7	9.7
147	M	7	14.5	I	7	10.0
148	M	6	9.8	I	7	8.4
149	F	6	11.7	I	6	8.8
150	F	12	18.7	19	9	11.1
151	F	8	11.2	16	9	11.5
152	F	14	25.9	19	13	15.8
153	M	12	18.7	16	14	19.2
154	M	11	15.1	16	10	16.0
155	M	20	35.1	21	16	20.0
156	M	6	26.5	I	5	8.0
157	F	7	14.1	I	4	5.9
158	M	22	29.6	20	24	34.3
159	F	23	62.9	31	22	31.2
160	M	26	63.0	24	5	91.5
A	F	6	9.6	I	6	8.9
B	M	7	9.1	I	5	7.6
C	F	26	48.9	33	17	26.0
D	H	0	NA	I	0	NA
E	H	0	NA	I	0	NA

* F: Female, H: Hatchling, M: Male; [1] Average Bone Age; [2] Humerus Resorption Age, NA: Not Applicable; [3] Age Since Maturity, I: Immature; [4] Scute Age; [5] Estimated Scute Age, NA: Not Applicable

APPENDIX C

Records of West Central Minnesota Common Snapping Turtles Examined During 1998–2000

Records of common snapping turtles sampled summers of 1998–1999.

ID*	Date	Site[1]	Mass (kg)	Sex*	ccl[2] (cm)	scl[3] (cm)	ccw[4] (cm)	scw[5] (cm)	Waist[6] (cm)	Thick[7] (cm)	pl[8] (cm)	pw[9] (cm)	t[10] (cm)	ct[11] (cm)	pc[12] (cm)	2csl[13] (cm)	2ssl[14] (cm)	2csl[15] (cm)	2ssw[16] (cm)	4csw[17] (cm)	4ssw[18] (cm)	4csl[19] (cm)	4ssl[20] (cm)
1	05/30/98	5	14.29		39.37		43.18		80.01		27.94	30.48	43.18			8.89		13.97					
2	06/02/98	13	7.26		33.02		35.56		63.50		22.86	22.86	26.67			6.35		11.43					
3	06/08/98	6	3.63		25.40		26.67		50.80		17.78	20.32	22.86			5.08		10.16					
4	06/17/98	6	5.90		30.48		33.02		60.96		22.86	22.86	26.67			6.35		11.43					
5	06/17/98	6	~0.46		11.43		11.43		22.86		7.62	7.62	8.89			2.54		3.81					
6	06/18/98	6	5.67		29.21		30.48		63.50		22.86	22.86	24.13			6.35		10.16					
7	06/22/98	6	10.55		34.29		39.37		71.12		24.13	27.94	27.94			6.99		13.02					
8	06/25/98	10	1.81		19.69		20.32		39.37		13.97	15.24	16.51			3.81		6.35					
9	06/25/98	14	7.26		30.48		35.56		63.50		14.29	23.81	26.67			6.67		11.43					
10	06/25/98	14	5.67		29.21		33.02		57.79		22.23	22.23	23.50			6.35		11.11					
11	06/26/98	2	1.36		14.94		15.24		29.21		10.48	11.75	10.49			3.18		4.45					
12	06/30/98	10	~3.18		26.67		27.94		52.07		20.32	20.64	22.86			5.40		8.89					
13	06/30/98	10	~4.56	F	30.48		30.48		59.39		22.23	21.59	26.67			6.35		10.16					
14	06/30/98	10	~1.36		19.69		19.69		37.47		13.97	15.24	15.57			3.81		6.35					
15	07/01/98	12	4.54	F	27.94		30.48		60.33		20.32	24.13	26.04			5.72		10.48					
16	07/06/98	10	4.08		26.04		27.94		53.34		19.05	21.59	20.32			5.72		9.53					
17	07/06/98	12	5.78		29.21		31.75		63.50		20.96	25.40	27.94			5.72		10.16					
18	07/10/98	6	0.45		13.97		13.97		27.64		9.21	10.80	10.80			2.54		3.81					
19	07/10/98	6	5.90		29.85		30.48		60.96		21.27	23.81	25.40			6.03		10.80					
20	07/10/98	6	6.58		30.48		30.48		60.66		21.59	23.50	27.31			6.35		10.16					
21	07/10/98	6	4.76		26.67		27.00		56.52		20.00	22.86	24.13			5.72		9.53					
22	07/14/98	13			27.94		30.81		60.96		20.32	22.86	29.54			6.35		10.16					
23	07/15/98	O	7.03	M	31.75		33.02		63.83		23.18	25.40	27.94			6.99		11.11					

Appendix C cont'd

ID*	Date	Site[1]	Mass (kg)	Sex**	ccl[2] (cm)	scl[3] (cm)	ccw[4] (cm)	scw[5] (cm)	Waist[6] (cm)	Thick[7] (cm)	pl[8] (cm)	pw[9] (cm)	t[10] (cm)	ct[11] (cm)	pc[12] (cm)	2csl[13] (cm)	2ssl[14] (cm)	2csl[15] (cm)	2ssw[16] (cm)	4csw[17] (cm)	4ssw[18] (cm)	4csl[19] (cm)	4ssl[20] (cm)
24	07/28/98	O	8.62		33.02		34.29		65.41		22.86	25.40	28.58			5.72		11.43					
25	08/01/98	6	0.45		13.67		15.24		28.58		9.84	11.75	12.70			2.86		4.45					
26	08/01/98	8	7.03		31.75		33.66		64.77		24.13	25.72	24.77			6.35		10.80					
27	08/01/98	8	5.90		29.21		31.09		61.93		22.23	24.77	27.64			6.03		10.80					
28	08/07/98	12	~3.18		24.13		25.40		49.53		17.78	19.69	23.50			8.26		5.08					
29	08/11/98	3	5.44		28.58		30.48		57.79		20.96	22.86	25.40			5.72		9.84					
30	08/13/98	3	10.21		33.02		38.10		70.82		25.40	27.94	32.08			7.30		13.02					
31	08/13/98	3	7.26		31.12		34.93		62.87		22.86	25.40	28.27			6.35		11.43					
32	08/23/98	9	9.53		34.93		38.74		69.85		22.86	27.94	28.58			7.62		12.70					
33	08/29/98	9	2.04		19.38		21.92		41.91		14.61	16.51	15.88			3.81		6.99					
34	08/29/98	9	2.04		20.65		22.86		43.51		14.61	16.83	15.24			4.13		7.30					
35	08/29/98	9	7.71		32.08		34.29		62.87		23.18	24.13	30.48			6.35		11.11					
36	08/29/98	9	7.26		31.45		33.02		63.50		22.54	24.45	28.91			6.35		11.11					
37	08/30/98	9	2.84		23.50		23.50		48.26		16.51	19.05	19.69			5.08		7.62					
38	08/30/98	9	4.76		27.31		29.85		57.15		20.32	24.13	22.43			5.72		9.84					
39	08/30/98	9	6.12		29.85		32.39		61.60		22.54	24.13	27.64			6.35		10.80					
40	09/04/98	9	1.93		19.69		22.23		43.18		13.97	17.15	19.38			3.81		6.99					
41	09/04/98	9	1.93		20.32		22.23		43.82		14.92	16.83	22.43			4.45		6.99					
42	09/04/98	5	15.20		38.74		43.82		78.31		28.89	31.12	36.20			8.57		14.61					
43	09/04/98	14	~6.80		29.54		33.66		62.87		25.40	26.67	26.67			6.35		11.43					
44	09/05/98	9	10.21		34.29		39.37		69.22		25.40	27.31	36.83			6.99		12.70					
45	09/17/98	O	11.00		34.29		39.37		71.12		23.50	29.21	28.58			7.30		13.02					
46	09/24/98	O	9.75		34.29		38.10		69.85		25.40	28.58	29.21			6.67		12.70					

Appendix C cont'd

ID*	Date	Site[1]	Mass (kg)	Sex**	ccl[2] (cm)	scl[3] (cm)	ccw[4] (cm)	scw[5] (cm)	Waist[6] (cm)	Thick[7] (cm)	pl[8] (cm)	pw[9] (cm)	t[10] (cm)	ct[11] (cm)	pc[12] (cm)	2csl[13] (cm)	2ssl[14] (cm)	2csl[15] (cm)	2ssw[16] (cm)	4csw[17] (cm)	4ssw[18] (cm)	4csl[19] (cm)	4ssl[20] (cm)
47	10/10/98	14	10.43		36.20		38.74		69.85		24.13	27.94	31.75			7.94		13.34					
48	10/17/98	O	10.89		35.89		38.10		70.18		25.40	25.40	33.02			7.30		12.70					
49	10/17/98	O	7.48		32.08		35.56		67.01		22.86	26.67	24.13			6.03		11.75					
50	10/17/98	14	0.21		9.86		10.80		20.32		7.30	7.94	8.26			1.91		2.86					
51	10/17/98	14	4.42	M	22.23		25.40		46.69		16.51	19.05	21.29			4.13		7.62					
52	10/17/98	14	8.16	M	31.75		35.56		63.50		23.50	25.40	33.02			6.35		11.75					
101	04/25/99	7	7.82	M	33.34	31.50	38.10	29.25	69.22	12.75	22.86	26.04	26.67	18.10	7.94	6.99	7.20			5.40		7.94	
102	05/05/99	7,9	7.94	M	32.39	31.30	36.20	28.00	65.72	13.40	23.18	26.04	27.31	20.96	12.07	6.99	6.80	11.11	11.70	8.40		5.90	
103	05/05/99	7,9	6.35	M	28.89	26.00	33.02	20.90	61.28	24.50	21.27	24.13	26.67	20.64	9.84	6.03	6.30	10.80	10.75	6.67	6.80	4.13	4.50
104	05/06/99	7,9	10.21	M	36.20	34.90	38.74	29.60	69.85	13.90	25.72	27.31	38.42	24.77	14.61	7.30	7.50	12.70	12.27	8.89		6.35	
105	05/01/99	O	4.08	M	26.04	23.00	29.21	25.50	53.02	23.10	20.64	21.27	23.50	16.19	8.89	5.40	5.70	9.21	9.47	6.67		3.81	
108	06/16/99	14	5.22	F	27.62	27.30	33.02	24.00	59.37	12.30	20.50	22.50	26.04	23.18	4.45	5.72	6.00	10.80	10.40	6.99	6.90	4.76	4.50
109	06/20/99	8	14.42	M	38.74	37.30	41.28	31.20	77.47	15.00	27.62	31.12	38.10	27.31	14.61	7.94	8.00	13.34	12.90	8.89	9.10	6.35	6.20
110	06/21/99	8	4.99	F	27.31	26.50	30.48	23.60	56.52	11.90	19.69	22.23	25.40	21.91	8.89	5.72	5.80	10.16	9.70	7.62	7.30	5.08	5.00
111	06/22/99	O	10.43	M	35.88	35.30	40.64	30.30	80.01	13.70	24.45	27.31	37.78	24.45	11.75	7.62	7.70	13.02	12.60	9.21	9.00	6.35	6.00
112	06/22/99	O	4.54	F	28.89	28.80	30.48	22.30	54.61	10.80	21.59	20.96	26.04	23.81	6.99	6.35	6.00	11.43	9.60	7.30	7.30	5.08	4.70
115	06/23/99	8	2.95	F	24.45	24.00	27.31	12.00	48.26	9.40	18.42	19.05	21.27	18.10	6.35	5.08	5.10	8.89	8.60	6.67	6.30	4.13	4.00
116	06/23/99	8	4.54	F	27.31	26.90	30.48	24.00	56.52	11.40	21.27	22.86	26.04	20.96	7.62	5.72	6.00	9.84	9.98	7.62		4.45	
117	06/23/99	6	0.23	M	11.11	10.30	11.43	9.00	21.59	4.60	7.30	8.89	9.53	6.99	2.87	0.00	2.00	0.00	2.80	0.00	3.50	0.00	2.20
118	06/24/99	6	7.71	F	32.70	31.40	36.83	28.00	66.36	12.20	23.75	26.04	29.85	27.31	8.89	6.67	6.50	11.75	11.30	8.57	8.50	5.72	5.80
119	06/24/99	8	3.63	F	25.72	25.00	28.58	21.30	52.07	10.20	19.69	19.69	22.23	18.42	5.72	5.40	5.50	9.21	8.40	7.30	6.90	4.45	4.20
120	07/06/99	16	12.25	M	38.42	36.70	44.45	33.20	79.69	14.90	27.62	30.48	30.48	23.18	13.34	7.94	8.00	14.29	14.00	9.53	10.10	5.91	6.20
121	07/03/99	16	6.35	F	29.21	28.20	33.02	26.00	60.64	13.20	22.86	23.81	24.13	22.86	4.13	6.03	6.20	10.80	10.70	5.40	7.60	4.76	4.90

Appendix C cont'd

ID*	Date	Site[1]	Mass (kg)	Sex**	ccl[2] (cm)	scl[3] (cm)	ccw[4] (cm)	scw[5] (cm)	Waist[6] (cm)	Thick[7] (cm)	pl[8] (cm)	pw[9] (cm)	t[10] (cm)	ct[11] (cm)	pc[12] (cm)	2csl[13] (cm)	2ssl[14] (cm)	2csl[15] (cm)	2ssw[16] (cm)	4csw[17] (cm)	4ssw[18] (cm)	4csl[19] (cm)	4ssl[20] (cm)
122	07/03/99	11	5.90	F	29.21	28.10	33.02	25.00	60.01	13.30	22.86	23.81	22.54	22.86	5.08	5.72	6.20	10.48	10.40	5.40	7.50	4.45	4.20
123	07/12/99	1	15.20	M	38.74	37.30	46.99	33.60	81.28	17.00	27.94	30.80	35.56	24.77	17.15	7.94	8.20	15.56	14.80	10.80	10.50	6.35	6.20
124	07/12/99	1	9.07	M	34.29	32.60	36.83	27.50	64.77	13.80	24.13	25.72	30.16	22.86	12.70	6.67	6.60	12.07	11.20	8.57	8.75	6.03	5.65
125	07/12/99	9	9.98	F	33.02	32.60	38.74	30.30	71.44	14.30	26.35	28.58	29.21	22.86	6.99	7.62	7.50	13.65	12.50	8.26	8.10	5.72	5.80
126	07/13/99	1	6.58	F	30.48	29.60	35.56	26.00	63.50	12.50	22.86	25.40	24.13	23.18	7.30	5.08	6.50	8.26	10.70	10.80	8.80	6.35	5.10
127	07/13/99	1	13.15	M	37.78	37.00	43.82	30.70	75.88	16.00	30.16	27.31	31.75	25.72	11.43	6.35	8.20	9.53	14.60	14.92	9.90	7.94	6.50
128	07/13/99	1	19.05	M	40.64	39.40	49.53	37.40	87.00	15.60	30.48	42.23	33.66	26.67	17.78	6.35	8.60	10.80	15.50	15.88	11.20	8.57	6.50
129	07/14/99	1	9.98	M	34.61	33.90	36.83	29.70	83.82	12.20	23.81	26.67	34.29	25.72	16.19	7.30	7.00	12.07	12.00	8.57	8.70	5.72	5.80
130	07/14/99	1	6.35	M	29.85	29.40	33.34	24.60	59.37	12.10	21.91	22.54	28.26	22.54	12.07	6.35	6.50	10.80	10.60	8.26	7.80	7.11	5.20
131	07/15/99	9	6.58	M	30.16	29.00	31.43	24.30	56.20	12.10	20.96	23.18	25.08	19.37	12.70	6.35	6.30	10.80	10.00	5.40	5.40	7.62	7.20
132	07/16/99	9	7.94	F	30.80	30.10	38.10	27.30	66.36	13.00	24.13	24.77	29.85	24.13	9.53	5.40	6.70	13.02	11.90	7.94	8.30	5.08	4.90
133	08/01/99	14	10.21	M	36.51	35.00	38.74	30.20	70.49	12.80	25.72	28.26	33.02	24.13	15.24	7.94	8.10	13.02	12.53	8.89		6.67	
134	08/10/99	14	1.36	M	19.05	19.00	20.96	16.00	37.78	7.00	13.65	14.61	15.24	13.97	5.72	4.45	4.30	6.35	6.20	5.08	4.70	3.49	3.40
135	08/18/99	O	0.68	F	13.65	12.80	14.92	11.30	27.31	6.00							2.80		4.20		3.70		2.20
137	08/27/99	O	~0.23	F	8.89	9.00	9.84	8.00	20.00	4.40	7.30	7.40	6.99	6.67	1.91	1.59	1.80	3.18	3.00	2.83	2.40	1.59	1.50
140	07/12/99	9	7.94	F	32.39	31.30	34.93	27.60	64.77	11.00	23.50	24.45	30.16	23.18	9.84	6.35	6.40	11.75	11.10	8.89	8.80	5.40	5.70
141	07/15/99	9	9.41	M	33.66	32.40	37.15	28.80	67.31	11.20	25.72	26.67	31.12	25.40	13.34	6.83	7.10	12.38	11.70	8.26	8.10	4.76	4.60
142	07/12/99	1	6.80	M	30.16	29.00	34.93	25.30	61.91	12.60	22.54	23.81	27.62	19.37	10.80	6.03	6.20	11.43	10.80	8.21	7.90	5.72	5.10
143	07/21/99	4	8.62	M	32.07	31.30	36.83	29.00	67.95	12.10	23.18	26.04	31.12	25.08	13.02	6.67	6.50	11.75	11.40	8.57	8.30	6.03	6.00
144	08/06/99	15	14.06	M	38.10	36.40	43.82	32.40	76.04	14.30	26.99	29.53	34.29	24.13	15.88	8.57	8.80	14.61	13.80	8.57	8.60	6.67	7.00
145	07/30/99	11	~4.08	M	24.45	23.40	28.58	22.00	50.17	8.90	18.10	20.64	23.81	19.69	9.53	4.76	4.80	8.57	8.50	6.35	6.35	4.13	4.20
146	07/22/99	8	4.65	F	27.31	26.80	29.53	23.40	54.29	10.40	21.27	21.91	25.40	21.91	6.67	5.40	5.60	9.84	9.30	6.83	6.80	5.08	4.70

Appendix C cont'd

ID*	Date	Site[1]	Mass (kg)	Sex**	ccl[2] (cm)	scl[3] (cm)	ccw[4] (cm)	scw[5] (cm)	Waist[6] (cm)	Thick[7] (cm)	pl[8] (cm)	pw[9] (cm)	t[10] (cm)	ct[11] (cm)	pc[12] (cm)	2csl[13] (cm)	2ssl[14] (cm)	2csl[15] (cm)	2ssw[16] (cm)	4csw[17] (cm)	4ssw[18] (cm)	4csl[19] (cm)	4ssl[20] (cm)
147	06/28/99	11	~6.35	M	28.26	27.40	31.75	25.00	58.42	9.70	20.64	22.86	26.35	18.73	11.43	4.76	5.70	7.94	9.70	12.38	7.50	5.72	4.70
148	06/28/99	8	4.92	M	27.31	26.30	30.80	23.90	55.25	9.90	20.00	22.54	27.62	21.59	7.62	5.40	5.40	9.84	9.30	7.30	7.10	5.08	4.60
149	06/28/99	6	4.97	F	26.35	25.40	29.21	21.90	52.07	10.90	21.27	20.32	24.77	20.32	6.35	5.72	5.70	7.94	8.80	7.30	7.00	4.76	4.50
150	07/08/99	15	8.16	F	29.85	28.90	36.20	25.70	63.50	13.20	22.86	24.45	26.67	21.91	5.72	6.03	6.35	11.43	11.10	7.94	8.20	6.03	6.10
151	07/17/99	9	6.58	F	31.12	30.20	35.24	25.70	62.87	13.20	24.77	23.81	27.31	23.81	7.62	6.35	6.30	11.75	11.10	7.78	7.70	5.40	5.50
152	07/02/99	16	7.12	F	31.12	29.30	36.20	27.90	65.41	12.20	23.81	25.40	24.77	22.86	7.30	6.67	6.85	12.07	11.40	8.26	8.32	5.08	5.22
153	07/02/99	16	10.57	M	35.88	34.20	39.05	29.00	69.85	14.10	25.72	27.31	27.62	24.77	14.61	7.62	7.40	12.70	12.30	8.89	9.07	6.35	6.34
154	07/02/99	16	11.48	M	36.20	34.30	40.64	30.90	73.03	12.90	24.13	27.94	31.43	24.13	13.97	7.62	7.76	13.34	12.32	8.26	8.16	6.03	6.30
155	06/24/99	15	16.78	M	40.64	39.10	42.55	31.90	75.88	13.60	27.62	29.85	35.88	24.13	16.19	8.26	9.21	13.97	12.63	8.89	9.21	6.67	6.76
156		O	1.90	M	22.54	21.80	26.04	19.50	46.36	8.30	16.19	17.46	17.15	21.27	6.03	4.76	4.91	8.26	8.74	6.99	6.17	3.49	3.73
157	07/01/99	O	1.05	F	17.46	16.50	19.05	15.90	35.08	5.60	11.75	14.29	13.34	11.75	3.81	3.49	3.39	5.72	5.61	5.08	4.64	2.86	2.82
158	07/02/99	16	13.43	M	39.05	36.50	45.09	32.80	78.42	15.90	27.94	31.43	33.34	26.04	13.34	8.10	8.10	13.97	13.70	9.21	9.42	6.35	6.24
159	07/29/99	9	11.34	F	35.24	34.30	41.28	30.50	73.18	14.40	27.62	26.35	31.75	28.89	9.53	7.46	7.72	13.34	13.33	8.26	8.40	5.72	6.06
160	06/12/99	O	12.47	M	37.47	36.50	43.18	34.00	78.42	13.50	27.62	31.12	31.75	24.13	13.65	8.10	8.12	14.61	14.08	9.84	10.08	5.87	6.20
A	1998	O	3.80	F	24.77	23.80	27.94	21.10	50.48	9.00	17.78	19.37	22.86	20.32	6.67	4.45	4.88	9.21	8.38	7.43	6.31	3.81	4.03
B	07/21/99	6	2.80	M	23.18	22.70	25.40	20.10	45.97	8.00	16.19	18.73	20.64	15.88	7.62	4.45	4.87	7.62	7.60	6.35	6.61	3.49	3.83
C	07/08/99	15	10.43	F	33.34	31.70	37.78	28.00	67.95	13.60	26.99	27.62	28.89	23.81	6.35	6.99	7.34	12.38	11.77	7.62	8.02	5.40	5.75
D	Aug-99	O	8.32g	H		3.01		3.08			2.21	2.83	4.23	3.95			0.66		1.01		0.96		0.55
E	Aug-99	O	7.53g	H		2.94		2.94			2.18	2.63	4.19	3.70			0.61		0.92		1.02		0.52

* ID 140-E were used for skeletochronological analysis; ** M: Male, F: Female, H: Hatchling; [1] see Figures 2 & 3, O = unknown or other; [2] curved carapace length; [3] straight line carapace length; [4] curved carapace width; [5] straight line carapace width; [6] circumference at midpoint; [7] thickness at midpoint; [8] plastron length; [9] plastron width; [10] length of tail from carapce to tip; [11] length from cloaca to tip of tail; [12] length from plastron to cloaca; [13] curved scute length of second left anterior costal scute; [14] straight line length of second scute; [15] curved scute width of second scute; [16] straight line width of second scute; [17] curved scute width of fourth vertebral scute; [18] straight line width of fourth scute; [19] curved lenght of fourth scute; [20] straight line length of fourth scute.

APPENDIX D

Developments in Trap Design Since Field Study Completion

At the completion of fieldwork for this study (Fall 1999), Mike Holme and Mike Lint, owners of West Central Bait, resolved to eliminate all inadvertent snapping turtle capture. It was determined that a device was needed to exclude snapping turtles and other large undesirable by-catch (e.g., muskrat and painted turtle) without excluding any desired baitfish.

Traps were modified with the placement of galvanized 4" x 6" (10.2 cm x 15.2 cm) welded wire mesh "turtle guards" in the trap mouth, which essentially reduces the trap's single mouth to an array of 4" mouths. In addition, when it is desirable to capture larger fish, "turtle guards" with larger openings can be installed. Since "turtle guard" installation, all incidental turtle capture has been successfully eliminated without restricting movements of desired baitfish (i.e., no reduced catch).

Other institutions (e.g., commercial bait trappers or MN DNR) are currently using modified fyke nets for baitfish harvest or population sampling from private and public waters (M. Holme and M. Lint, pers. comm., J. Jenniges, pers. obs.). The author is currently unaware if any exclusionary devices have been installed in these traps, thus there is a substantial opportunity for accidental capture and death with each "turtle guard" free trap in use. Installation of "turtle guards" on all traps capable of capturing turtles should eliminate virtually all unintentional turtle capture.