EXECUTIVE SUMMARY
Five-Year Review of the Status of Iowa's Turtle Populations, 2016-2020

Gear

- Turtle traps were the primary gear used to complete turtle surveys by all DNR fisheries units during the study (2016-2020); they were the most often used gear since 2011. Hoop nets (n=102) similar to currently used turtle traps were deployed in the southeast region in 2010-2011. The greatest number of turtle trap sets were in southeast Iowa (n=705) followed by the southwest (n=630), northeast (n=512), northwest (n=203), and Mississippi River (n=66) regions.

Catch

- The statewide turtle catch (n=6,443; 2010-2020) according to species (%) is as follows: painted turtle (51%), common snapping turtle (24%), red-eared slider (12%), spiny softshell (8%), map turtles (3%), smooth softshell (1%), and others (1%). Map turtles include the common map turtle, false map turtle, and Ouachita map turtle. Others include Blanding's turtle, common musk turtle, ornate box turtle, and three-toed box turtle. It is unsurprising that the western painted turtle represented just over half of all individuals collected given they are commonly the most abundant turtle in suitable shallow water habitats across its range.

Length & Weight (LW)

Western Painted Turtle (LW)

- Western painted turtle average lengths (SCL, in.) and weights (lbs.) ranged from 5.0-5.7 in. and 0.79-1.0 lbs. across regions from 2010-2020. Female paints were slightly larger than males statewide. The range of lengths for painted turtles collected in this study was consistent with length ranges documented in the scientific literature.

Common Snapping Turtle (LW)

- Common snapping turtle average lengths (SCL, in.) and weights (lbs.) ranged from 9.7-11.6 in. and 10.3-15.9 lbs. across regions from 2010-2020. The largest snappers were observed in northwest Iowa and snappers were larger in northern Iowa as compared to southern regions (including the Mississippi River region). DNR fisheries crews have not collected a common snapping turtle near the historically documented maximum (19.75 in.) for the state which was sampled in Emmet County in 2004. One should note that commercial harvest was most prominent in southern regions of Iowa and that large adults are often targeted for their market value. The possibility exists that large adults have been removed over time.

Spiny Softshell Turtle (LW)

- Spiny softshell average lengths (SCL, in.) and weights (lbs.) ranged from 8.7-11.2 in. and 2.7-5.7 lbs. across regions from 2010-2020. Females were 1.7 times larger (SCL) on average than males statewide. Strong sexual dimorphism is typical of the species. Published ratios suggest that adult females are more than 1.6 times larger than adult males. The ratio determined for this study is consistent with the published value.

Smooth Softshell Turtle (LW)

- Smooth softshells are the harvestable turtle species that was observed least in statewide collections. In fact, this species was primarily caught in the southeast and southwest regions of the state. Only four individuals were caught in the northeast and Mississippi River regions. None were caught in the northwest region. Smooth softshell average lengths (SCL, in.) and weights (lbs.) ranged from 6.0-8.3 in. and 0.61-1.6 lbs. across regions from 2010-2020. Females were 1.3 times larger (SCL) on average than males. Adult female smooths are generally smaller than adult female spinys according to the scientific literature. This size difference is reflected in the smooth softshell length ratio determined for this study.

Size Distribution (SD)

Western Painted Turtle (SD)

- The portion of male painted turtles in the 5.0-6.0 in. size classes by region was 52% (northeast, 2013-2020), 57% (northwest, 2013-2020), 63% (southeast, 2010-2020), 51% (southwest, 2012-2020), and 81% (Mississippi River, 2013-2020). The 5.5-7.0 in. size classes were the most dominant for female painted turtles across regions with the exception of the southwest and Mississippi River regions. Female paints reached greater maximum sizes than males across all regions. It is typical for painted turtles to be well-represented by adults. Small turtles may not be as scarce as some size distributions suggest; instead they may be difficult to catch.

Common Snapping Turtle (SD)

- Dominant size classes for male and female snappers differed across regions. The portion of male common snapping turtles in the 11.0-13.0 in. size classes by region was 50% (northeast, 2012-2020), 52% (northwest, 2013-2020), 52% (southeast, 2010-2020), 54% (southwest, 2012-2020), and 50% (Mississippi River, 2013-2020). The northwest region had the highest percentage of male snappers greater than 15.0 in. (13%) while other regions ranged from about 2% (Mississippi River) to 4% (northeast). Females in the 10.0-12.0 in. size classes composed 51% (northeast), 56% (northwest), 62% (southeast), 59% (southwest), and 38% (Mississippi River) of sample collections across the aforementioned regions. The northeast, northwest, and southwest regions had female snappers greater than 14.0 in, but only eight individuals were represented. Size distributions suggest that males are reaching larger sizes in northern Iowa. The absence of larger specimens from southern Iowa may suggest an effect of harvest. Generally, females from 10-11 inches are most prominent. Larger females are present but not well-represented across regions. Larger females lay the most eggs with the greatest clutch mass. It's been determined that neither egg nor hatchling mass is related to survival or growth rate, but logic indicates that the deposition of more eggs leads to more chances of replacing oneself.

Spiny Softshell Turtle (SD)

- Only three female spiny softshells were captured in the northwest region (2013-2020), all were in the 11.0-13.0 in. size classes. The size distributions of female spiny softshells in the southeast (2010-2020) and southwest regions (2012-2020) were fairly uniform. Females were slightly more abundant in the 12.0-14.0 in. size classes (42%) in the southwest region (2010-2020). Male spiny softshells were most abundant in the 6.0-7.0 in. size classes (72%) in the southeast region (2010-2020), but 5.0-6.0 in. size classes were the most dominant in the southwest region (2012-2020). Only nine male spiny softshells were caught in the northern regions (2012-2020); likewise, there were only seven captures (6.0-7.0 in. size classes) in the Mississippi River region (2013-2020). An extended female length distribution (low and relatively uniform sizes classes) in southern regions is concerning. This may suggest an effect of commercial harvest if, indeed, large females have been removed from populations due to their market value.

Smooth Softshell Turtle (SD)

- About 71% of female smooth softshells were greater than 9.0 in. in the southeast region (2010-2020) while over 92% were represented by the 7.0-9.0 in. size classes in southwest Iowa (2012-2020). Only two female smooth softshells were collected in the northeast region (2012-2020). None were collected in the northwest region (2013-2020), and only one was sampled in the Mississippi River region (2013-2020). Smooth softshell turtles were, generally, less abundant than spiny softshells in the southeast region across years (2010-2020). Catch increased slightly for spiny softshells, but decreased slightly for smooth softshells over the same time period. Previous studies have found smooth softshells to be much less abundant than spiny softshells where the two species coexist; Iowa populations are no exception. The smooth softshell is intolerant of poor water quality. Given Iowa's water quality concerns, harvest of smooth softshells may be an added pressure on the species.

Sex Ratio (SR)

All species (SR)

- Uneven sexes were detected across all harvestable turtle species statewide (2010-2020) with the exception of the common snapping turtle. Unbalanced sex ratios may suggest sex-biased harvest pressure, female road mortality, use of a single capture method, trap bias, etc. Such observations may also be influenced by varying environmental factors.

Western Painted Turtle (SR)

- Statewide sex ratio (M:F) was skewed towards males (1.5:1.0) for this species. Sexes were uneven across regions for the western painted turtle (2010-2020). Males were more prominent across all regions except the Mississippi River region. Male dominated sex ratios in painted turtles have been observed by other researchers. Population studies with a single collection method may favor a particular sex. This being said, the Iowa study utilized many methods of capture, although turtle traps were the most deployed gear across regions.

Common Snapping Turtle (SR)

- Statewide sex ratio (M:F) was nearly balanced (1.1:1.0) for the common snapping turtle (2010-2020), and there was no consistent trend in sex ratio favoring a particular sex across regions over the same time period. Snapper sex ratio was slightly skewed male (1.2:1.0) in the northeast region. Conversely, sex ratio was slightly skewed female (1.0:1.4) for the Mississippi River region. Sex ratio was nearly balanced in the southeast and southwest regions (1.1:1.0) as well as the northwest region (1.0:1.1), but transposed. Researchers have found that a slight male bias in sex ratio may be a normal occurrence for the common snapping turtle. The female bias observed in the Mississippi River region is likely a result of immature turtles collected from fish hatchery ponds. Excluding immatures from analyses reduces the magnitude of difference in male-female sex ratio for this region.

Spiny Softshell Turtle (SR)

- Statewide sex ratio (M:F) was skewed towards females (1.0:2.9) for the spiny softshell turtle (2010-2020). Sex ratios were uneven across all regions for this species (2010-2020) with females being more prevalent; the one exception was the Mississippi River region (1.0:1.0). The majority of spiny softshell turtles were captured in southern Iowa. Trap bias, i.e., the potential for turtle traps to select for a particular sex or certain size classes such as larger female softshells, needs exploration.

Smooth Softshell Turtle (SR)

- Statewide sex ratio (M:F) was skewed female (1.0:2.8) for the smooth softshell turtle (2010-2020). Sex ratios were uneven across regions for this species (2010-2020). A heavily skewed female sex ratio (1:12.8) in the southwest region contributed greatly to the overall trend. Trap bias, i.e., the potential for turtle traps to select for a particular sex or certain size classes such as larger female softshells, needs exploration.

Catch-Per-Unit-Effort (CPUE)

Western Painted Turtle (CPUE)

- Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.84 (0.09) per net night in the southwest region (2012-2020) to 2.5 (0.30) per net night in the northwest region (2013-2020). Annual CPUEs ± SE ranged from as low as zero per net night in the southwest region (2014) to as high as 3.8 (1.2) per net night in the southeast region (2013). Catch per net night for the western painted turtle was higher in the southeast region (2010-2020) as compared to the southwest region (2012-2020), but catch increased slightly in both regions over a similar time period. Variable CPUEs across years and regions may be a reflection of weather conditions, habitat preferences, or both. In the regions where turtle surveys have been conducted the longest, positive trends in CPUE may suggest a slight increase in western painted turtle numbers.

Common Snapping Turtle (CPUE)

- Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.35 (0.03) per net night in the southwest region (2012-2020) to 1.2 (0.08) per net night in the northeast region (2013-2020). Annual CPUEs ± SE ranged from 0.08 (0.08) per net night for the Mississippi River region (2016) to 2.2 (0.43) per net night in the southeast region (2013). Catch per net night was higher for the common snapping turtle in the southeast region (2010-2020) than in the southwest region (2012-2020); however, catch decreased slightly in the southeast region while remaining relatively constant in the southwest region over a similar time period. A slight decreasing trend in CPUE in southeast Iowa (2010-2020) is cause for some concern, as this region has long been the epicenter for commercial harvest in the state.

Spiny Softshell Turtle (CPUE)

- Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.03 (0.01) per net night for the northwest region (2013-2020) to 0.39 (0.05) per net night for the southwest region (2012-2020). Annual CPUEs ± SE ranged from as low as zero per net night in multiple regions (across multiple years) to 0.64 (0.17) per net night for the southwest region (2019). Higher catches in southern Iowa may be the result of warmer climatic conditions. Previous research suggests that softshells become active earlier and remain active longer in more southern climates. Southern Iowa's interior and mainstem rivers warm quicker and cool later making these environments more conducive to softshell populations.

Smooth Softshell Turtle (CPUE)

- Catch-per-unit-effort (CPUE ± SE) across years ranged from zero per net night for the northwest (2013-2020) and Mississippi River regions (2013-2020) to 0.13 (0.03) per net night for the southwest region (2012-2020). Annual CPUEs ± SE ranged from zero per net night for all regions (across multiple years) to 0.29 (0.13) per net night for the southwest region (2017). Smooth softshell turtles were, generally, less abundant than spiny softshells in the southeast region across years (2010-2020), but catch increased for spiny softshells while decreasing slightly for smooth softshells over the same time period. Low catches of smooth and spiny softshells may be related, in part, to the type of habitat in which traps were set. Catch may have been higher if a greater proportion of traps were set in interior and large river habitats. Regardless the low numbers observed for both species and a slightly decreasing catch trend for smooth softshells is concerning.

Weight-Length Relationships (WL)

Painted, Common Snapping, Spiny Softshell, and Smooth Softshell Turtles (WL)

- Weight increased with increasing length for painted, common snapping, spiny softshell, and smooth softshell turtles and this relationship was similar across regions (2010-2020). Maximum attained sizes among the regions were not consistent for most of these species. Species may regionally benefit from factors such as a longer growing season while others may be negatively affected by extreme temperatures.

Red-Eared Sliders (WL)

- Red-eared sliders are not a harvestable species in Iowa. Nevertheless they are common in collections, with the majority sampled in the southeast region. Only 24 sliders were collected in the Mississippi River region (2013-2020), two in the northeast, and none in the northwest and southwest regions (2012-2020). Weight increased with increasing length for sliders across regions (2010-2020). Sliders had similar length-weight relationships to Iowa's harvestable species.

Map Turtles (WL)

- None of the map turtle species are harvestable species in the state. However, maps are relatively common in rivers and streams across Iowa. Weight increased with increasing length for map turtles (all species combined, 2010-2020). Map turtles had similar length-weight relationships to Iowa's harvestable species.

<u>Conclusions</u>

- Many of Iowa's harvestable turtles may be exhibiting the effects of harvest pressure in combination with a number of other factors, i.e., habitat loss and degradation, environmental pollution, disease, global climate warming, which pose threats to their continued existence.

- Western painted turtles may be Iowa's single harvestable species which is exhibiting little impact of harvest. Trends such as this one have been observed by other researchers, but some still question how painted turtle populations will respond to continued harvest over time.

- Iowa's common snapping turtle populations are lacking large individuals and there is little difference in magnitude between numbers of intermediate and large individuals. Both of these findings may suggest an effect of harvest. Questions surround whether common snapper populations can be sustained by smaller females.

- Iowa's spiny and smooth softshell populations may be of the most concern. Large individuals are not vastly more abundant than their smaller counterparts in samples. Given large softshells are targeted for their market value, one could gather that harvest is negatively affecting softshell populations. It may be justified to consider whether the harvest of softshells, especially smooths, should even be permitted.

- Catch trends have appeared to stabilize for all harvestable species following implementation of turtle harvest regulations. One must also consider that regulations may be working in concert with decreased market demand and reduced commercial harvest to benefit Iowa's turtle populations.

- It is critical to keep harvest regulations in place as they will serve as the primary limiting factor in preventing overharvest of Iowa's turtles should the commercial market rebound in the future.

- Continued monitoring is needed in order to detect changes (either positive or negative) in Iowa's turtle population characteristics. Adjustments to turtle harvest regulations should only be considered if scientific data suggest reasons for reevaluation and modification.

- The DNR's new turtle harvest regulations are aimed at conserving and, hopefully, restoring a portion of Iowa's turtle populations. Given high life expectancy, high-age at sexual maturity, low reproductive output, and high nest and hatchling mortality, Iowa's turtle populations may require many years to show signs of recovery resulting from the implementation of harvest regulations.

PROJECT: Five-Year Review of the Status of Iowa's Turtle Populations, 2016-2020
PROJECT LEADER: Chad Dolan
LOCATION: Statewide
PERIOD OF RESEARCH: January 2016 through December 2020

ABSTRACT

The DNR Fisheries Bureau implemented a comprehensive statewide turtle monitoring program in summer 2016, but collections started in some regions of the state as early as 2010. To date, fisheries personnel have collected 12 turtle species at 207 sites in five statewide regions (northeast, northwest, southeast, southwest, Mississippi River) in lake/pond, marsh/wetland, interior river, and large river habitats. Sample collections have been dominated by western painted turtle (51%), common snapping turtle (24%), red-eared slider (12%), and softshells (9%). Map, Blanding's, common musk, and box turtles composed the remainder of the catch (4%). Weight increased with increasing length for all harvestable species (common snapping turtle, softshells, painted turtle); this relation was similar across regions. Common snapping turtles were, on average, 1.2 in. longer and 4.8 lbs. heavier in northwest Iowa as compared to snappers in other regions; also, the largest snappers were caught in the northern half of the state. Sex ratios (M:F) across regions were nearly comparable for the common snapping turtle (1.1:1), but strongly skewed male for the western painted turtle (1.5:1); conversely, sex ratios were strongly skewed female (1:2.9) for softshells. Slightly more stable catch trends were observed possibly due to both the implementation of statewide harvest regulations in 2017 and decreasing harvest trends (2016-2020). Turtles are long-lived, have a high age at sexual maturity, low fecundity, and high nest and hatchling mortality; thus, it will be important to maintain harvest regulations and monitor populations closely for signs of distress.

INTRODUCTION

Historically, Iowa has had liberal commercial and recreational turtle harvest regulations as compared to surrounding states. This led to concerns for Iowa's turtle populations by many groups including the Center for Biological Diversity which petitioned the Iowa Department of Natural Resources (DNR) and the Natural Resources Commission (NRC) to close commercial turtle harvest in the state in March 2009; subsequently, the NRC denied that petition but instructed the DNR to form a committee to explore Iowa's turtle populations. Thereafter, Iowa's Joint Committee on Turtle Harvest began a comprehensive review of Iowa's turtle harvest program as well as the life histories of Iowa's harvestable turtle species (common snapping turtle, western painted turtle, spiny softshell, and smooth softshell). Life history information indicates that turtles are long-lived, have a high age at sexual maturity, low fecundity, and high nest and hatchling mortality (Congdon and Gibbons 1996). These characteristics led Ernst and Lovich (2009) to suggest that turtles cannot withstand commercial exploitation and still maintain their numbers. Long-term trends (1987-2012) associated with Iowa's commercial turtle harvest reporting data revealed increasing numbers of harvesters, increasing annual harvest, but decreasing harvest per individual harvester (Gritters et al. 2013). This data, in combination with the suite of life history traits indicative of slow recruitment, led Iowa's Joint Committee on Turtle Harvest to recommend the implementation of a turtle harvest season (July 16-December 31; Gritters et al. 2013). The purpose of this season was to allow females the opportunity to nest before being subject to harvest. This first rule-making process proceeded throughout 2015 culminating in a review by the Governor's Office. The DNR was advised not to pursue turtle harvest regulations at that juncture; however, natural resources staff were encouraged to continue conversations with stakeholders regarding the potential for future regulatory efforts.

The DNR met with stakeholder groups in late 2015 and early 2016 to resume discussions about the need for more stringent turtle harvest regulations. Simultaneously, the Iowa General Assembly introduced and passed a bill (House File 2357, amending Iowa Code section 481A.67) in March 2016 that instructed the NRC (through the DNR) to establish a turtle harvest season and catch limits, and required the DNR to conduct a five-year review (January 1, 2016-January 1, 2021) of the status of Iowa's turtle populations.

Governor Terry Branstad signed House File 2357 into law on March 23, 2016. The ensuing rule-making effort resulted in the establishment of a harvest season (July 16-May 14) as well as daily catch and possession limits (common snapping turtle - 4, 20; western painted turtle - 1, 5; spiny or smooth softshell - 1, 5) that became effective in late March 2017.

The aforementioned statute led the DNR Fisheries Bureau to implement a comprehensive statewide turtle monitoring program in summer 2016. Fisheries units were proactive as they began surveying turtle populations in southeast Iowa beginning in 2010 and in other regions in 2012. The objective of this study (Five-Year Review of the Status of Iowa's Turtle Populations) was to gather information regarding the status of Iowa's turtle populations. Analysis and interpretation of both the biological and commercial harvest reporting datasets provided insights on whether to adjust or maintain Iowa's turtle harvest season and catch limits.

METHODS

Targeted turtle surveys were completed with turtle traps (Table 1). Baited hoop nets and baited fyke nets were used in conjunction with turtle traps for some collections prior to 2016. Nets were set overnight. Turtle by-catch in Fisheries Bureau sampling gear (including those caught with dip nets) was retained for data collection. Turtles were also collected by hand from roadways and other sites as encountered.

Table 1. Turtle sampling gears and specifications.

Gear type	Description
Hand	Captured by hand or dip net
Baited hoop nets	2.0' hoop, ¾" bar mesh set for turtles
	2.5' hoop, ¾" bar mesh set for turtles
	2.5' hoop, ¾" bar mesh set for catfish
Turtle trap	2.5'hoop, 1" bar mesh, flat throat (single)
Basking trap	4' X 4' X 22", ½" hardware cloth
Fyke net	2, 36" X 72" frames, 4, 30" hoops, ½" bar mesh

Surveys were generally conducted in summer (July 15-August 15). Nets were baited with 2-3, large, dead fish such as common carp or buffalo and a single can of smoked sardines in oil (can was slightly cracked open) placed freely in the turtle trap or net. Multiple small fish were, in some instances, used in lieu of larger specimens. Bait was replaced daily in subsequent trap or net sets.

Fisheries crews sampled (at a minimum) one each of the following: 1) large or interior river, 2) wetland or marsh, and 3) lake or pond. Large river sampling was primarily conducted by the Fisheries Bureau's large river research or management units. Crews visited core sites at least twice during the summer sampling period, setting a minimum of five turtle traps per visit. Traps were placed near areas where turtles bask, e.g., sunny areas adjacent to snags, when such sites were available. Care was taken to set traps near basking areas without a shoreline connection to maximize captures rates while reducing the risk of predation by terrestrial predators. When possible, turtle traps were placed strategically in areas in which the wind was blowing away from the shoreline. Such conditions facilitated the scent of the turtle bait to be carried to a greater proportion of the aquatic habitat. Surveys were avoided when the near-term weather forecast called for heavy rain given concerns for increasing water level in lakes, ponds, wetlands, and rivers that can fully submerge gear and result in turtle drownings.

The entire turtle catch was processed regardless of whether a species was commercially harvestable. All captured turtles were identified to species and sex. For common snappers, crews measured the length (to nearest mm) of the posterior plastral lobe as well as the preanal length to permit accurate sex determination (Gibbons and Lovich 1990). Also, common snapping turtles were grasped by the rear of the carapace, held vertically, and jostled to determine gender (males will expose penis when shaken, female sex organs remain not visible). Sex was determined in painted turtles, red-eared sliders, and map turtles by taking note of 1) length of foreclaws (elongated in males), 2) shell height (higher carapacial dome in females), and 3) cloacal position (outstretched tail) in relation to the posterior carapacial margin (cloaca extends well beyond the posterior carapacial margin in males). Sex was determined in both of Iowa's softshell species (smooth and spiny) by observing 1) size (mature females are often greater than 1.6 times larger as compared to mature males), 2) shell markings (the carapace of a female is marked with large blotches or mottling while a male is marked with dashes/spots/ocelli), 3) thickness of tail (thicker in males) and cloacal position (outstretched tail) in relation to the posterior carapacial margin (cloaca extends beyond the posterior carapacial margin in males, but not in females except for extremely large specimens).

The following morphometric measures were collected (length to nearest mm) on all turtle species: straight-line carapace length (SCL), plastron length (PL), shell height (SH), shell width (SW), and curvilinear carapace length (CCL). Weight (W) to the nearest gram was also collected on all turtles. The aforementioned morphometric measures compose the suite of data commonly collected in turtle research studies (Ernst and Lovich 2009). The minimum amount of data that was collected on any turtle includes 1) species, 2) sex, 3) SCL, and 4) W. All length measures were made with forestry tree-calipers, as this device is the standard measuring tool used in turtle data collections in North America (Bjorndal and Bolten 1989, Wyneken 2001, Tucker and Lamer 2004, Budischak et al. 2006, Reehl et al. 2006, Ferland 2009). Curvilinear carapace length was measured with a flexible measuring tape.

For fisheries units that assessed age on individual turtles, hard-shelled turtles were aged by counting carapacial or plastral growth-annuli (Sexton 1959, Galbraith and Brooks 1987, Brooks et al. 1997, Aresco and Guyer 1998, Litzgus and Brooks 1998).

Hard-shelled turtles were individually marked on carapacial, marginal scutes or combinations of scutes (12 on right side of carapace, R1-R12 and 12 on left side of carapace, L1-L12). Turtles, occasionally, have extra marginal scutes on the carapace. Regardless of whether a turtle had extra marginal scutes, the last, posterior marginal scutes were always defined as R12 or L12; likewise, the first, anterior marginal scutes were always defined as R1 or L1. A note was made regarding the presence of extra marginal scutes. Tag codes were repeated across sexes (one male marked R1, one female marked R1). For common snappers, the marginal scutes on the rear half of the carapace (L8-L12 and R8-R12) were marked before considering other scutes or scute combinations. Softshells were marked via a hog ear notcher along the carapacial margin in defined zones (also in zone combinations) corresponding to the numbers on a standard clock; alternatively, the carapace was notched (v-notched) via a scissors or sharp knife in the zones mentioned above. Map turtles were identified to species; however, difficulty in identification among species led crews to use the same set of tag codes across all map turtle species (common map, false map, Ouachita map). This helped to alleviate mistakes caused by misidentification. Passive Integrated Transponder (PIT) tags were used to mark turtles in some Iowa regions during later years of the study as this technology eliminated the potential for coding errors when marking shell scutes. Marking of turtles will permit future identification of individuals, and subsequently, the derivation of important age and growth information or population estimates. Marking combinations were not repeated for populations located within a five-mile radius as indeterminate rates of immigration and emigration may be occurring among habitats located within these boundaries (Ernst et al. 2009).

The following water quality measures were collected at each turtle trap site (if time permitted): water temperature (°F or °C), air temperature (°F or °C), secchi (cm) and/or turbidity (ntu), pH, and specific conductivity (µS/cm). Notes were made at each site regarding weather conditions, e.g., sunny, cloudy, rainy.

Summary statistics such as frequency of gear types, catch composition, average length and weight, sex ratio, catch per-unit-effort (CPUE), and length frequency were calculated (SAS Institute 2015) for each of the harvestable species and, in some cases, non-target turtle species. These data were analyzed on a statewide basis, across regions (northeast, northwest, southeast, southwest, and Mississippi River), by sex, or in combinations of all the aforementioned variables. Chi-square analysis or Fisher's exact test (SAS Institute 2015) was used to test for unevenness in statewide and regional sex ratios across species. Subsequently, multiple linear contrasts (SAS Institute 2015) were used to make pairwise comparisons of sexes across species (statewide) and across regions for each harvestable turtle species. Regression analysis (SAS Institute 2015) was used to determine the relationship between SCL and weight across regions. Alpha level was set *a priori* at 0.05 for all statistical tests.

RESULTS

Turtle traps were the primary gear used to complete turtle surveys by all DNR fisheries units in 2020 (Table 2); they were the most often used gear after 2011. Hoop nets similar to currently used turtle traps were deployed in the southeast region in 2010-2011. The greatest number of turtle trap sets in 2020 were in southwest Iowa followed by the southeast, northeast, northwest, and Mississippi River regions.

Table 2. Types and number of turtle gear sets by year for each of five Iowa regions.

Region	Basking trap	Hand capture	Hoop net	Fyke net	Turtle trap
Northeast					
2012	-	-	3	2	-
2013	-	-	-	4	36
2014	-	1	-	-	-
2016	-	1	-	-	155
2017	-	-	-	-	107
2018	-	-	-	-	76
2019	-	2	10	-	78
2020	-	-	6	-	60
Northwest					
2013	-	-	-	-	3
2016	-	1	1	-	40
2017	-	-	-	-	40
2018	-	-	-	-	40
2019	-	-	-	-	40
2020	-	-	-	-	40
Southeast					
2010	-	1	73	-	-
2011	1	8	29	1	27

Region	Basking trap	Hand capture	Hoop net	Fyke net	Turtle trap
2012	-	9	1	4	52
2013	-	8	-	-	28
2014	-	9	-	-	32
2015	-	14	7	2	31
2016	-	29	-	-	111
2017	-	23	-	-	137
2018	-	65	-	-	110
2019	-	71	-	1	97
2020	-	39	-	-	80
Southwest					
2012	-	-	-	2	27
2013	-	-	-	8	10
2014	-	-	-	4	5
2015	-	2	-	4	115
2016	-	-	-	1	61
2017	-	-	-	2	104
2018	-	1	-	-	93
2019	-	-	-	-	111
2020	-	-	-	-	104
Mississippi River					
2013	-	1	-	-	5
2014	-	3	-	4	4
2015	-	15	-	-	1
2016	-	11	-	-	12
2017	-	15	-	-	11
2018	-	12	-	-	10
2019	-	17	1	2	13
2020	-	9	-	-	10

The western painted turtle *Chrysemys picta belli* was the species observed most often in collections (51%) followed by common snapping turtle *Chelydra serpentina* (24%), red-eared slider *Trachemys scripta elegans* (12%), and spiny softshell *Apalone spinifera* (8%); smooth softshell *Apalone mutica* (1%), map turtles *Graptemys* spp., and other species such as the Blanding's turtle *Emydoidea blandingii*, common musk turtle *Sternotherus odoratus*, ornate box turtle *Terrapene ornata*, and three-toed box turtle *Terrapene carolina triunguis* accounted for the remaining catch (4%; Figure 1).

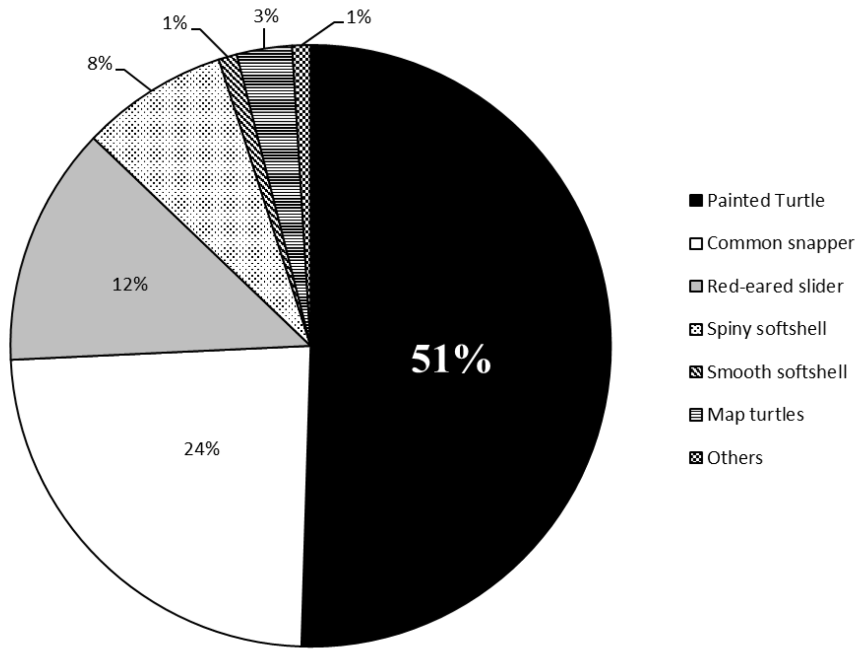


Figure 1. Statewide turtle catch (%; 2010-2020) according to species, n=6,443. Recaptures excluded. Map turtles are common map turtle, false map turtle, and Ouachita map turtle. Others are Blanding's turtle, common musk turtle, ornate box turtle, and three-toed box turtle.

Western painted turtle average lengths (SCL, in.) and weights (lbs.) ranged from 5.0-5.7 in. and 0.79-1.0 lbs. across regions from 2010-2020 (Table 3 & Table 4). Female paints were slightly larger than males statewide. On average, the smallest paints were caught in the Mississippi River region. Uneven sexes were detected across all harvestable turtle species statewide (chi-square analysis, χ^2=252.0, DF=3, P<0.01). Such differences were also apparent for the western painted turtle across regions (chi-square analysis, χ^2=38.0, DF=4, P<0.01). Statewide sex ratio (M:F) was significantly skewed towards males (1.5:1.0) for this species (multiple linear contrast, χ^2=137.8, DF=1, P<0.01), and males were significantly more prevalent than female paints across all regions except the Mississippi River (Table 5). Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.84 (0.09) per net night in the southwest region (2012-2020) to 2.5 (0.30) per net night in the northwest region (2013-2020; Table 6). Annual CPUEs ± SE ranged from as low as zero per net night in the southwest region (2014) to as high as 3.8 (1.2) per net night in the southeast region (2013; Table 7). Catch per net night for the western painted turtle was higher in the southeast region (2010-2020) as compared to the southwest region (2012-2020), but catch remained relatively stable in the southeast region while increasing slightly in the southwest region over a similar time period (Figure 2). Catch was also slightly less variable from 2017-2020 for the southern regions than in prior years. The portion of male painted turtles in the 5.0-6.0 in. size classes by region was 52% (northeast), 57% (northwest), 63% (southeast), 51% (southwest), and 81% (Mississippi River; Figure 3-Figure 7). The portion of females in the 5.5-7.0 in. size classes averaged 61% across all regions (excluding the Mississippi River region). Female paints reached greater maximum sizes than males across most regions. Weight increased with increasing length (regression analysis, F=138,243, DF=1, P<0.01; Figure 8) for painted turtles, and this relationship was similar across regions (Figure 9).

Table 3. Average length (in.), sample size (n; parentheses), and range (in.) of Iowa's harvestable turtle species by region (2010-2020). WPTT=Western Painted Turtle, CSNT=Common Snapping Turtle, SPSS=Spiny Softshell, SMSS=Smooth Softshell.

Species	NE	NW	SE	SW	MR
WPTT					
All	5.4 (660) 1.0-7.8	5.7 (463) 2.4-8.3	5.5 (1,404) 1.1-8.1	5.6 (517) 2.3-8.7	5.0 (223) 1.1-7.5
Male	5.2 (447) 1.3-7.6	5.6 (285) 2.4-8.3	5.4 (845) 1.8-7.9	5.4 (283) 2.3-8.2	5.6 (105) 3.2-6.6
Female	5.8 (206) 2.4-7.8	5.9 (178) 2.5-8.0	6.1 (501) 2.2-8.1	5.9 (228) 2.4-8.7	6.1 (66) 3.3-7.5
Immature	2.4 (7) 1.0-3.6	-	3.1 (57) 1.1-4.7	3.8 (6) 3.3-4.2	2.5 (51) 1.1-4.1
CSNT					
All	10.5 (404) 2.8-17.2	11.6 (163) 2.9-17.0	10.7 (655) 1.5-15.8	10.7 (167) 3.5-15.6	9.7 (135) 1.3-15.3
Male	11.2 (220) 5.3-17.2	12.7 (77) 5.6-17.0	11.6 (350) 5.0-15.8	11.4 (83) 5.7-15.2	11.6 (56) 7.2-15.3
Female	9.7 (181) 2.8-15.0	10.7 (86) 2.9-14.6	10.6 (258) 2.2-13.7	10.2 (80) 4.1-15.6	10.6 (45) 6.7-13.9
Immature	4.8 (3) 3.3-6.6	-	4.8 (46) 1.5-7.7	5.6 (4) 3.5-7.9	5.2 (34) 1.3-8.3
SPSS					
All	11.2 (78) 4.9-16.7	10.1 (6) 7.3-13.6	9.5 (230) 2.9-16.7	9.4 (195) 3.9-16.6	8.7 (16) 2.0-13.2
Male	6.2 (6) 4.9-6.8	7.7 (3) 7.3-8.1	6.6 (64) 3.4-8.1	6.0 (55) 3.9-7.3	7.0 (7) 6.0-8.0
Female	11.6 (72) 5.1-16.7	12.5 (3) 11.5-13.6	10.7 (163) 2.9-16.7	10.7 (140) 3.9-16.6	10.9 (8) 7.2-13.2
Immature	-	-	4.1 (3) 3.9-4.3	-	2.0 (1) -
SMSS					
All	8.3 (3) 6.9-10.7	-	7.5 (36) 4.4-10.9	8.1 (55) 5.4-9.6	6.0 (1) -
Male	7.2 (1) -	-	6.3 (19) 5.4-7.5	7.4 (4) 5.4-9.3	6.0 (1) -
Female	8.8 (2) 6.9-10.7	-	9.6 (14) 6.5-10.9	8.2 (51) 5.9-9.6	-
Immature	-	-	4.8 (3) 4.4-5.1	-	-

Table 4. Average weight (lbs.), sample size (n; parentheses), and range (lbs.) of Iowa's harvestable turtle species by region (2010-2020). WPTT=Western Painted Turtle, CSNT=Common Snapping Turtle, SPSS=Spiny Softshell, SMSS=Smooth Softshell.

Species	NE	NW	SE	SW	MR
WPTT					
All	0.81 (644) 0.01-2.1	0.95 (463) 0.06-2.5	0.86 (1,383) 0.01-2.7	1.0 (515) 0.07-2.8	0.79 (222) 0.01-2.1
Male	0.71 (436) 0.10-1.8	0.87 (286) 0.06-2.5	0.72 (834) 0.09-1.8	0.80 (282) 0.07-2.5	0.81 (104) 0.19-1.3
Female	1.1 (200) 0.08-2.1	1.1 (177) 0.08-2.5	1.2 (493) 0.06-2.7	1.2 (228) 0.08-2.8	1.3 (66) 0.19-2.1
Immature	0.12 (8) 0.01-0.25	-	0.21 (55) 0.01-0.51	0.33 (5) 0.23-0.42	0.13 (51) 0.01-0.34
CSNT					
All	11.7 (395) 0.38-44.0	15.9 (162) 0.16-42.0	12.0 (630) 0.03-34.3	11.3 (163) 0.34-28.0	10.3 (135) 0.02-35.8
Male	13.9 (215) 0.99-44.0	19.6 (77) 1.5-42.0	14.1 (340) 0.67-34.3	13.0 (79) 1.8-28.0	14.8 (56) 3.1-35.8
Female	9.3 (177) 0.51-28.1	12.6 (85) 0.16-27.9	11.0 (245) 0.11-22.3	10.0 (80) 0.69-27.7	11.4 (45) 2.2-22.9
Immature	1.1 (3) 0.38-2.1	-	1.2 (45) 0.03-3.9	1.8 (4) 0.34-4.3	1.5 (34) 0.02-4.2
SPSS					
All	5.7 (78) 0.37-14.1	3.8 (5) 1.2-8.1	3.6 (232) 0.10-16.2	3.8 (194) 0.22-13.2	2.7 (16) 0.03-7.6
Male	0.81 (6) 0.37-1.1	1.5 (3) 1.2-2.0	1.0 (65) 0.16-2.6	1.0 (56) 0.25-10.5	1.1 (7) 0.74-1.6
Female	6.1 (72) 0.44-14.1	7.3 (2) 6.5-8.1	4.7 (164) 0.10-16.2	4.9 (138) 0.22-13.2	4.5 (8) 1.0-7.6
Immature	-	-	0.23 (3) 0.22-0.23	-	0.03 (1) -
SMSS					
All	1.6 (3) 0.52-3.7	-	1.4 (36) 0.20-4.2	1.6 (55) 0.45-2.4	0.61 (1) -
Male	0.65 (1) -	-	0.62 (19) 0.36-1.4	1.3 (4) 0.45-2.2	0.61 (1) -
Female	2.1 (2) 0.52-3.7	-	2.6 (14) 0.75-4.2	1.7 (51) 0.62-2.4	-
Immature	-	-	0.25 (3) 0.20-0.30	-	-

Table 5. Sex ratio (M:F) and sample size (n; parentheses) for Iowa's harvestable turtle species statewide and by region (2010-2020). Immatures designated female. WPTT=Western Painted Turtle, CSNT=Common Snapping Turtle, SPSS=Spiny Softshell, SMSS=Smooth Softshell. Statewide and regional unevenness of sexes was tested with multiple linear contrasts. An asterisk (*) indicates a significant difference (α=0.05) in sex ratio; NE=non-estimable.

Species	Statewide	NE	NW	SE	SW	MR
WPTT	1.5:1.0*	2.1:1.0*	1.6:1.0*	1.5:1.0*	1.2:1.0*	1.0:1.1
	(3,271)	(663)	(466)	(1,403)	(517)	(222)
CSNT	1.1:1.0	1.2:1.0	1.0:1.1	1.1:1.0	1.1:1.0	1.0:1.4*
	(1,528)	(406)	(163)	(657)	(167)	(135)
SPSS	1.0:2.9*	1.0:12.2*	1.0:1.0	1.0:2.5*	1.0:2.5*	1.0:1.3
	(529)	(79)	(6)	(232)	(196)	(16)
SMSS	1.0:2.8*	1.0:2.0	-	1.0:1.1	1.0:12.8*	1.0:0.0[NE]
	(95)	(3)		(36)	(55)	(1)

Table 6. Catch-per-unit-effort (catch per net night) including number of gear sets for Iowa's harvestable turtle species across years (2010-2020) for five regions. Parenthetical values represent standard error. WPTT=Western Painted Turtle, CSNT=Common Snapping Turtle, SPSS=Spiny Softshell, SMSS=Smooth Softshell.

Category	NE	NW	SE	SW	MR
Gear Sets	511	203	814	628	65
Species					
WPTT	1.7 (0.13)	2.5 (0.30)	1.8 (0.13)	0.84 (0.09)	1.3 (0.24)
CSNT	1.2 (0.08)	0.85 (0.09)	0.87 (0.05)	0.35 (0.03)	0.92 (0.14)
SPSS	0.18 (0.03)	0.03 (0.01)	0.30 (0.04)	0.39 (0.05)	0.18 (0.07)
SMSS	<0.01 (<0.01)	0 (-)	0.04 (0.01)	0.13 (0.03)	0 (-)

Table 7. Annual catch-per-unit-effort (catch per net night) for Iowa's harvestable turtle species for five regions. Parenthetical values represent standard error and gear sets, respectively. WPTT=Western Painted Turtle, CSNT=Common Snapping Turtle, SPSS=Spiny Softshell.

Species	NE	NW	SE	SW	MR
WPTT					
2010	-	-	1.5 (0.31, 73)	-	-
2011	-	-	1.0 (0.36, 56)	-	-
2012	-	-	1.7 (0.49, 53)	0.48 (0.18, 27)	-
2013	0.69 (0.29, 36)	0.33 (0.33, 3)	3.8 (1.2, 28)	0.70 (0.34, 10)	1.0 (0.77, 5)
2014	-	-	1.6 (0.42, 32)	0 (0, 5)	1.3 (0.75, 4)
2015	-	-	2.5 (0.57, 38)	0.62 (0.11, 115)	-
2016	2.1 (0.26, 155)	1.9 (0.54, 40)	2.4 (0.53, 111)	0.74 (0.21, 61)	0.83 (0.37, 12)
2017	1.8 (0.28, 107)	3.5 (0.80, 40)	1.8 (0.35, 136)	1.0 (0.26, 104)	0.55 (0.37,11)
2018	1.8 (0.43, 76)	1.9 (0.48, 40)	1.6 (0.28, 110)	1.1 (0.26, 93)	2.4 (0.78, 10)
2019	1.8 (0.37, 77)	2.7 (0.79, 40)	1.9 (0.38, 97)	0.87 (0.23, 111)	0.64 (0.25, 14)
2020	0.53 (0.20, 60)	2.4 (0.68, 40)	1.4 (0.30, 80)	0.85 (0.30, 102)	2.7 (1.1, 9)
CSNT					
2010	-	-	1.4 (0.18, 73)	-	-
2011	-	-	0.64 (0.19, 56)	-	-
2012	-	-	1.2 (0.24, 53)	0.26 (0.11, 27)	-
2013	0.81 (0.19, 36)	0.67 (0.33, 3)	2.2 (0.43, 28)	0.60 (0.31, 10)	1.4 (0.40, 5)
2014	-	-	0.78 (0.20, 32)	0.60 (0.60, 5)	1.5 (0.65, 4)
2015	-	-	1.1 (0.26, 38)	0.31 (0.06, 115)	-
2016	1.7 (0.17, 155)	1.2 (0.26, 40)	0.63 (0.10, 111)	0.39 (0.10, 61)	0.08 (0.08, 12)
2017	0.93 (0.14, 107)	0.78 (0.16, 40)	0.70 (0.09, 136)	0.39 (0.08, 104)	0.91 (0.37, 11)
2018	1.2 (0.20, 76)	0.33 (0.12, 40)	0.71 (0.10, 110)	0.33 (0.07, 93)	1.6 (0.31, 10)
2019	1.1 (0.18, 77)	1.2 (0.25, 40)	0.85 (0.12, 97)	0.32 (0.06, 111)	1.2 (0.37, 14)
2020	0.85 (0.16, 60)	0.83 (0.20, 40)	0.69 (0.15, 80)	0.37 (0.07, 102)	0.33 (0.17, 9)
SPSS					
2010	-	-	0.14 (0.07, 73)	-	-
2011	-	-	0.30 (0.15, 56)	-	-
2012	-	-	0.30 (0.20, 53)	0.52 (0.23, 27)	-
2013	0.28 (0.16, 36)	0 (-, 3)	0.46 (0.18, 28)	0 (-, 10)	0 (-, 5)
2014	-	-	0.31 (0.13, 32)	0 (-, 5)	0 (-, 4)
2015	-	-	0.11 (0.06, 38)	0.01 (0.01, 115)	0 (-, 1)
2016	0.08 (0.03, 155)	0.03 (0.03, 40)	0.22 (0.07, 111)	0.62 (0.21, 61)	0.50 (0.26, 12)
2017	0.24 (0.06, 107)	0.03 (0.03, 40)	0.24 (0.08, 136)	0.59 (0.16, 104)	0 (-, 11)

Species	NE	NW	SE	SW	MR
2018	0.22 (0.07, 76)	0.05 (0.03, 40)	0.35 (0.08, 110)	0.28 (0.09, 93)	0.1 (0.1, 10)
2019	0.18 (0.07, 77)	0.05 (0.03, 40)	0.33 (0.11, 97)	0.64 (0.17, 111)	0 (-, 14)
2020	0.17 (0.06, 60)	0 (-, 40)	0.56 (0.19, 80)	0.31 (0.08, 102)	0.56 (0.29, 9)
SMSS					
2010	-	-	0 (0, 73)	-	-
2011	-	-	0.27 (0.14, 56)	-	-
2012	-	-	0 (0, 53)	0.07 (0.05, 27)	-
2013	0 (-, 36)	0 (-, 3)	0.07 (0.05, 28)	0 (-, 10)	0 (-, 5)
2014	-	-	0 (0, 32)	0 (-, 5)	0 (-, 4)
2015	-	-	0 (0, 38)	0 (-, 115)	-
2016	0 (-, 155)	0 (-, 40)	0 (0, 111)	0.16 (0.10, 61)	0 (-, 12)
2017	0.01 (0.01,107)	0 (-, 40)	0.02 (0.01, 136)	0.29 (0.13, 104)	0 (-, 11)
2018	0 (-, 76)	0 (-, 40)	0.03 (0.02, 110)	0.09 (0.03, 93)	0 (-, 10)
2019	0 (-, 87)	0 (-, 40)	0.08 (0.05, 97)	0.23 (0.10, 111)	0 (-, 14)
2020	0 (-, 60)	0 (-, 40)	0.05 (0.03, 80)	0.08 (0.04, 102)	0 (-, 9)

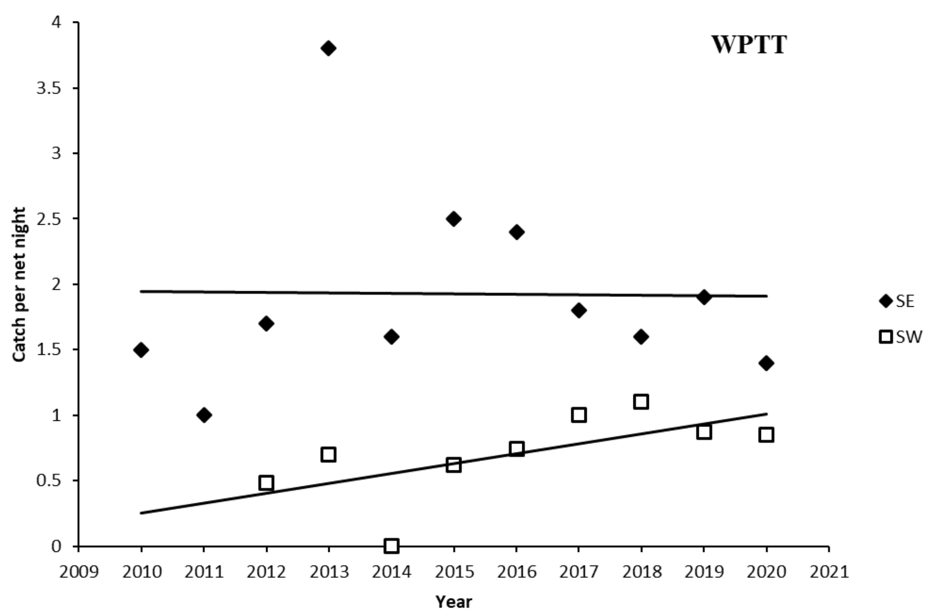


Figure 2. Catch per net night for the western painted turtle (WPTT) in the southeast (2010-2020) and southwest (2012-2020) regions. The vertical dashed line indicates the year (2017) in which harvest regulations were enacted.

Northeast Region (2013-2020)

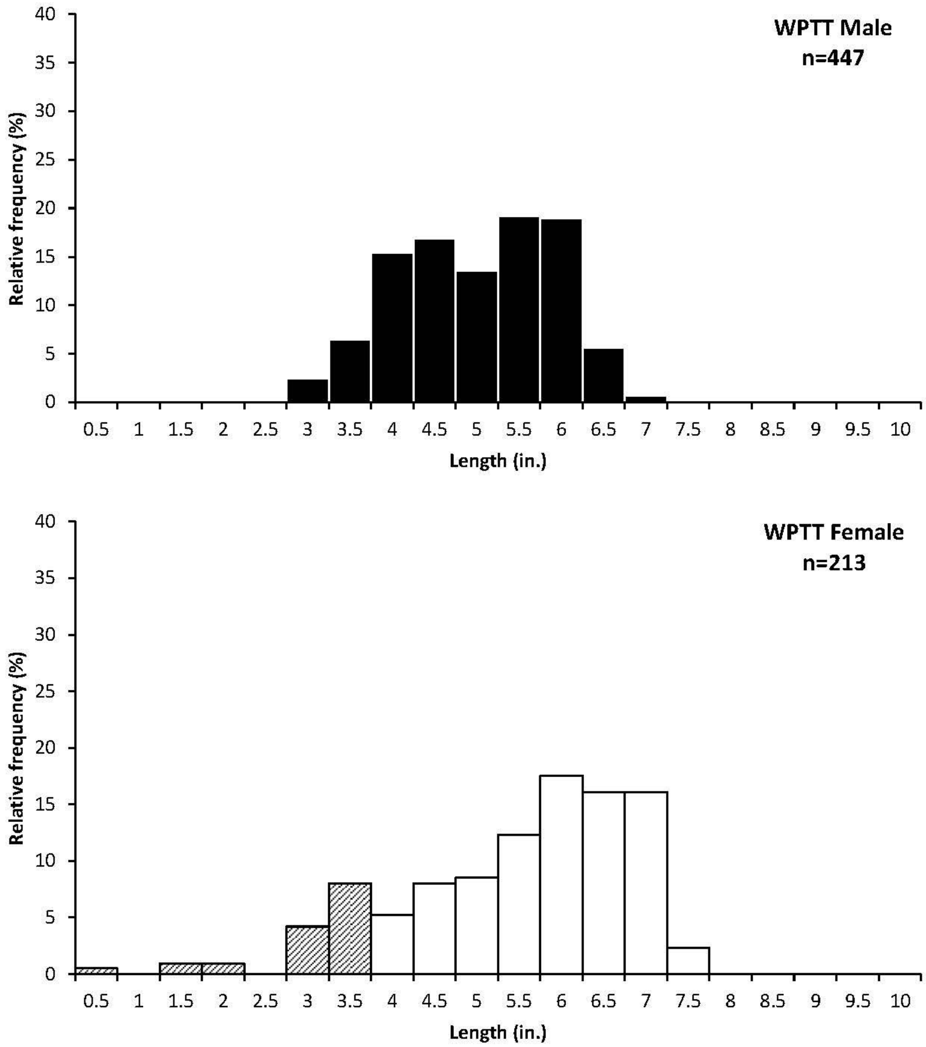


Figure 3. Relative frequency (%) of the western painted turtle (WPTT) in northeast Iowa according to length group (½ in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

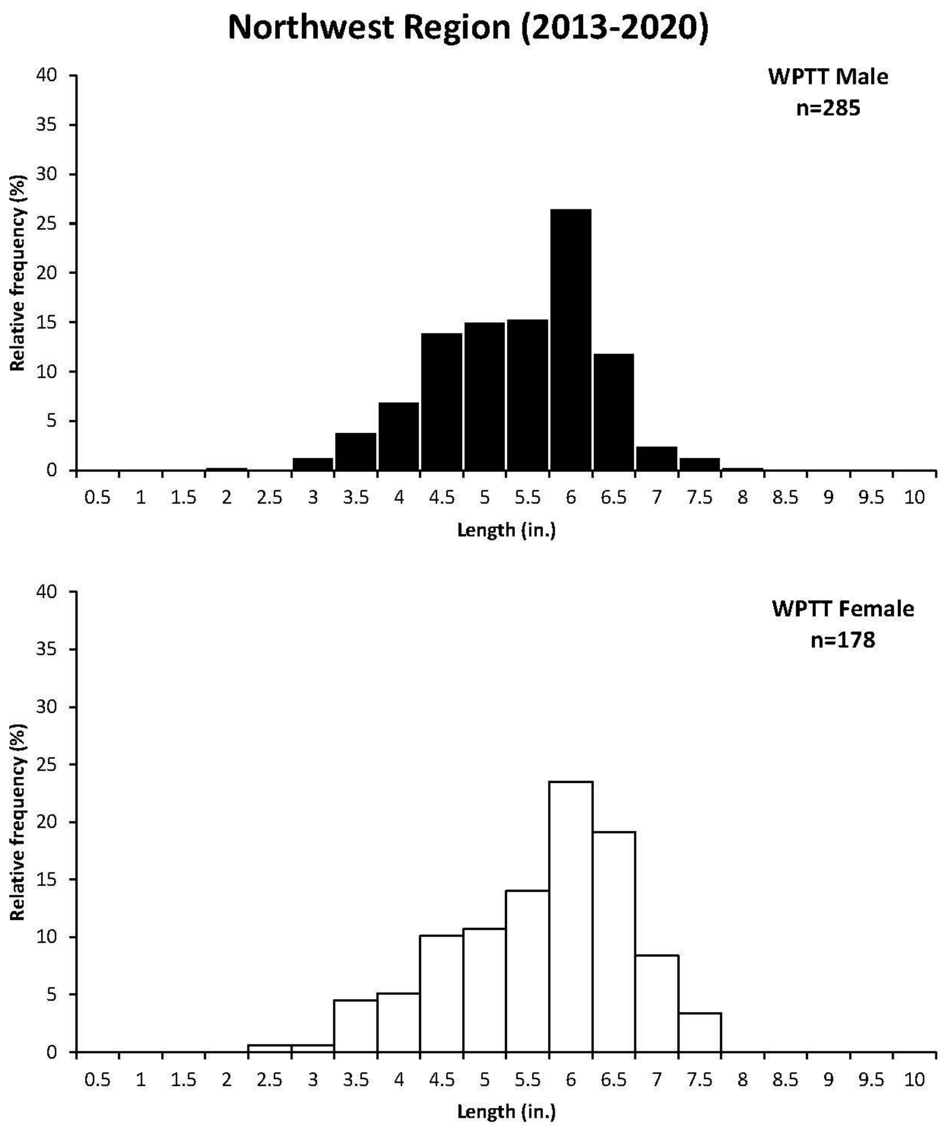
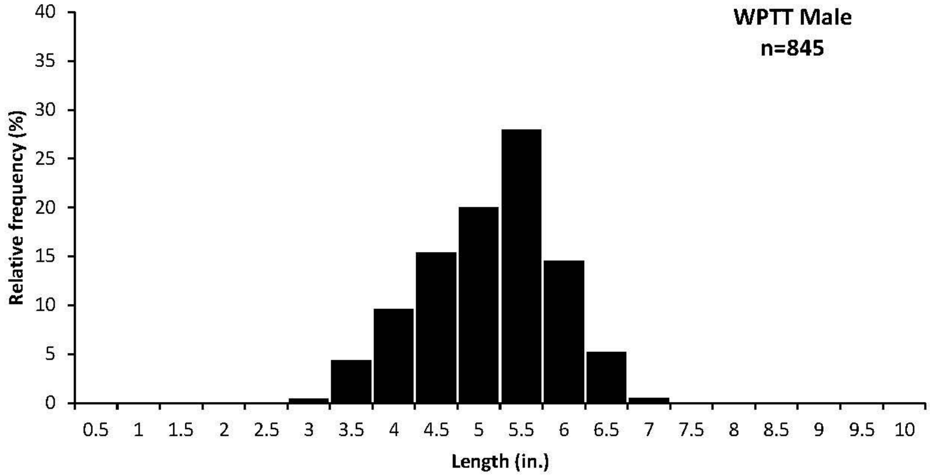


Figure 4. Relative frequency (%) of the western painted turtle (WPTT) in northwest Iowa according to length group (½ in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southeast Region (2010-2020)



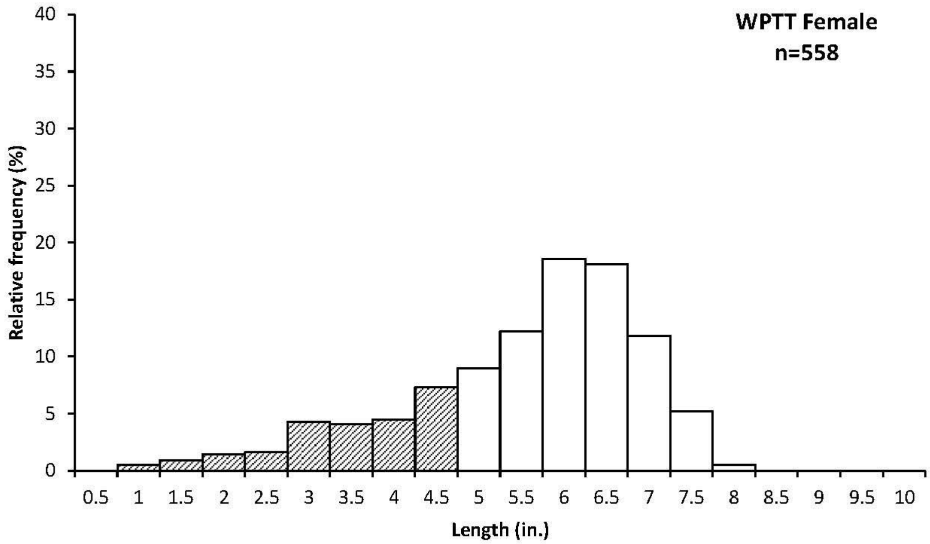


Figure 5. Relative frequency (%) of the western painted turtle (WPTT) in southeast Iowa according to length group (½ in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southwest Region (2012-2020)

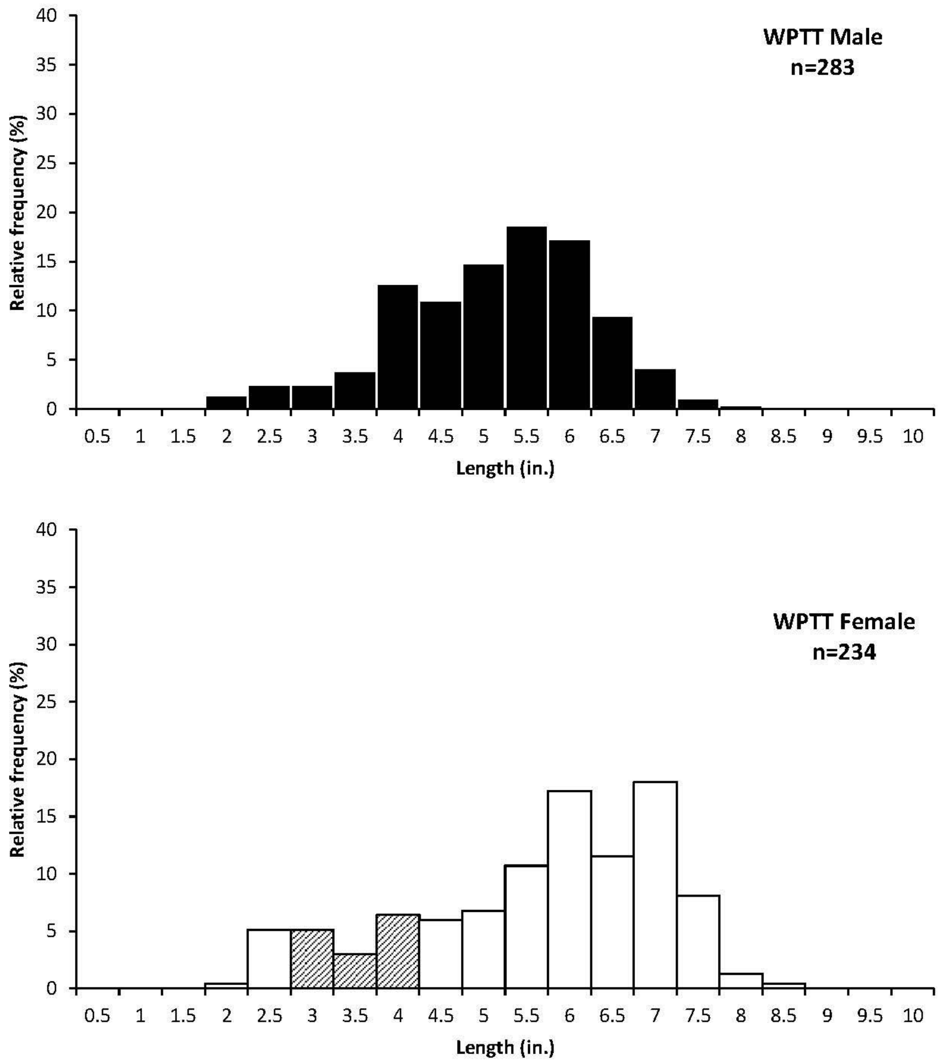
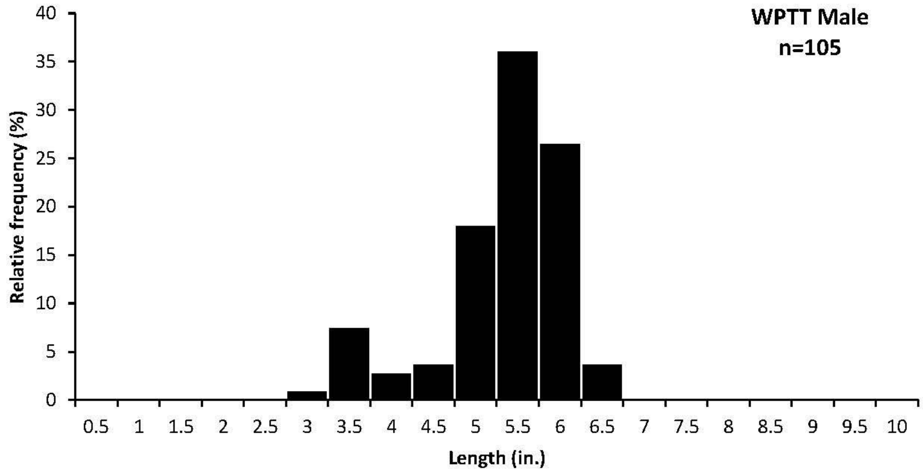


Figure 6. Relative frequency (%) of the western painted turtle (WPTT) in southwest Iowa according to length group (½ in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Mississippi River (2013-2020)



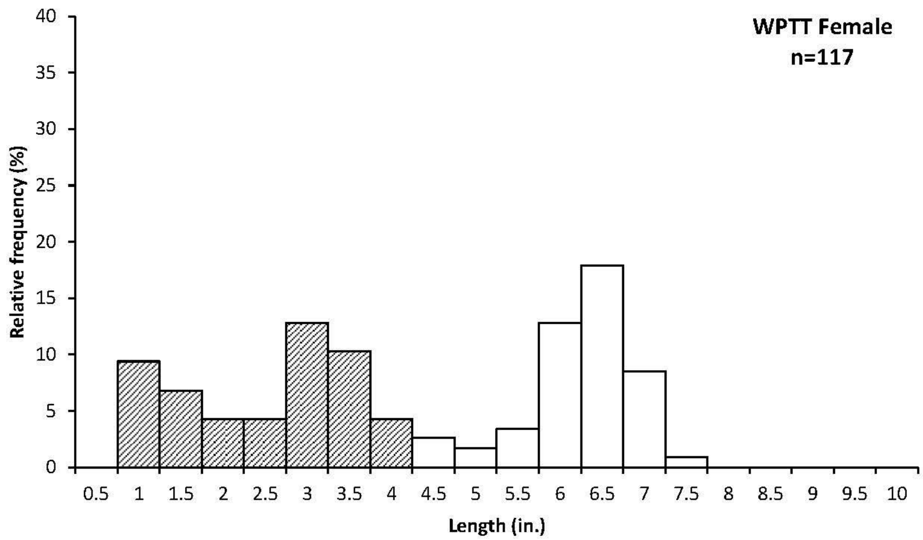


Figure 7. Relative frequency (%) of the western painted turtle (WPTT) in the Mississippi River region according to length group (½ in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

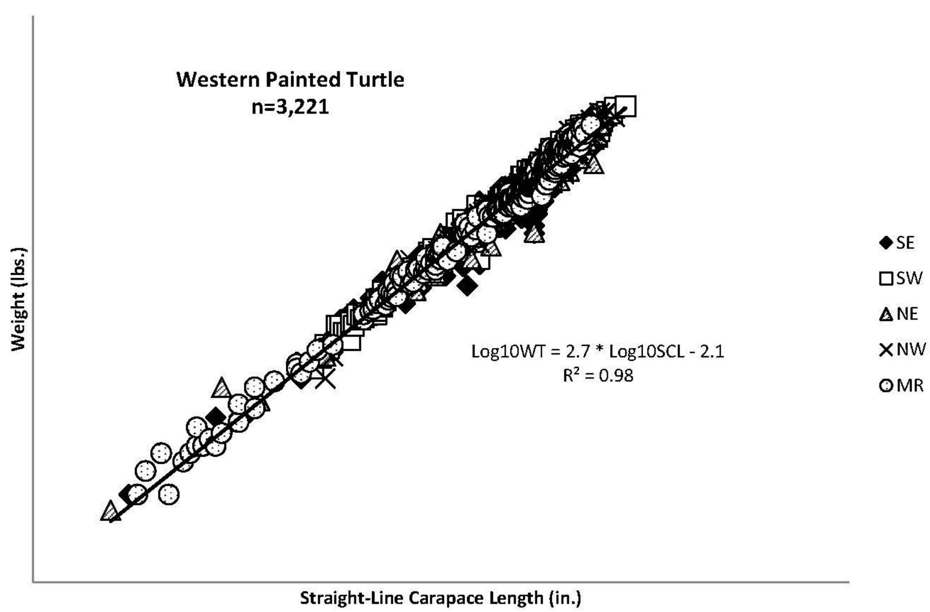


Figure 8. Length-weight relationship for western painted turtle across five statewide regions (SE=southeast, SW=southwest, NE=northeast, NW=northwest, MR=Mississippi River); both sexes combined.

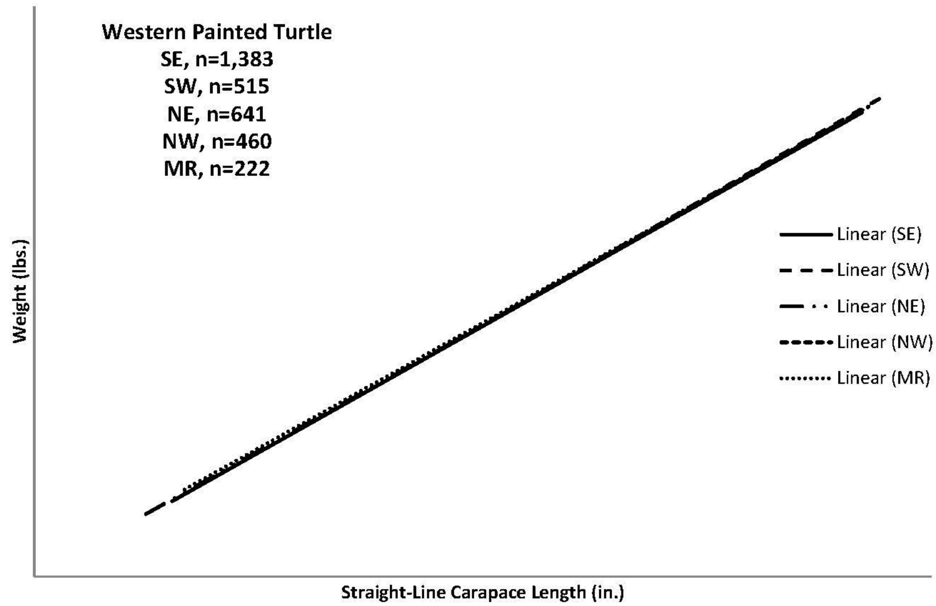


Figure 9. Length-weight relationships for western painted turtle by region. Sample sizes (n) for respective regions are listed.

Common snapping turtle average lengths (SCL, in.) and weights (lbs.) ranged from 9.7-11.6 in. and 10.3-15.9 lbs. across regions from 2010-2020 (Table 3 & Table 4). The largest snappers were observed in northwest Iowa and snappers were on average larger in northern Iowa as compared to southern regions. Uneven sexes were detected across all harvestable turtle species statewide (chi-square analysis, χ^2=252.0, DF=3, P<0.01). No differences were apparent for the common snapping turtle across regions (chi-square analysis, χ^2=9.2, DF=4, P=0.06). M:F was slightly skewed towards males (1.1:1.0) for this species, but this relation was not significant (multiple linear contrast, χ^2=1.51, DF=1, P=0.22). There was no consistent trend in snapper sex ratio favoring one sex or the other across regions (Table 5). Sexes were nearly equal for the northwest, southeast, and southwest regions. Sex ratio was slightly skewed male (1.2:1.0) in the northeast region; conversely, it was slightly skewed female (1.0:1.4) in the Mississippi River region. Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.35 (0.03) per net night in the southwest region (2012-2020) to 1.2 (0.08) per net night in the northeast region (2013-2020; Table 6). Annual CPUEs ± SE ranged from 0.08 (0.08) per net night for the Mississippi River region (2016), to 2.2 (0.43) per net night in the southeast region (2013; Table 7). Catch per net night for common snapping turtles in the southeast region (2010-2020) was higher than in the southwest region (2012-2020); however, catch decreased slightly in the southeast region while remaining relatively constant in the southwest region over a similar time period (Figure 10). Catch was also less variable in the southern regions from 2017-2020 as compared to prior years. Dominant size classes for male and female snappers differed across regions. The portion of male common snapping turtles in the 11.0-13.0 in. size classes by region was 50% (northeast), 52% (northwest), 52% (southeast), 54% (southwest), and 50% (Mississippi River; Figure 11-Figure 15). The northwest region had the highest percentage of male snappers 15.0 in. or greater (13%) while other regions ranged from about 2% (southeast, southwest, and Mississippi River) to 4% (northeast). Females in the 10.0-12.0 in. size classes composed 51% (northeast), 56% (northwest), 62% (southeast), 59% (southwest), and 38% (Mississippi River) of sample collections across the aforementioned regions (Figure 11-Figure 15). The northeast, northwest, and southwest regions had female snappers 14.0 in. or greater, but only eight individuals were represented. Weight increased with increasing length (regression analysis, F=99,654, DF=1, P<0.01; Figure 16) for common snapping turtles, and this relationship was similar across regions (Figure 17).

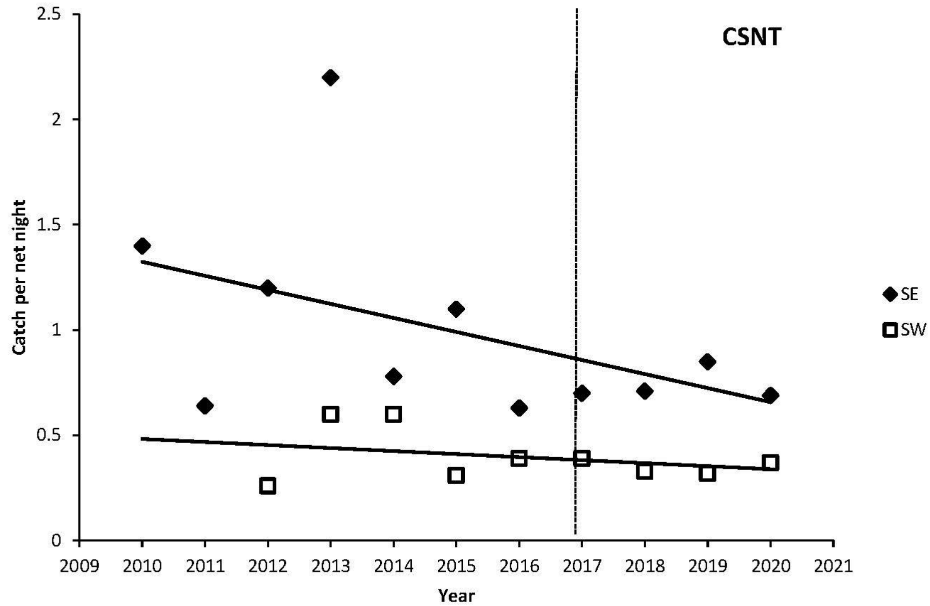
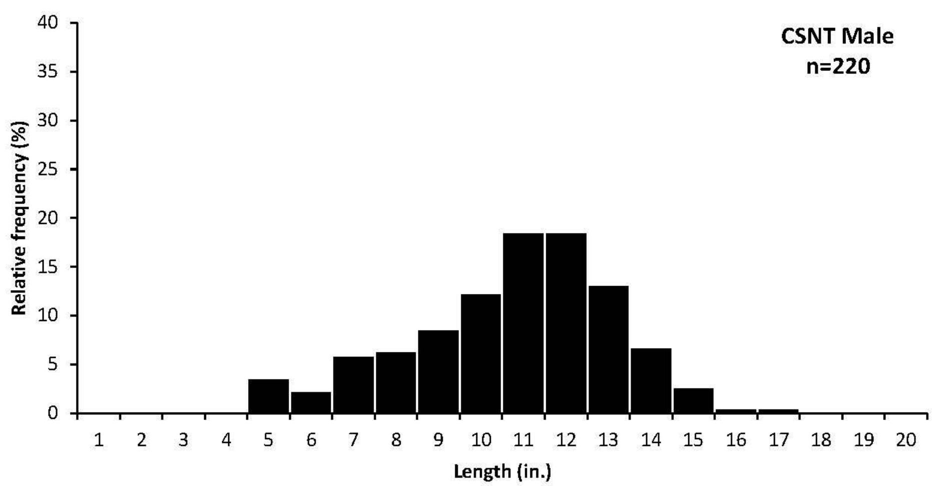


Figure 10. Catch per net night for the common snapping turtle (CSNT) in the southeast (2010-2020) and southwest (2012-2020) regions. The vertical dashed line indicates the year (2017) in which harvest regulations were enacted.

Northeast Region (2013-2020)



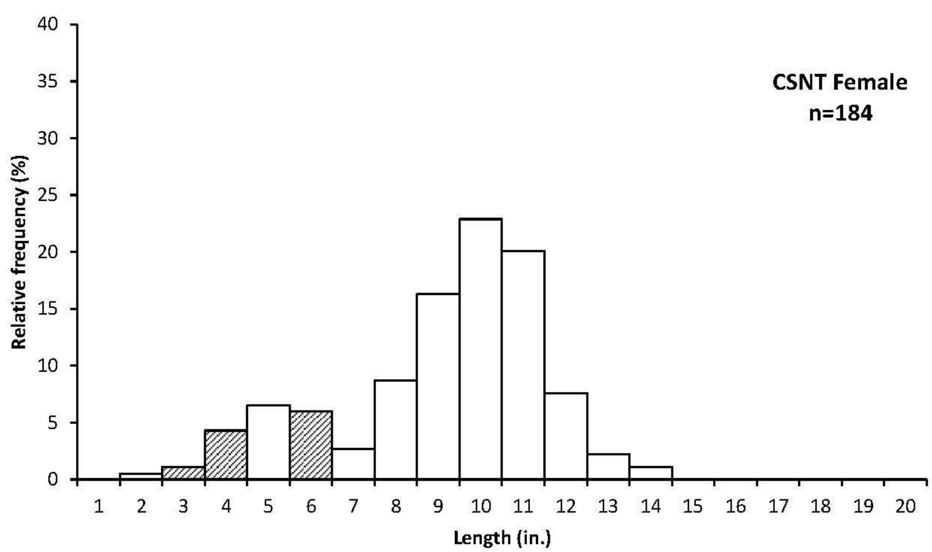


Figure 11. Relative frequency (%) of the common snapping turtle (CSNT) in northeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

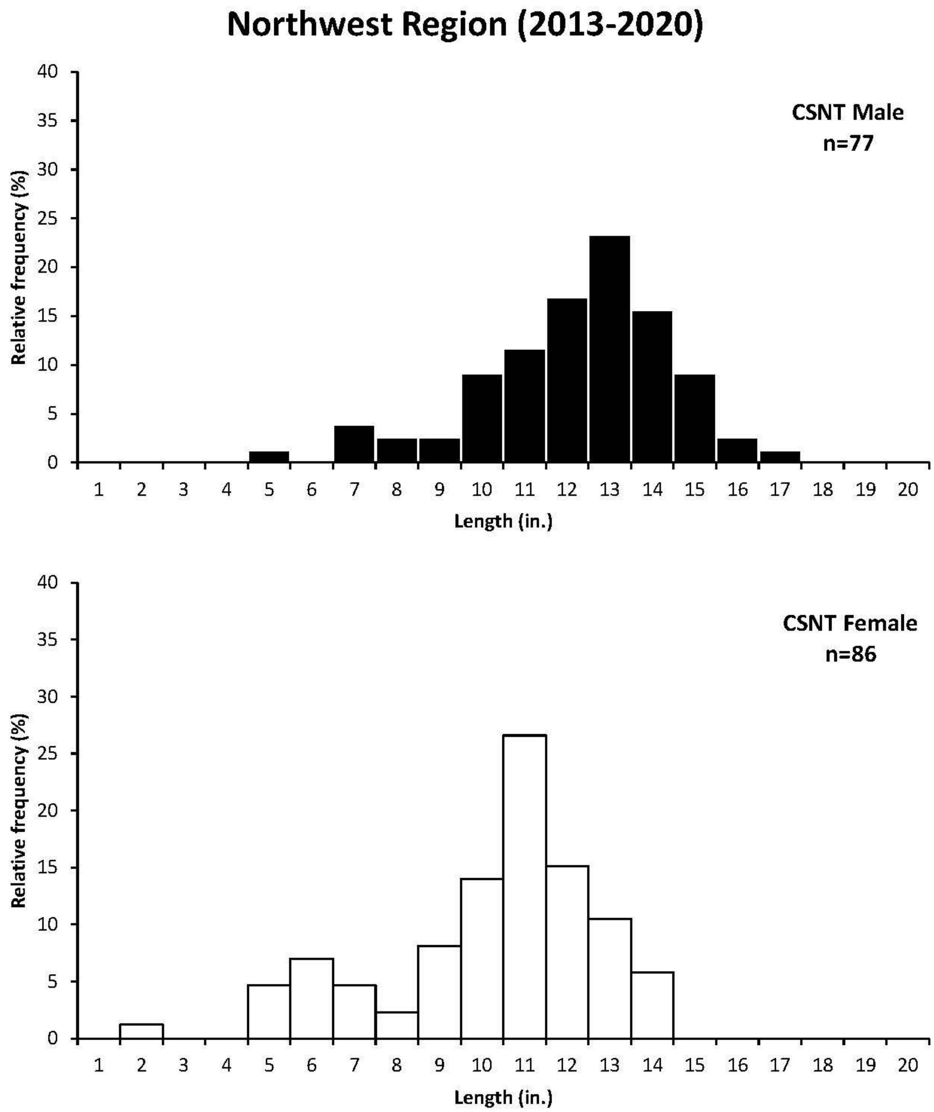


Figure 12. Relative frequency (%) of the common snapping turtle (CSNT) in northwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southeast Region (2010-2020)

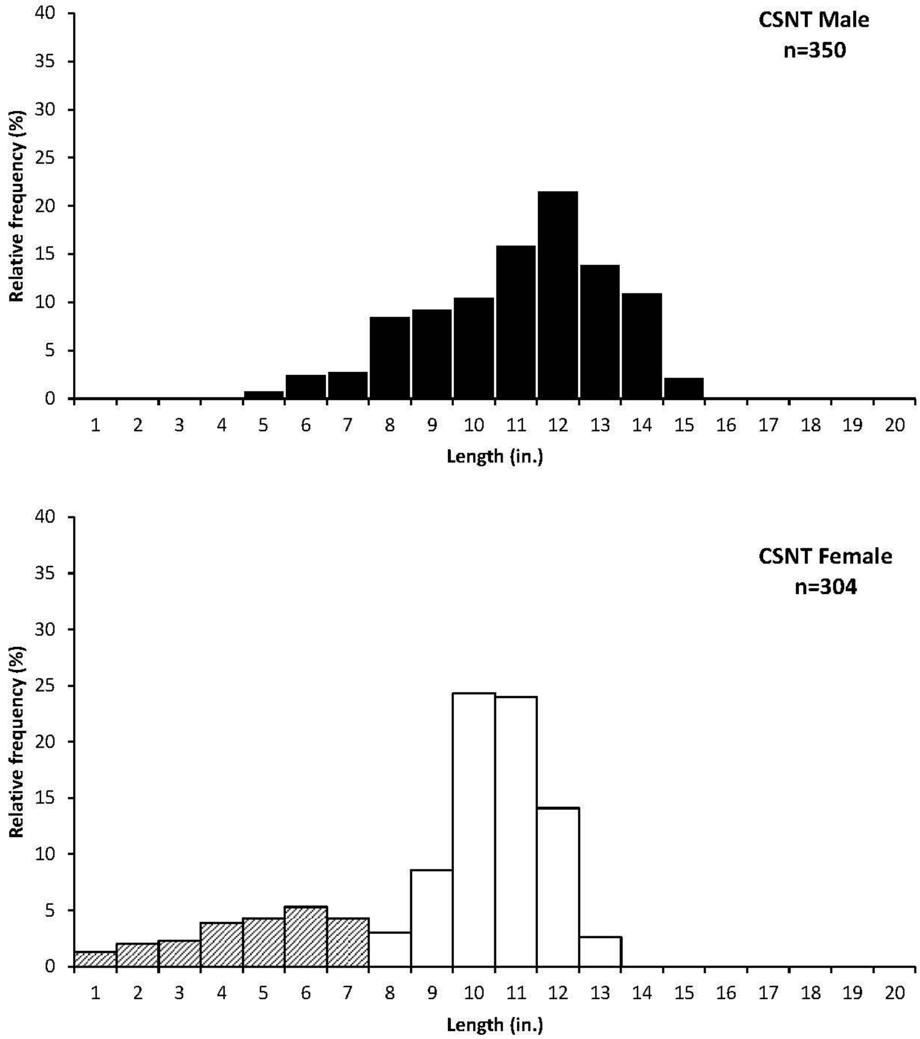


Figure 13. Relative frequency (%) of the common snapping turtle (CSNT) in southeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

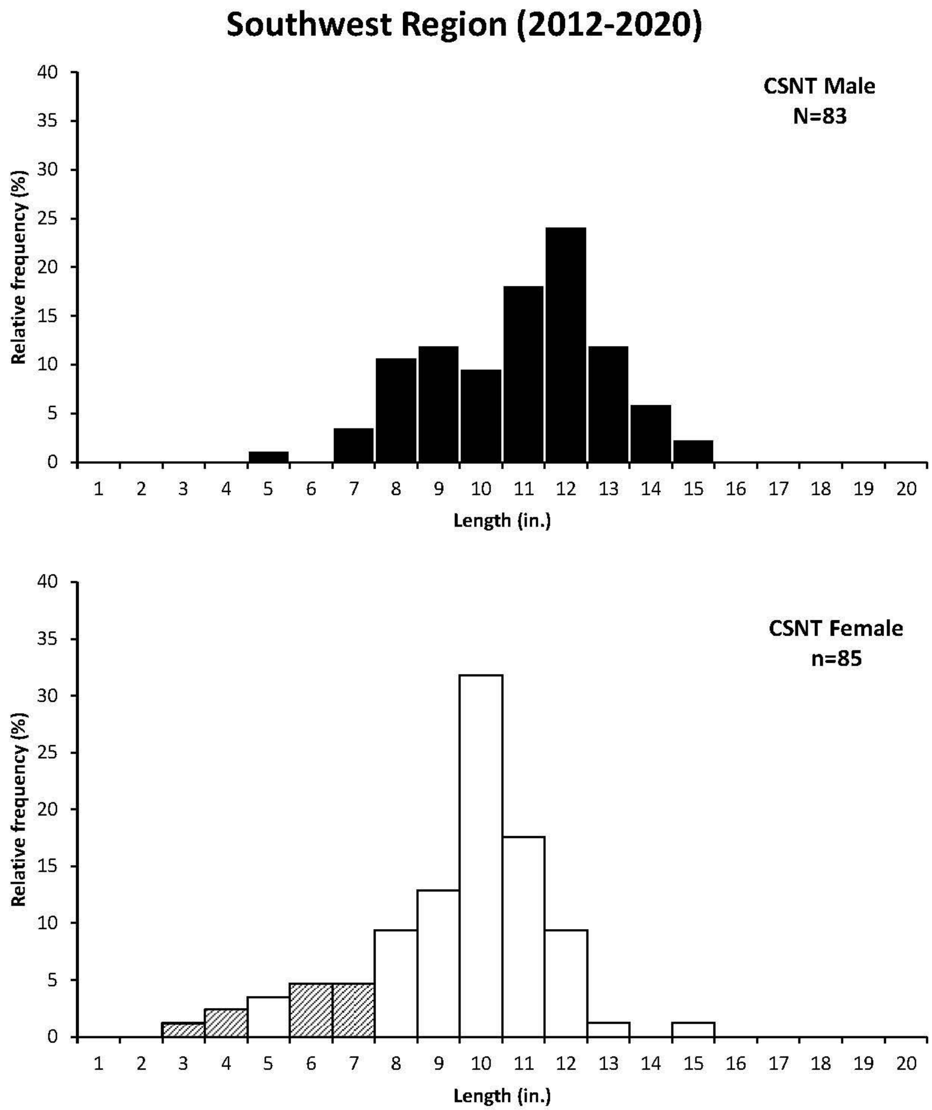


Figure 14. Relative frequency (%) of the common snapping turtle (CSNT) in southwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

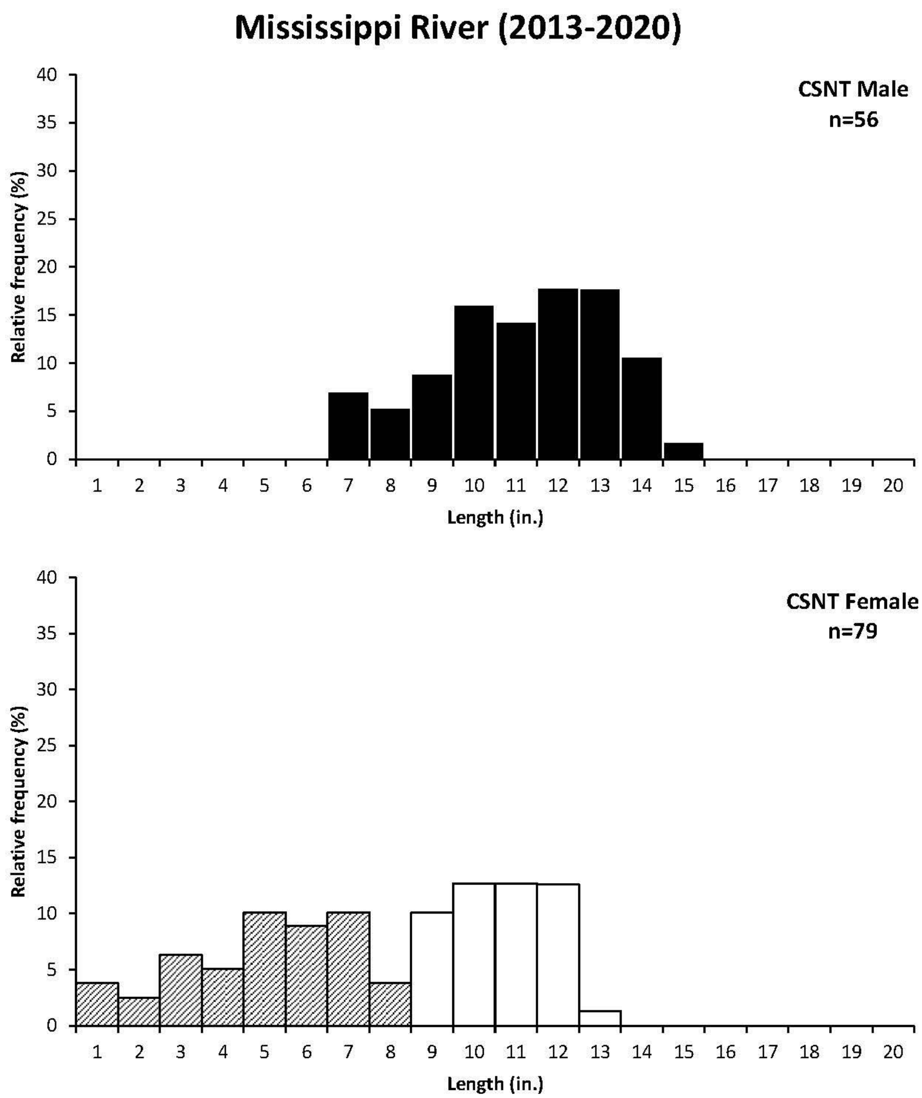


Figure 15. Relative frequency (%) of the common snapping turtle (CSNT) in the Mississippi River region according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

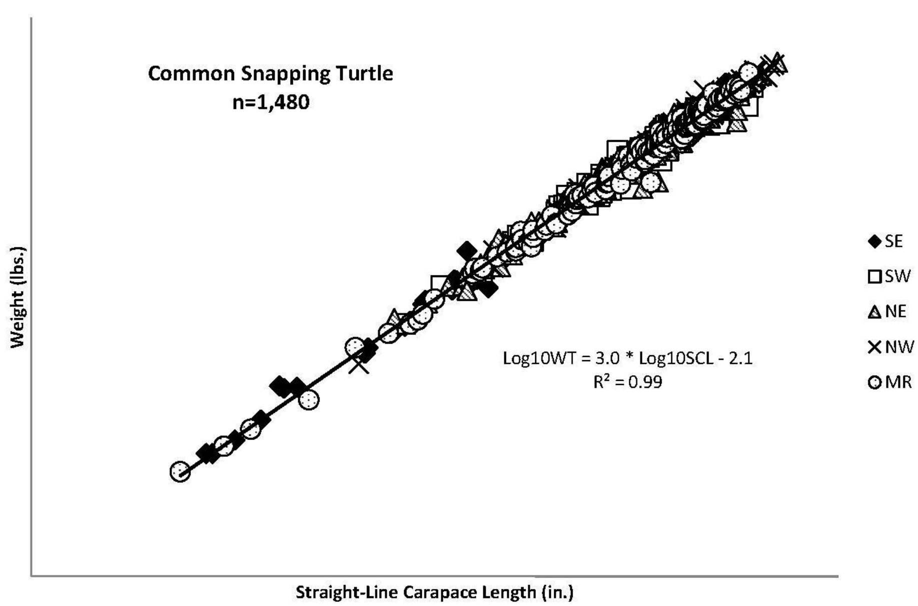


Figure 16. Length-weight relationship for common snapping turtle across five statewide regions (SE=southeast, SW=southwest, NE=northeast, NW=northwest, MR=Mississippi River); both sexes combined.

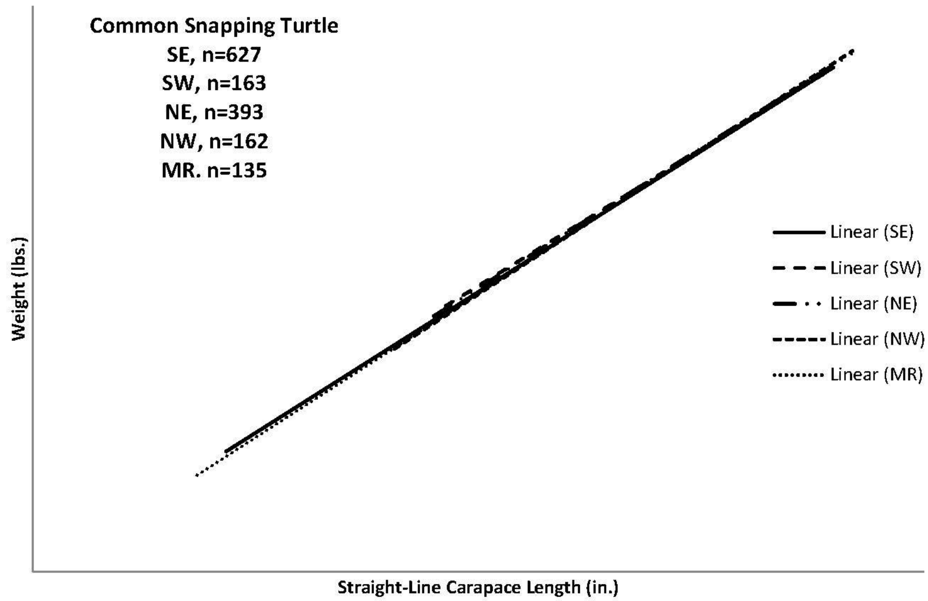
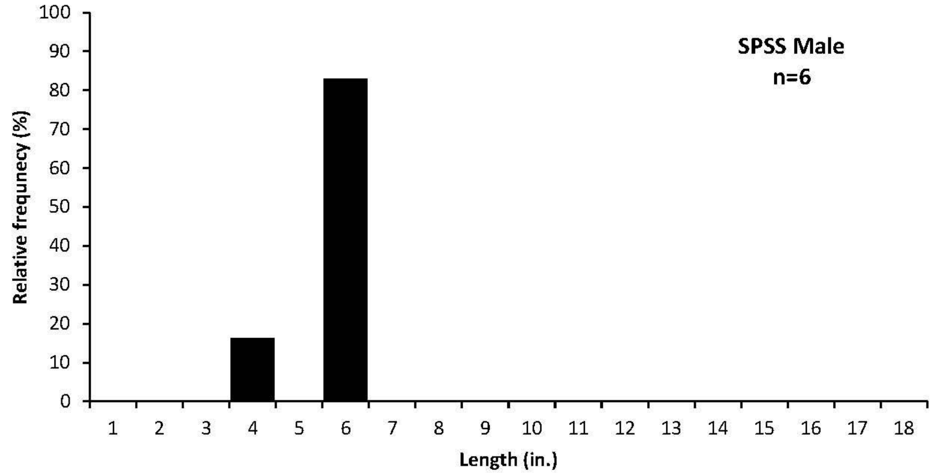


Figure 17. Length-weight relationships for common snapping turtle by region. Sample sizes (n) for respective regions are listed.

Spiny softshell average lengths (SCL, in.) and weights (lbs.) ranged from 8.7-11.2 in. and 2.7-5.7 lbs. across regions from 2010-2020 (Table 3 & Table 4). Females were 1.7 times larger (SCL) on average than males statewide. Uneven sexes were detected across all harvestable turtle species statewide (chi-square analysis, χ^2=252.0, DF=3, P<0.01). Such differences were also apparent for the spiny softshell turtle across regions (chi-square analysis, χ^2=19.5, DF=4, P=<0.01). M:F was significantly skewed towards females (1.0:2.9) for this species (multiple linear contrast, χ^2=128.2, DF=1, P<0.01), and females were more prevalent across most regions (Table 5). The majority of spiny softshell turtles were captured in southern Iowa. Catch-per-unit-effort (CPUE ± SE) across years ranged from 0.03 (0.01) per net night for the northwest region (2013-2020) to 0.39 (0.05) per net night for the southwest region (2012-2020; Table 6). Annual CPUEs ± SE ranged from as low as zero per net night in the northwest (2013, 2020), southwest (2013-2014), and Mississippi River (2013-2015, 2017, and 2019) regions to 0.64 (0.17) per net night for the southwest region (2019; Table 7). Mainly female spiny softshells were captured in the northeast region, 60.0% were in the 12.0-15.0 in. size classes (Figure 18). The three females caught in the northwest region were in the 11.0-13.0 in. size classes (Figure 19). The size distributions of female spiny softshells in the southeast and southwest regions were fairly uniform (Figure 20 & Figure 21). Females were more abundant in the 12.0-14.0 in. size classes (42%) in the southwest region. Male spiny softshells were most abundant in the 6.0-7.0 in. size classes (72%) in the southeast region (Figure 20), but 5.0-6.0 in. size classes were the most dominant in the southwest region (Figure 21). Only nine male spiny softshells were caught in the northern regions (Figure 18 & Figure 19), and there were only seven captures (6.0-7.0 in. size classes) in the Mississippi River region (Figure 22). Weight increased with increasing length (regression analysis, F=36,755, DF=1, P<0.01; Figure 23) for spiny softshell turtles, and this relationship was similar across regions (Figure 24).

Northeast Region (2013-2020)



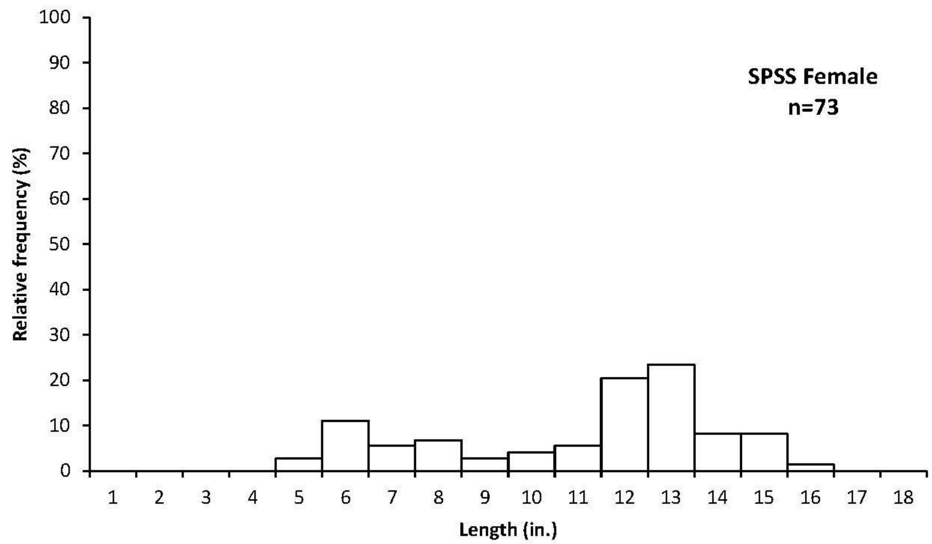
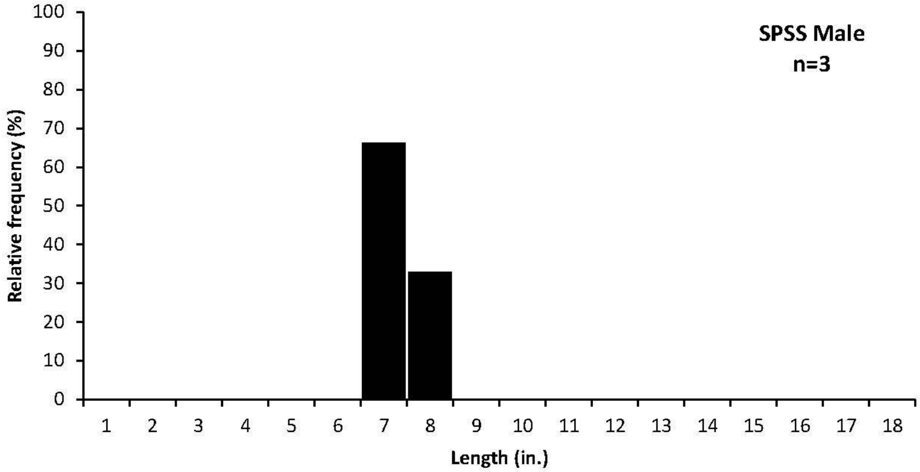


Figure 18. Relative frequency (%) of the spiny softshell (SPSS) in northeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Northwest Region (2013-2020)



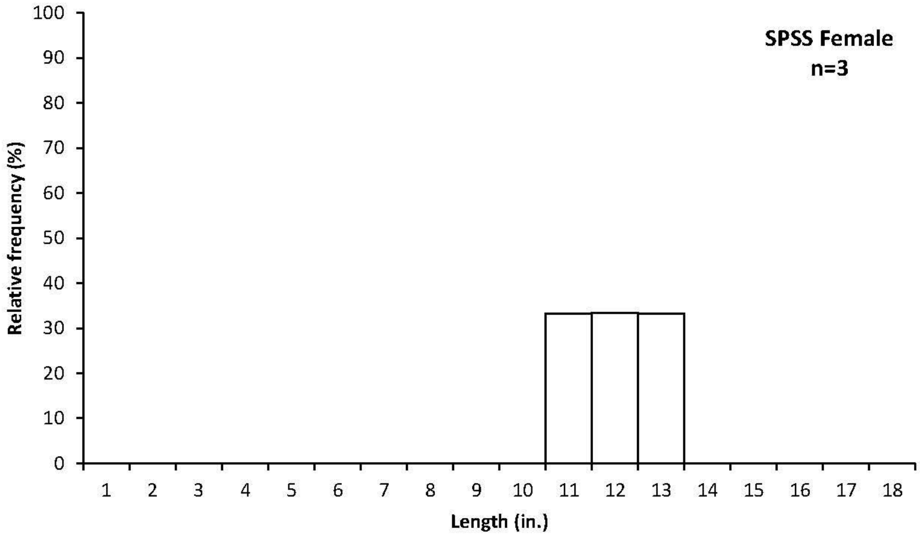


Figure 19. Relative frequency (%) of the spiny softshell (SPSS) in northwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

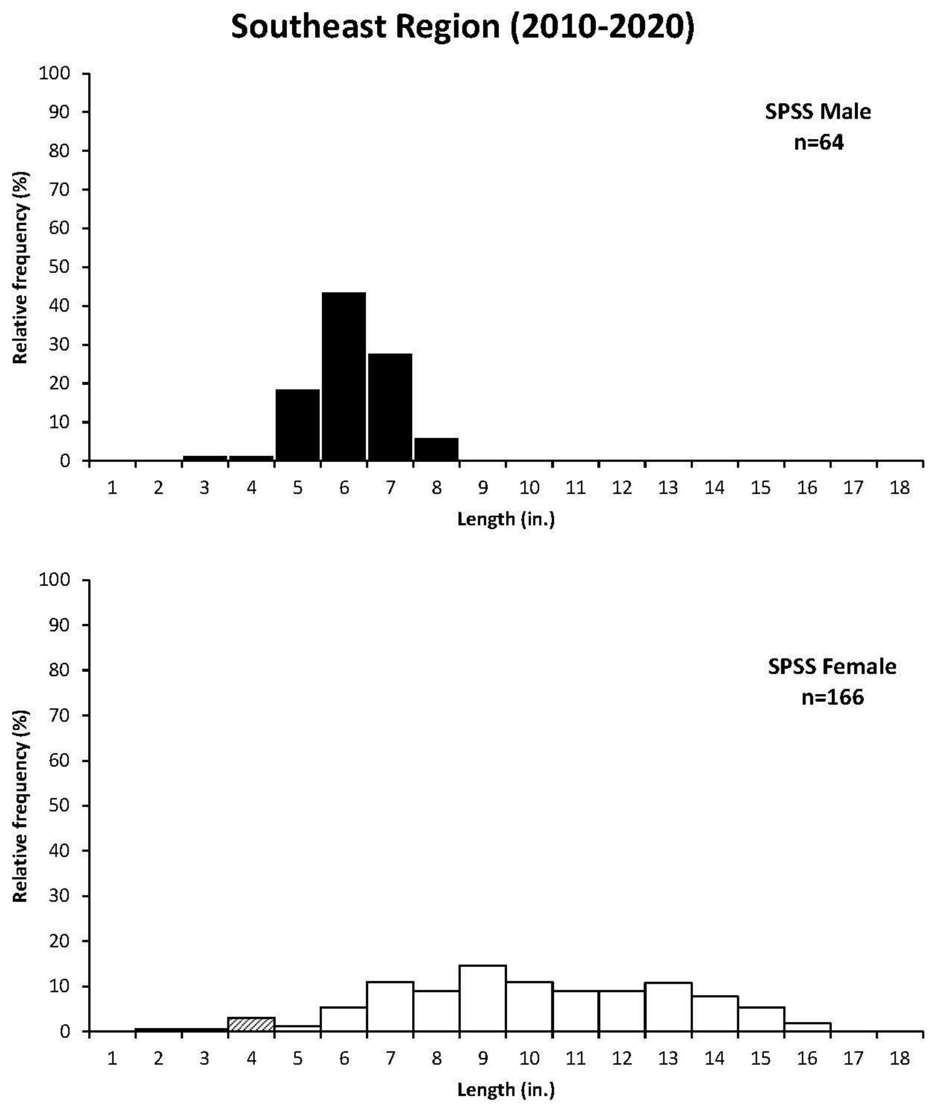
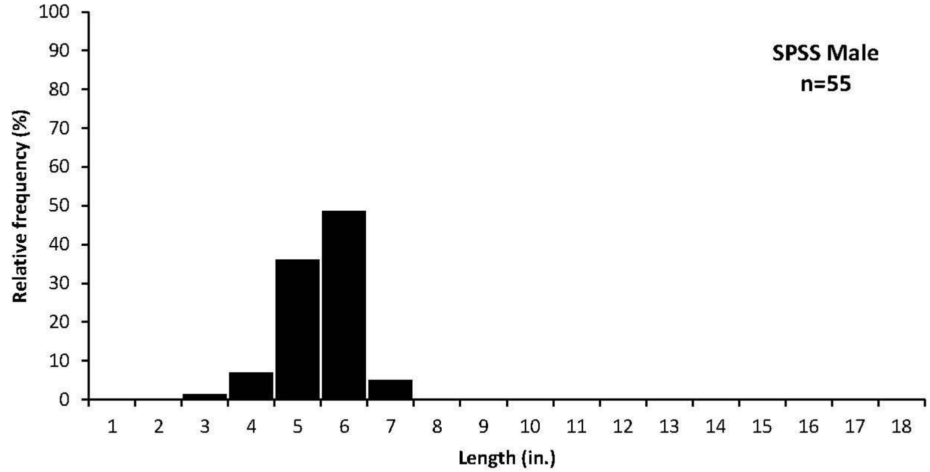


Figure 20. Relative frequency (%) of the spiny softshell (SPSS) in southeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southwest Region (2012-2020)



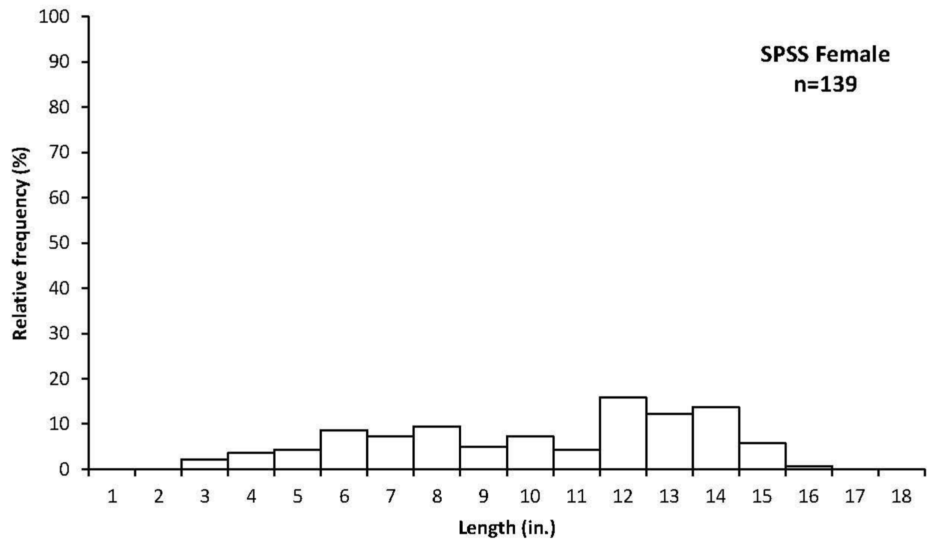


Figure 21. Relative frequency (%) of the spiny softshell (SPSS) in southwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

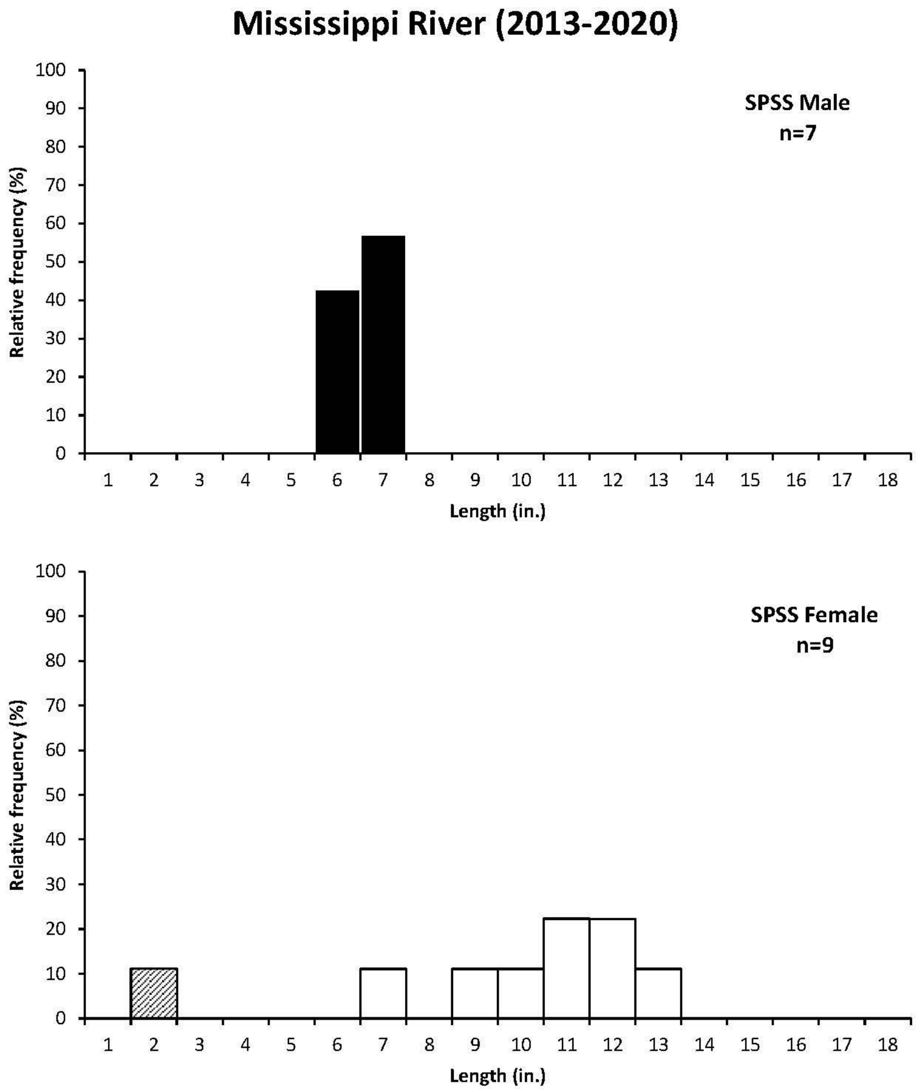


Figure 22. Relative frequency (%) of the spiny softshell (SPSS) in the Mississippi River region according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

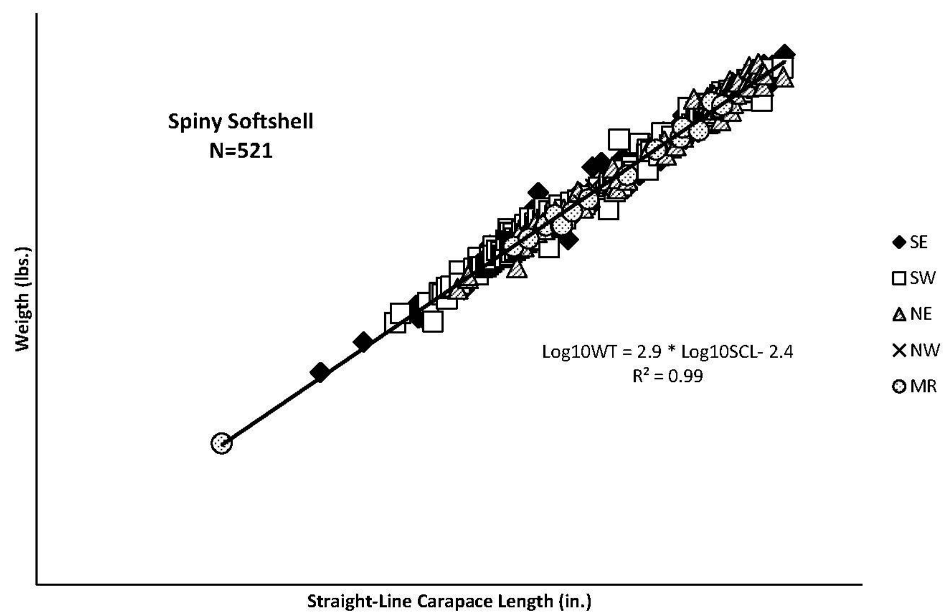


Figure 23. Length-weight relationship for spiny softshell across five statewide regions (SE=southeast, SW=southwest, NE=northeast, NW=northwest, MR=Mississippi River); both sexes combined.

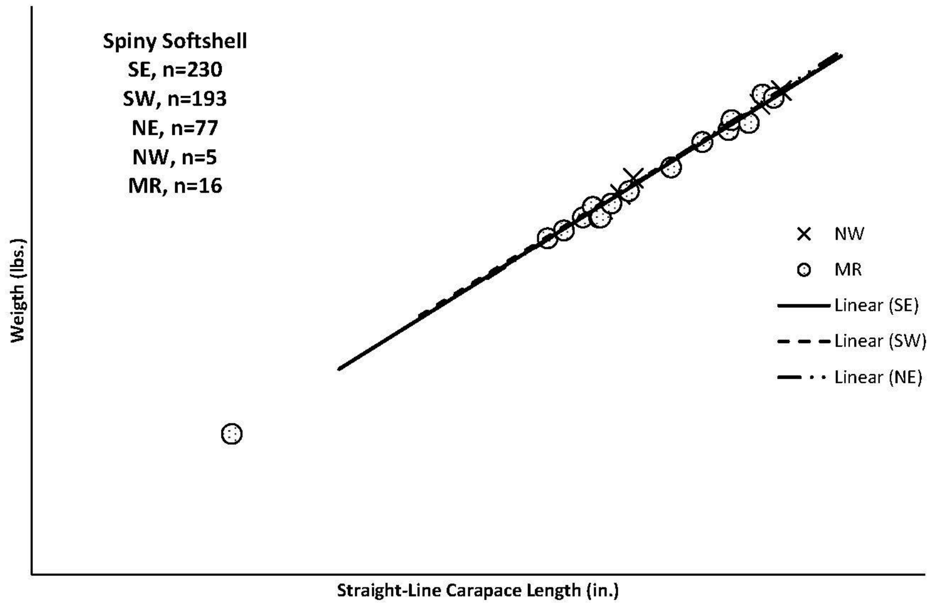


Figure 24. Length-weight relationships for spiny softshell turtle by region. Sample sizes (n) for respective regions are listed.

Smooth softshells were the harvestable turtle species that was observed the least in statewide collections. In fact, this species was primarily caught in the southeast and southwest regions of the state (only four observations across the northeast and Mississippi River regions). Smooth softshell average lengths (SCL, in.) and weights (lbs.) ranged from 6.0-8.3 in. and 0.61-1.6 lbs. (Table 3 & Table 4) across regions from 2010-2020. Females were 1.3 times larger (SCL) on average than males. Uneven sexes were detected across all harvestable turtle species statewide (chi-square analysis, χ^2=252.0, DF=3, P<0.01). Such differences were also detected for the smooth softshell across regions (Fisher's exact test, χ^2=26.2, DF=3, P<0.01). M:F was heavily skewed female (1.0:2.8). This trend was significant (multiple linear contrast, χ^2=22.2, DF=1, P=<0.01), but not consistent across the southeast and southwest regions (Table 5). Catch-per-unit-effort (CPUE ± SE) across years ranged from zero per net night for the northwest and Mississippi River regions (2013-2020) to 0.13 (0.03) per net night for the southwest region (2012-2020; Table 6). Annual CPUEs ± SE ranged from zero per net night for all regions (across multiple years) to 0.29 (0.13) per net night for the southwest region (2017; Table 7). About 71% of female smooth softshells were 9.0 in. or greater in the southeast region while over 92% were represented by the 7.0-9.0 in. size classes in southwest Iowa. Only two female smooth softshells were collected in the northeast region, one in the Mississippi River region, and none in the northwest region (Figure 25-Figure 29). Weight increased with increasing length (regression analysis, F=1,918, DF=1, P<0.01; Figure 30) for smooth softshell turtles, and this relationship was similar across regions (Figure 31).

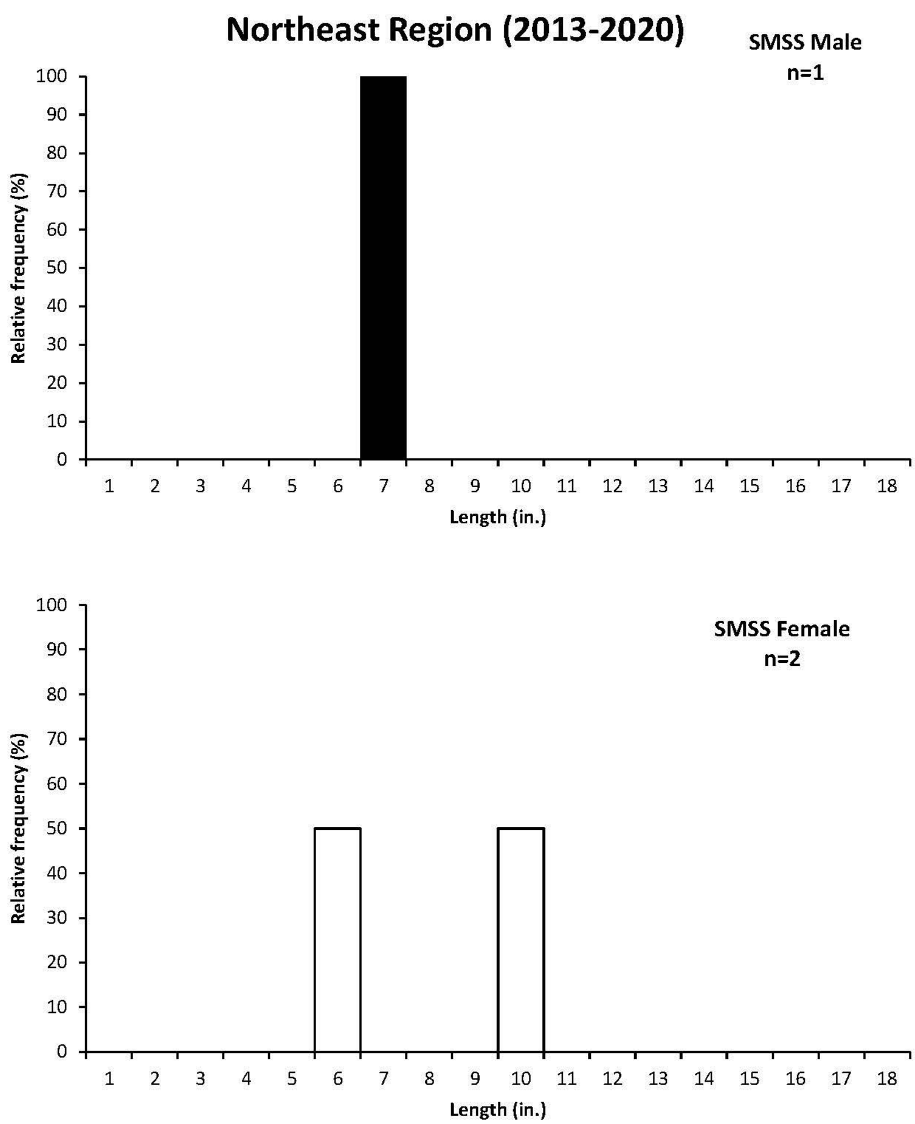
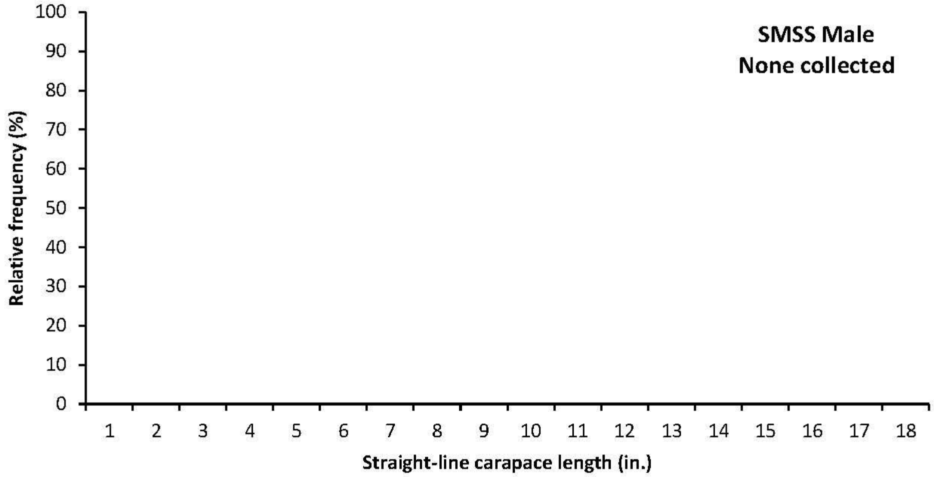


Figure 25. Relative frequency (%) of the smooth softshell (SMSS) in northeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Northwest Region (2013-2020)



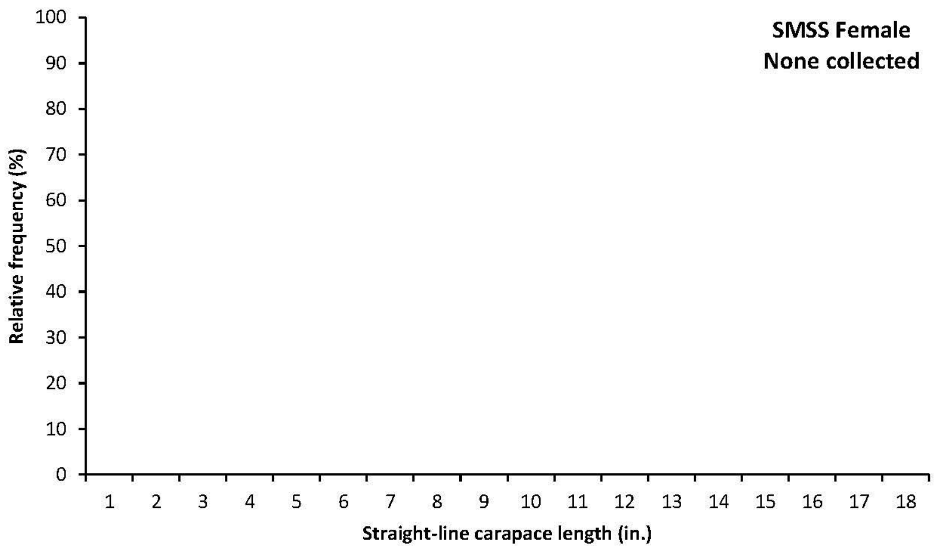
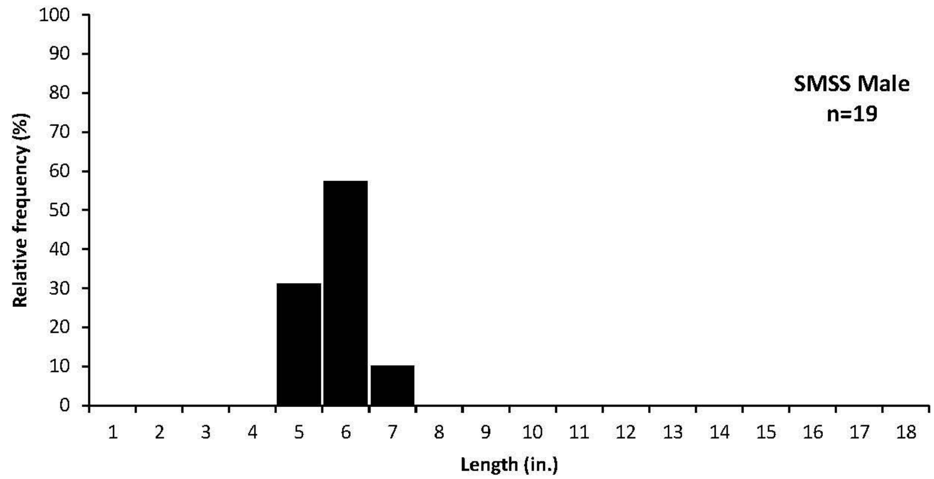


Figure 26. Relative frequency (%) of the smooth softshell (SMSS) in northwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southeast Region (2010-2020)



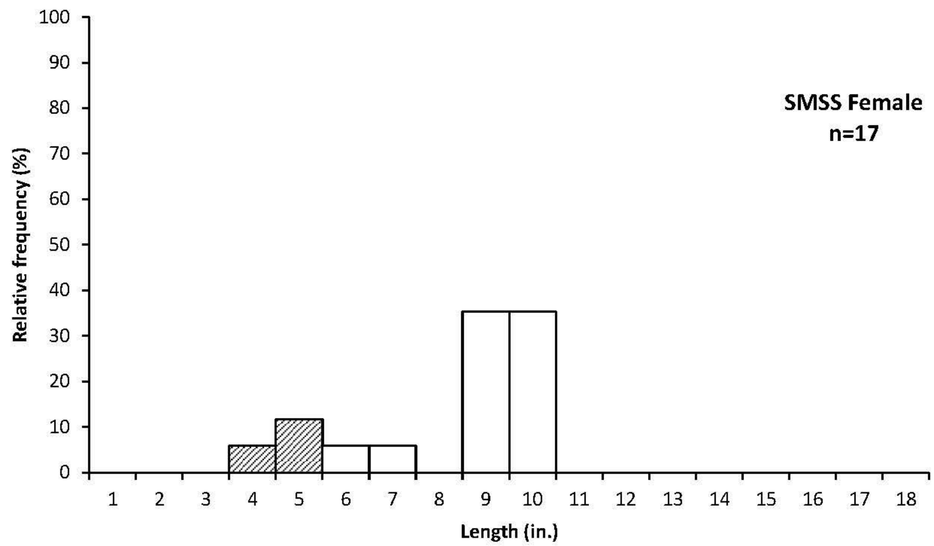
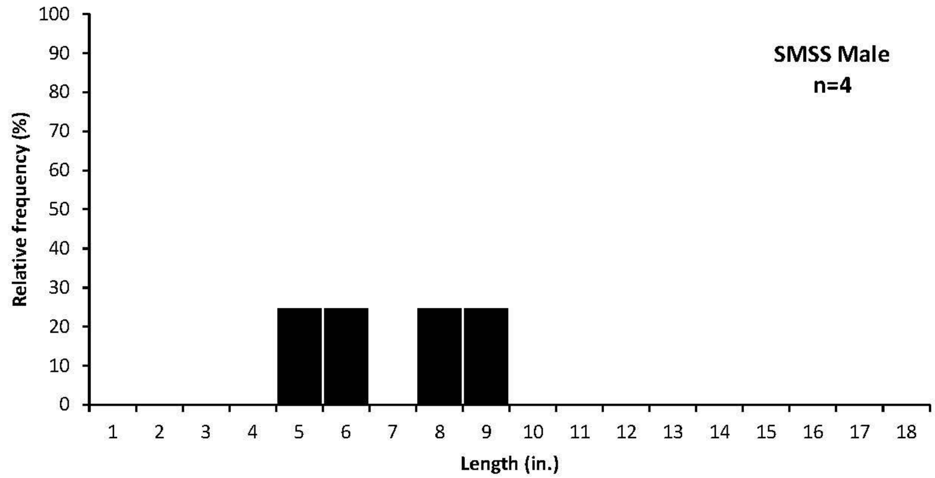


Figure 27. Relative frequency (%) of the smooth softshell (SMSS) in southeast Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

Southwest Region (2012-2020)



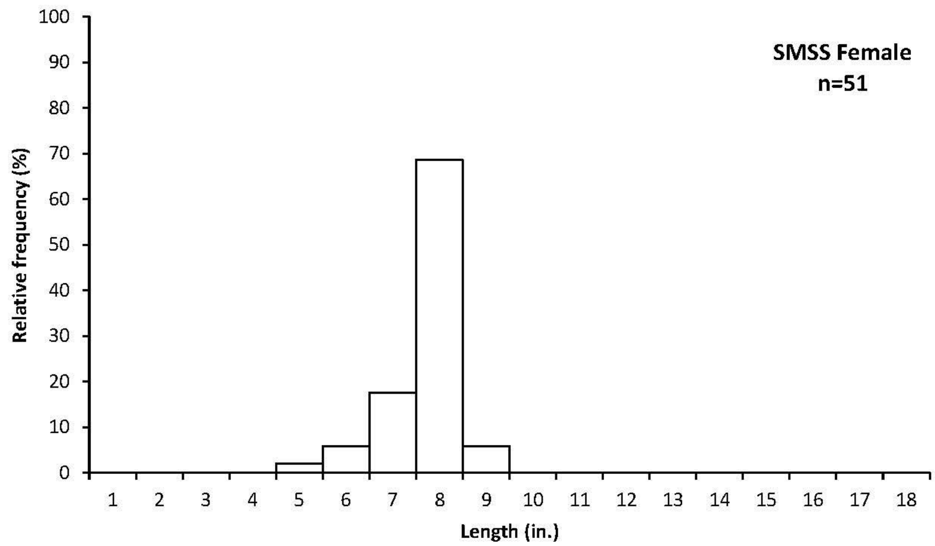


Figure 28. Relative frequency (%) of the smooth softshell (SMSS) in southwest Iowa according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

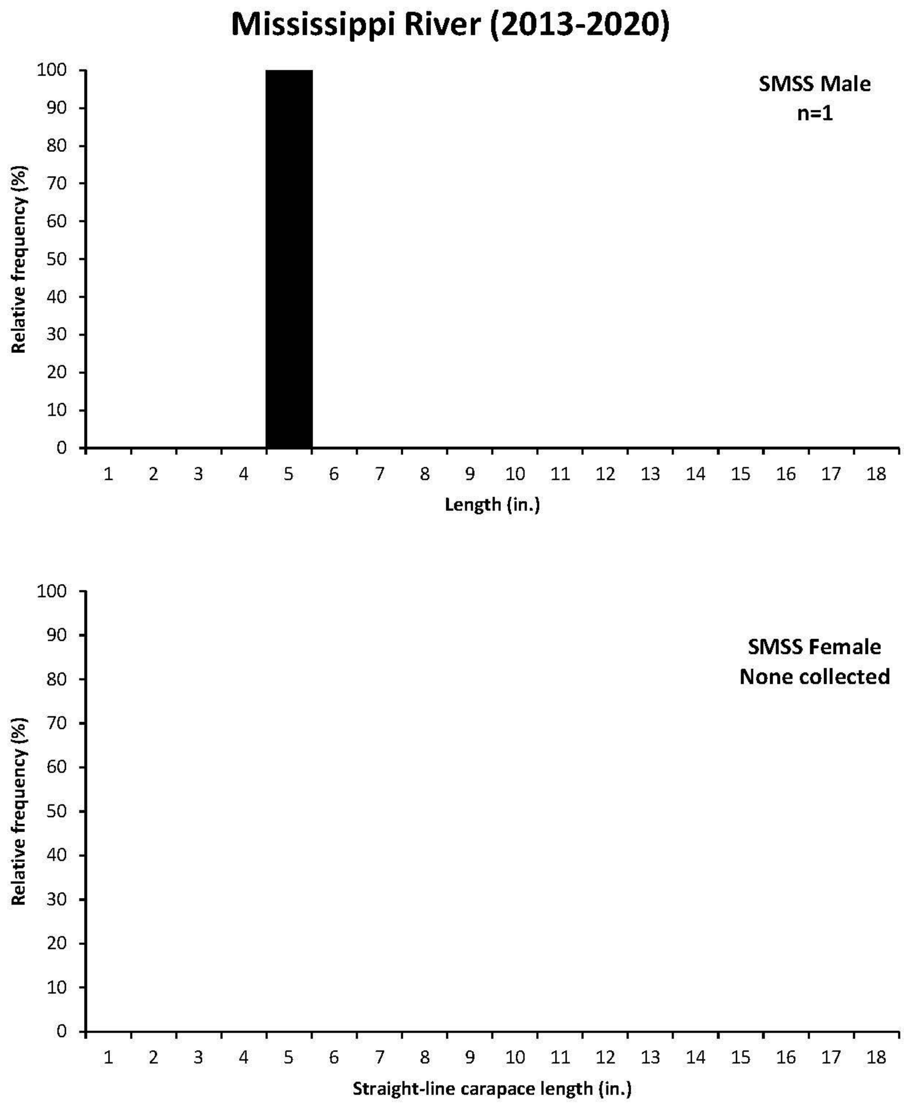


Figure 29. Relative frequency (%) of the smooth softshell (SMSS) in the Mississippi River region according to length group (in.). Immatures designated female; cross-hatched bars represent length categories containing immature turtles. Recaptures excluded.

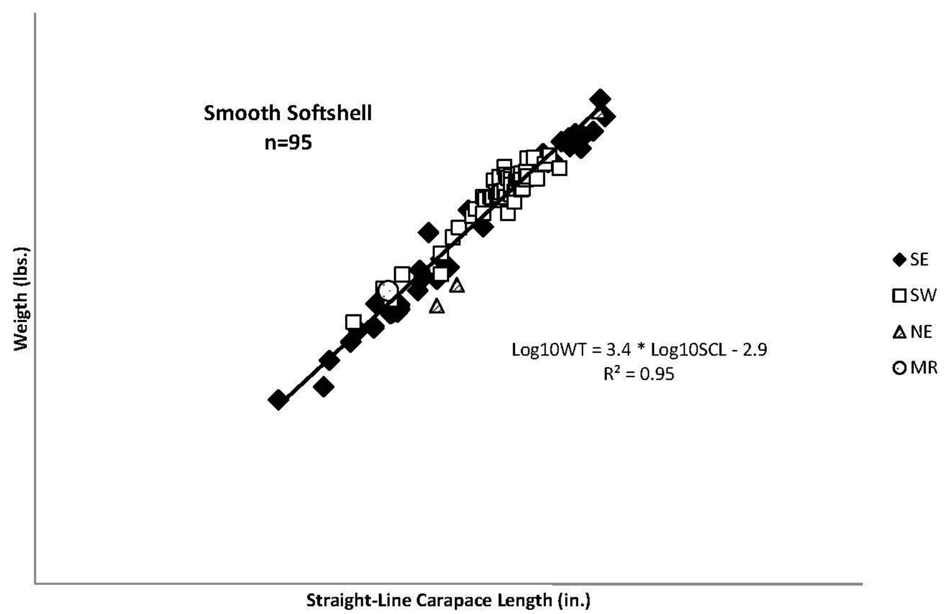


Figure 30. Length-weight relationship for smooth softshell across four statewide regions (SE=southeast, SW=southwest, NE=northeast, MR=Mississippi River); both sexes combined.

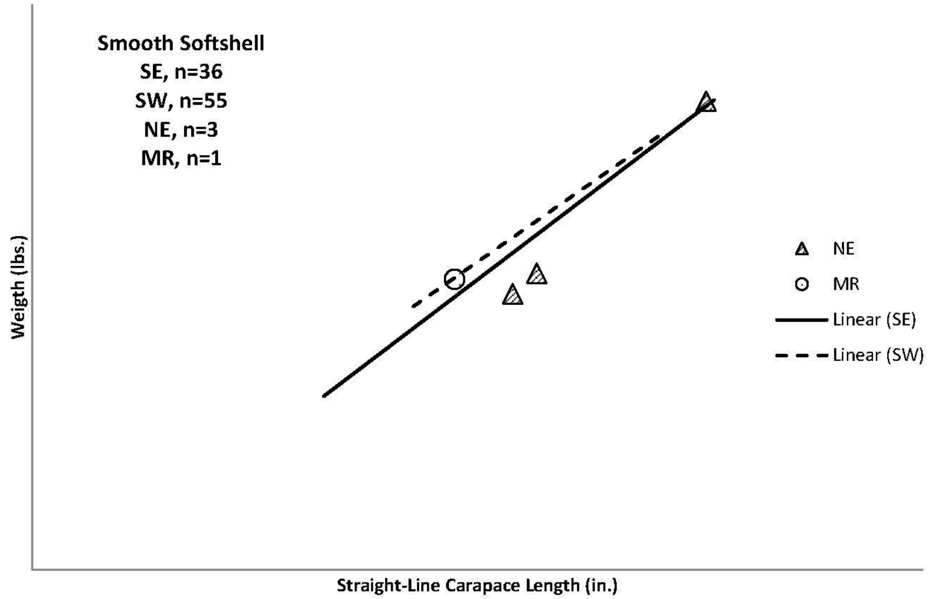


Figure 31. Length-weight relationships for smooth softshell turtle by region. Sample sizes (n) for respective regions are listed.

Smooth softshell turtles were less abundant than spiny softshells in the southeast region across years (2010-2020). Catch increased slightly for spiny softshells, but decreased slightly for smooth softshells over the same time period (Figure 32). Catch was generally less variable for spiny softshells in the southeast region from 2017-2020, with 2020 an exception as the catch reached its highest level in a decade. Catch was often zero or nearly zero for smooth softshells prior to 2017, but increased slightly thereafter and remained fairly consistent.

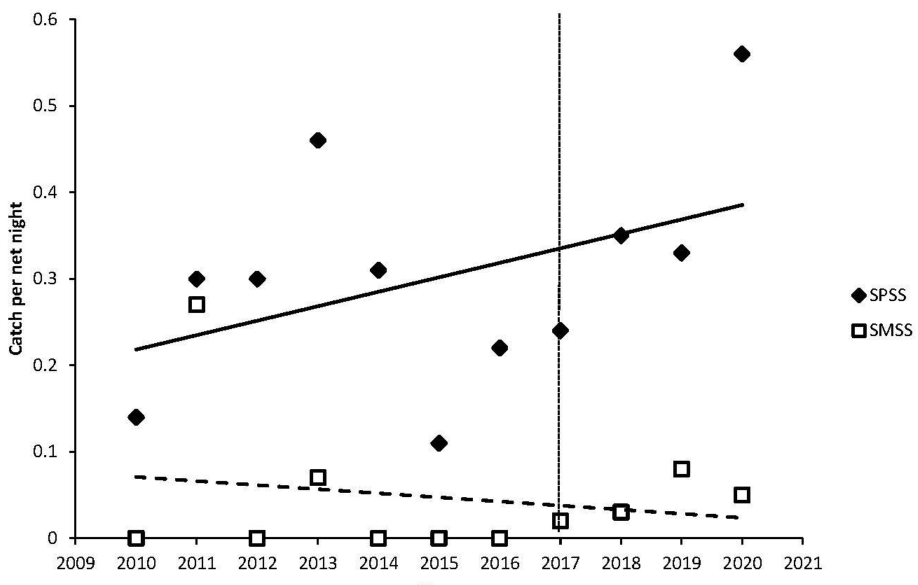


Figure 32. Catch per net night for spiny (SPSS) and smooth softshells (SMSS) in the southeast region from 2010-2020. The vertical dashed line indicates the year (2017) in which harvest regulations were enacted.

Red-eared sliders are not a harvestable species in Iowa. Nevertheless, they were common in collections with the majority sampled in the southeast region. Weight increased with increasing length (regression analysis, F=67,345, DF=1, P<0.01; Figure 33) for sliders, and this relationship was similar across regions (Figure 34).

None of the map turtle species are harvestable species in the state. However, maps are relatively common in rivers and streams across Iowa. Weight increased with increasing length (regression analysis, F=16,623, DF=1, P<0.01; Figure 35) for map turtles (all species combined), and this relationship was similar across regions (Figure 36).

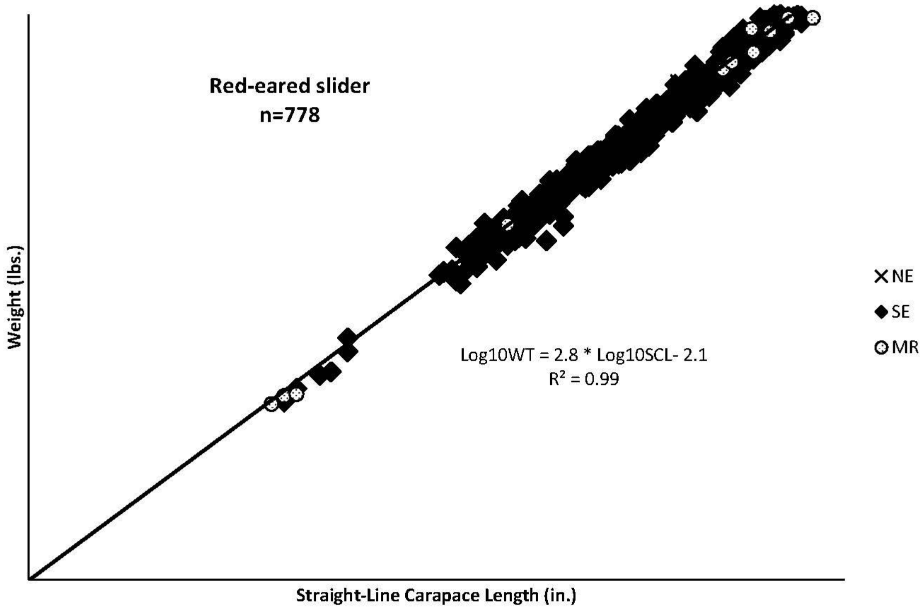


Figure 33. Length-weight relationship for red-eared slider across three statewide regions (SE=southeast, NE=northeast, MR=Mississippi River); both sexes combined.

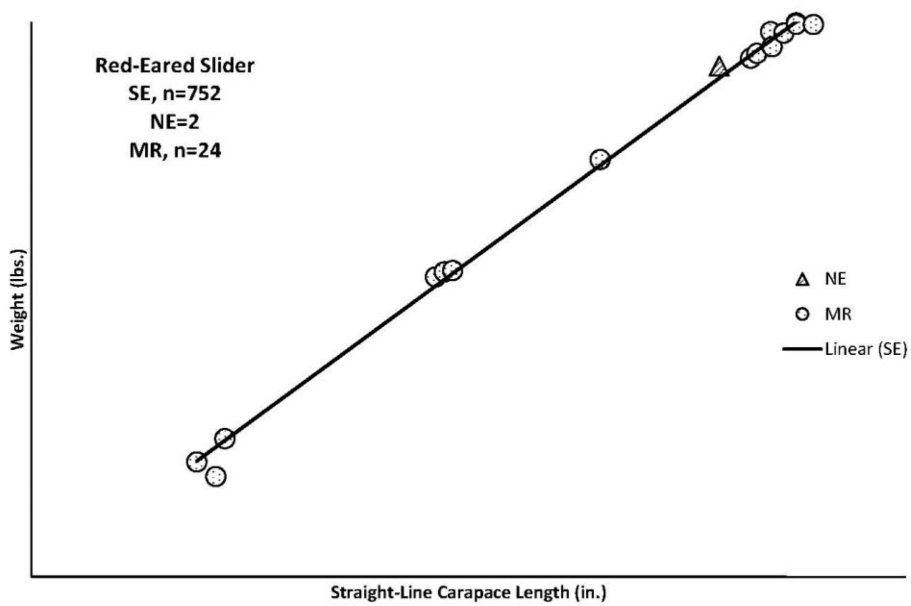


Figure 34. Length-weight relationships for the red-eared slider by region. Sample sizes (n) for respective regions are listed.

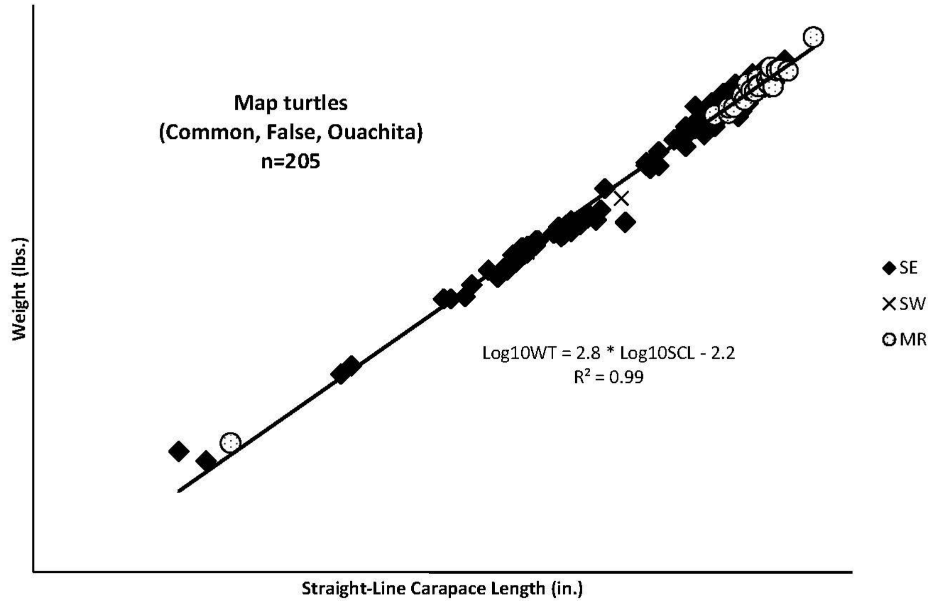


Figure 35. Length-weight relationship for map turtles (common, false, and Ouachita) across three statewide regions (SE=southeast, SW=southwest, MR=Mississippi River); both sexes combined.

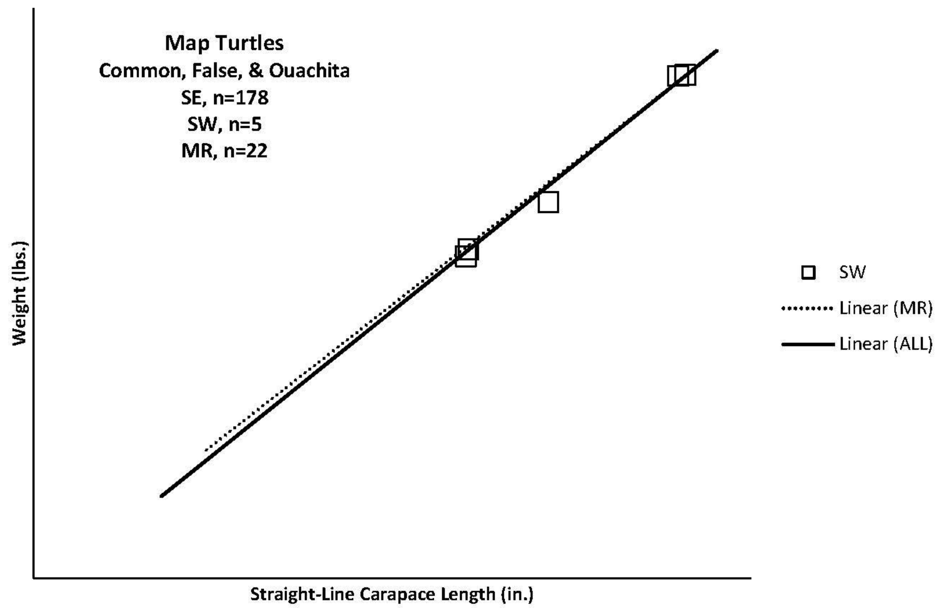


Figure 36. Length-weight relationships for map turtles (common, false, Ouachita) by region. Sample sizes (n) for respective regions are listed.

Length-weight relationships were very similar for all turtle species collected throughout this study (Figure 37). Turtles within the same family tended to have the most homogeneous length-weight relationships. Emydids (paints, sliders, maps) grouped closely together as did the trionychids (spiny and smooth softshells). The single chelydrid (common snapper) was the pinnacle and was distinctly separate from the aforementioned species. This being said, none of the length-weight relationships were vastly different. Weight increased with increasing length for all species combined (F=107,663, DF=1, P<0.01). The coefficient of determination was very high (R^2=0.94), and when softshells were excluded from the analysis this value increased (R^2=0.96).

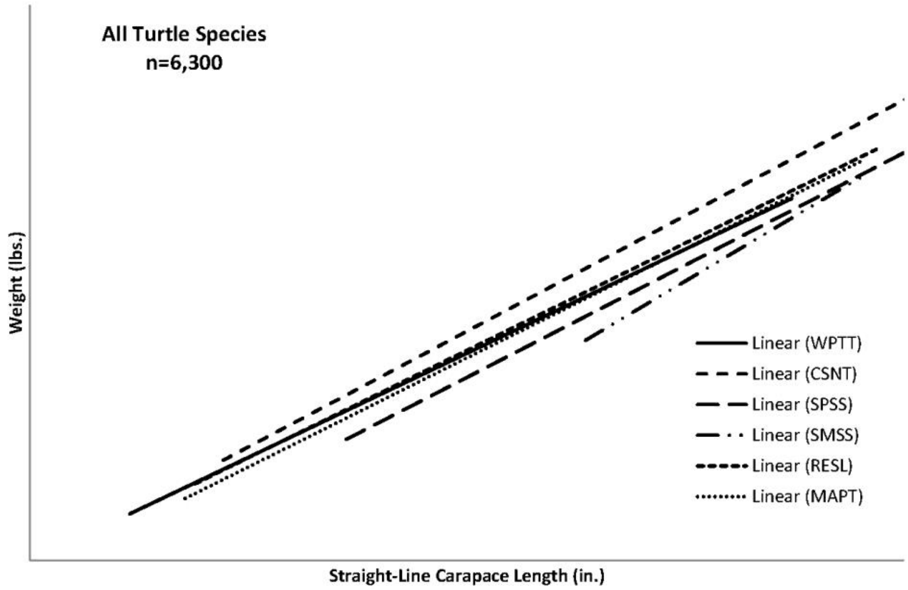


Figure 37. Length-weight relationship for Iowa's turtle species across all statewide regions (northeast, northwest, southeast, southwest, Mississippi River); both sexes combined.

DISCUSSION

Turtles face many challenges in today's society and, unfortunately, such hurdles can be a detriment to their continued existence. Gibbons et. al (2000) stated that habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use, and global climate change (https://climate.fisheries.org/world-climate-statement) are six major reasons scientists believe that turtles are in decline. Although Iowa fisheries biologists believe many of these reasons may be working in concert within the state, it is unsustainable use that is the cause for most concern. Iowa has historically had liberal laws governing the sport and commercial harvest of turtles. Harvest continued unabated since 1987 despite limited knowledge of the status of Iowa's turtle populations. Natural resources staff primarily relied on commercial harvest reporting to make inferences regarding Iowa's harvestable turtle species. Map turtles were removed from the list of commercially harvestable species in 2006 due to concerns regarding morphological similarities among the three Iowa map turtle species, all of which were included in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix III (USFWS 2005).

Recognizing the need for biological data to corroborate commercial harvest trends, crews used a variety of gears to survey turtle populations from 2010-2020. Of these gears, baited turtle traps were the primary gear used to survey Iowa turtles. Baited turtle traps are a commonly used method for the study of semi-aquatic and aquatic turtles (Lagler 1943, Reehl, et al. 2006, Bluett et al. 2011). Most North American turtles are omnivorous opportunists who have very wide-ranging diets (Ernst and Lovich 2009). The opportunity presented by fresh bait leads turtles to readily enter traps.

It is unsurprising that the western painted turtle represented over half of all individuals collected during the study. Painted turtles are commonly the most abundant turtle in suitable shallow water habitats across its range (Ernst and Lovich 2009). The common snapping turtle typically occurs in lesser numbers across habitats it shares with emydids such as the painted turtle (Ernst and Lovich 2009), but even so it was observed frequently in this study. Red-eared sliders were quite common in collections, but this percentage was driven mainly by their high abundance in the far southeast corner of Iowa. Sliders were rarely collected or absent from collections elsewhere in the state. This species is known to occur in some abundance in southwest Iowa (B. Hayes, personal communication), but it was not represented in collections from the current suite of study sites within that region. Softshells accounted for only 9% of the total catch. Populations of both smooth and spiny softshells are highly variable (Ernst and Lovich 2009), with both species numbers subject to decline due to poor water quality or habitat degradation (Vandewalle and Christiansen 1996, Trauth et al. 2004, Ernst and Lovich 2009). Common snapping turtle and softshell species are taken for food (Clark and Southall 1920, Moler 2006, Ernst and Lovich 2009), while painted turtles are likely harvested for both the pet and biological trades. Exploitation for human consumption has severely decimated some populations of common snapper (Harding and

Holman 1990; Tucker and Lamer 2004), and similar concerns surround softshells. A Minnesota study of the harvesting effects on painted turtles found that commercial collecting had minimal impact, but the authors were also uncertain about the long-term sustainability of the painted turtle harvest (Gamble and Simmons 2004).

Western Painted Turtle
The range of lengths (SCL) for painted turtles collected in this study were consistent with length ranges documented in the scientific literature (Ernst and Lovich 2009, LeClere 2013). The maximum size painted turtle collected in Iowa (8.7 in.) was slightly smaller than that documented for the U.S. and Canada (approximately 10.0 in.; Conant and Collins 1998, Ernst and Lovich 2009).

A sex ratio skewed towards male painted turtles, like that observed in this study, has been previously documented by other researchers (Ernst and Ernst 1973, Bayless 1975, Gibbons and Lovich 1990, Congdon and Gibbons 1996, DonnerWright et al. 1999). Ream and Ream (1966) cautioned that population studies with a single collection method may favor a particular sex. The Iowa study utilized many methods of capture, although turtle traps were the most deployed gear across regions during the duration of the study.

CPUEs for the painted turtle across years and regions were variable. This is potentially a reflection of weather conditions, habitat preferences, or both. In southwest Iowa, one region where turtle surveys have been conducted the longest, a positive trend in CPUE may suggest a slight increase in western painted turtle numbers. The fact that CPUEs were generally stable across southern regions after 2017 may lend early support to a positive effect of Iowa's turtle harvest regulations, although paints were never harvested in the same capacity as common snappers in the state and even more sparingly after 2016 (Fowler 2016-2020).

It is typical for samples of painted turtles to be well-represented by adults. This was the case for samples collected in conjunction with this study. Small turtles may not be as scarce as some size distributions suggest; instead, they may be difficult to locate and capture (Ernst and Lovich 2009). Ream and Ream (1966) found that different collection methods resulted in different size class distributions. To address this issue, crews in this project used multiple gears in order to increase the chance of collecting smaller size classes. Small turtles were observed in all regions sampled throughout Iowa. The Mississippi River region accounted for a large number of small painted turtles which is likely a result of hand captures from fish hatchery ponds adjacent to the river. Smaller individuals may be utilizing the ponds as nursery areas given many of the challenges the mainstem river poses to hatchlings and juveniles.

An important finding associated with this study is that the length-weight relationship (W_s) for the painted turtle was the same across all regions of the state. However, maximum attained sizes among the regions were not consistent. This species may reach larger sizes in southern regions of the state. This is consistent with comments by Ernst and Lovich (2009), who stated that the growth period of painted turtles is limited by air and water temperature, amount of rainfall, and availability of food. Further investigations of potentially responsible factors may be needed to pinpoint an explanation. However, one might surmise that the growing season in southern Iowa is longer resulting in the availability of abundant food resources for a greater portion of the year.

Common snapping turtle
To date, DNR fisheries crews have not collected a common snapping turtle near the historically documented maximum SCL for the state (SCL_{max}=19.75 in; LeClere 2013). The aforementioned specimen was collected from Emmet County (northwest Iowa) in 2004 (Mark Rouw, Science Center of Iowa, personal communication). The largest specimens collected during this study (16.0-17.0 in. size classes) were in northern regions of the state, nearly three inches shy of LeClere's (2013) record. Carapace growth is strongly influenced by environmental conditions such as food availability, air temperature, and water temperature (Ernst and Lovich 2009). Rhen and Lang (1999) found that common snapper hatchlings grow more slowly in cool environments than warmer ones (> 82º F). Growth rate, however, is negatively correlated with maintenance metabolism adjusted for body mass (Steyermark 2002). This suggests that common snapper growth may actually slow during warm temperature extremes given metabolism is positively correlated with external temperature. It may be pertinent to investigate differences in average temperature among southern versus northern Iowa regions to determine if extended periods of slow growth may partly explain the differences in common snapper maximum SCLs. One might ponder how consequential such an effect is on snapper growth as periods of high

external temperatures are typically short even in southern Iowa. Common snappers prefer shallow water, but are capable of diving to depths of at least 2-3 m where they remain for some time (Ernst, personal observation). This suggests that this species may seek refuge in cooler water. Little is known about feeding behavior following such events; perhaps food intake increases, translating to increased growth. Brown and Brooks (1991) found that Ontario snappers did not try to bask or increase their external temperature after feeding, but instead buried themselves in substrate and became less active. One should also note that commercial harvest was most prominent in southern regions of Iowa (particularly, southeast Iowa) and that large adults are often targeted for their market value (Fowler 2020). The possibility exists that large adults have been removed over time.

Mosimann and Bider (1960) reported that the sex ratio of common snapper hatchlings is about 1:1, and it seems this ratio is maintained into adulthood. Slight male-bias in sex ratio is likely a normal occurrence (Ernst and Lovich 2009). Gibbons and Lovich (1990) reported male bias in all populations they studied. Geographic variation can explain some of the deviations in sex ratios as populations in northern latitudes are typically more male-biased while populations in southern latitudes are more female-biased (Ernst and Lovich 2009). Female snappers are especially susceptible to road mortality and harvest by humans during the nesting season (Haxton 2000, Gibbs and Steen 2005, Ernst and Lovich 2009, LeClere 2013). Recent studies suggest that sex ratios of populations near roads are heavily male-biased (Tucker and Lamer 2004, Steen and Gibbs 2004, Aresco 2005, Ernst and Lovich 2009, Beaudry et al. 2010). In Iowa, common snapper populations were balanced or only slightly male-biased which was consistent with aforementioned trends. Samples collected in northeast Iowa in 2016 suggested that the population was composed of nearly twice as many males (1.7:1) (Dolan 2016). Male-bias was still evident by 2017 (1.4:1), 2018 (1.3:1), 2019 (1.2:1), and 2020 (1.2:1), but the differential between males and females seems to have decreased and stabilized. This may simply indicate an effect of increased sample size as additional specimens were incorporated into the dataset. The female bias observed in the Mississippi River region is likely a result of the immature turtles collected from hatchery ponds. Immatures in this study were designated female for mark-recapture purposes. Many immature males, despite their small size, display physical characteristics that allow them to be categorized accurately. Conversely, designating small specimens as female is risky given they may be males that have yet to outwardly express gender-specific sex characteristics. Excluding immatures from the analyses for the Mississippi River region changes the male:female ratio to 1.2:1, which is similar to observations from other regions albeit slightly skewed male.

CPUE information has been collected since early in this decade in Iowa's southern regions. A slight decreasing trend in CPUE in southeast Iowa (2010-2020) for the common snapping turtle is cause for some concern. Southeast Iowa has long been the epicenter for commercial harvest in the state. Harvest efforts had expanded statewide by 2015 (Osterkamp and Hanson 2015), but many southeast Iowa counties were targeted again thereafter even as harvest distribution became more concentrated and reflected limited travel by active turtle harvesters (Fowler 2016-2020). The southeast Iowa catch trend differs from that in southwest Iowa (2012-2020) in that the latter appears to have remained stable; however, one should note that the overall magnitude of CPUE is reduced (2.5 times lesser) from that in the southeast. There also appears to be less variability in CPUE for the southern regions from 2017-2020. This may have resulted from the implementation of more stringent harvest regulations during this time interval, and may be an early sign that regulations are having a positive effect on common snapper populations. Consider also that there was less commercial harvest after 2017 than in prior years (Fowler 2020). Catch trends were not apparent for the other regions given shorter time periods of collection, and because CPUE data was lacking for these areas prior to 2016.

Size distributions for common snapping turtles demonstrate that males are reaching larger sizes in northern Iowa. The absence of these larger male specimens from southern Iowa may suggest an effect of harvest. According to commercial harvest reports (Fowler 2016-2020), large snappers (which would be primarily male) have the highest market value. Large snappers are likely rare, old, and have been vulnerable to harvest for many years. Once such individuals are removed from populations, it is difficult for smaller specimens to achieve larger sizes given the extended time period required to reach maximum growth potential. Hammer (1969) found that growth may be rapid in small snappers, but slows significantly in larger turtles. Slow growth in larger snappers is especially concerning given this mechanism has been operating in conjunction with unregulated harvest over much of Iowa's history. It is possible that such a scenario has led to large snappers becoming rarer or absent from current populations. One must be cognizant that commercial harvest has been centered in southeast Iowa since 1987 and snappers have been the most harvested species over that time period (Fowler 2020). It is also noteworthy to mention that female common snappers, across all Iowa regions, generally peak at SCLs in the 10.0-11.0 in. size classes. Larger females typically lay the most eggs with the greatest clutch mass (Ernst and Lovich 2009). It follows that the presence of larger females would be beneficial to the long-term viability of the species. Females greater than the 11.0 in. size class are present, but rare as these larger size classes are not well-represented across regions. Such an observation may have real impacts on the ability of Iowa common snapping turtles to replace themselves. Brooks et al. (1991) found that neither egg nor hatchling mass is related to survival or rate of growth; however, logic indicates that the deposition of more eggs leads to more chances of replacing oneself.

As with painted turtles, common snapping turtles were found to have similar W_s across all regions of the state. This finding was not necessarily indicative of maximum size, as this differed across regions. Specifically, the largest common snapping turtles were found in northern Iowa, while the largest painted turtles were located in southern Iowa. Mechanisms that contribute to this finding could be extreme temperatures that potentially slow growth in common snappers in southern regions, but one might assume that this environmental mechanism should similarly affect both turtle species. One must also consider that harvest may restructure size distributions in individual regions throughout the state. Harvest pressure has not been consistent across all regions of the state since commercial harvest reporting was required in 1987, and harvest of common snapping turtles has been much greater in southern Iowa than in northern Iowa (Osterkamp and Hanson 2015, Fowler 2020). Since W_s are the same across regions, but maximum size differs, it seems that environmental factors may have greater influence than harvest pressure for painted turtles achieving maximum size in southern Iowa. Conversely, if environmental factors were the greatest influence on common snapping turtles, they would also be largest in southern Iowa. They are, however, larger in northern Iowa where there has been less harvest pressure. It follows that unregulated harvest is a potential cause for depressed maximum size of southern Iowa snappers as well as the opposite maximum size results between painted and common snapping turtles.

Spiny Softshell Turtle

The spiny softshell was much rarer in statewide collections than the other harvestable species. This was partially because it is primarily a riverine species (Vandewalle and Christiansen 1996, Bodie et al. 2000; Jackson 2005), and that the flashiness of river levels often dictated the frequency at which crews could sample these environments. Many spiny softshells were captured in lakes, ponds, and backwaters located adjacent to rivers throughout the study. This is consistent with the findings of Williams and Christiansen (1981) who also studied Iowa populations.

The largest spiny softshells (SCL, 16.0-17.0 in.) were collected in southern regions of the state and were female. Females were significantly larger than males statewide. Ernst and Lovich (2009) noted that strong sexual dimorphism is typical of the species as adult females are more than 1.6 times larger than adult males. This published ratio was consistent with the ratio (1.7) determined for this study.

Spiny softshell sex ratio was heavily skewed female statewide. It is likely this magnitude of difference is heavily influenced by regions where only a few spiny softshells were caught. This being said, populations in regions where the catch was higher (southeast and southwest regions) were heavily female-biased. Statistically unbiased sex ratios of spiny softshells have been recorded in Alabama, Illinois, Minnesota, Mississippi, and Vermont (Cagle 1942, Breckenridge 1955, Grahm and Grahm 1997, Vogt and Bull 1982), so a 1:1 ratio may be normal. However, a St. Croix River study observed populations skewed towards males (4:1) with the exception of one site where more females were represented (DonnerWright et al. 1999). Barko and Briggler (2006) reported a female skewed sex ratio (0.5:1.0) in their southern Illinois-Missouri study. It will be of interest to determine if the sex ratio observed in this study remains female-biased or approaches evenness as more samples are collected. This species can be difficult to collect unless conditions are ideal (warm, sunny, moderate to low flows; Denny Weiss, Iowa DNR, personal communication). Sexual trap bias is also worthy of exploration. It is possible that smaller males are escaping the traps once captured. Males seem to spend more time in riffles than females, which prefer open water (William and Christiansen 1981, Plummer et al. 1997). It follows that net location may also explain female-biased sex ratio as most traps in this study were set near sandbars in open water areas as opposed to riffles.

CPUEs across regions were relatively low. The size of spiny softshell populations varies over its natural range, probably due to environmental conditions and the capture methods used (Ernst and Lovich 2009). CPUEs were higher in southern Iowa, and spiny softshells sampled from the Mississippi River region were captured in southern, down-river pools. Spiny softshells become active earlier and remain active longer in more southerly climates versus those in the north (Ernst and

Lovich 2009). This may partially explain why more spiny softshells were caught in southern Iowa. It's likely the interior and mainstem rivers in southern Iowa warm quicker and cool later making these environments more conducive to softshell populations. Stability in CPUE for spiny softshells from 2016-2020 was apparent with the exception of 2020. This relationship was more variable as compared to that observed for paints and snappers, perhaps due in part to smaller sample size. Trends still provide some indication that Iowa's harvest regulations are improving CPUE for this species. Commercial harvest of softshells also decreased greatly during this study (Fowler 2016-2020).

Male spiny softshells occupy a very limited size range. Their length (SCL) distribution begins and ends very abruptly. This may have more to do with the difficulty in catching small specimens via the methods of capture used in this study. Furthermore, the few small specimens that were caught were immature and could not be sexed accurately; thus, they were designated "immature". Females had a much extended length (SCL) distribution in regions where adequate samples have been collected including northeast, southeast, and southwest Iowa. The magnitude across size classes was low and relatively uniform. This is concerning if the assumption is that most females caught in turtle traps were retained. Such size distributions may be the effect of harvest in that larger female spiny softshell turtles are removed from populations due to their market value given this species is utilized as a food source (Reese 1917, Klemens and Thorbjarnarson 1995, Ernst and Lovich 2009; Fowler 2020).

W_s for the spiny softshell turtle was the same across regions. Maximum sizes attained within each region were more consistent than with painted and common snapping turtles, with the exceptions of the northwest and Mississippi River regions where only a few specimens were collected.

Smooth Softshell Turtle

Smooth softshells were the harvestable species that was observed the least in statewide collections. All were captured in southern regions of the state (including Mississippi River specimen) except three individuals, whereas spiny softshells were observed statewide. These observations are consistent with the comments of Williams and Christiansen (1981) and LeClere (2013) who stated that of the two softshell species, the smooth softshell is clearly less abundant and utilizes fewer habitats than the spiny softshell. This species is observed most often in open waters of medium-sized to large rivers and streams (Vandewalle and Christiansen 1996, Bodie et al. 2000, Dreslik and Phillips 2005, Jackson 2005) with moderate to fast currents and visibility varying from clear to cloudy (Ernst and Lovich 2009). It occurs in other habitats, but usually in low densities (Dreslik et al. 2005). Smooth softshells are the most aquatic North American softshell, seldom leaving the water to bask or nest (Ernst and Lovich 2009). Smooth softshells are intolerant of poor water quality, and water pollution has reduced populations in some rivers (Trauth et al. 2004). Smooth softshells are unlikely to be observed in sections of river or stream lacking flat, broad sandbars or mudflats (Williams and Christiansen 1981, LeClere 2013).

Sexual dimorphism in terms of SCL was almost as strong in smooth softshells versus spiny softshells as adult females were found to be 1.3 times larger than adult males. The largest female smooth softshell captured during the study (10.9 in.) was nearly 6.0 in. smaller than the largest spiny softshell (16.7 in.). The largest male smooth softshell caught during the study was 7.4 in. Although adult male smooth softshells reach lengths comparable to adult male spinys, adult female smooths are generally smaller than adult female spinys (Ernst and Lovich 2009).

CPUEs for smooth softshells were quite low across Iowa's southern regions (only four individuals were caught in the northeast and Mississippi River regions) during the study. Comparison of trends in CPUE (2010-2020) for smooth and spiny softshells in the southeast region revealed opposite relationships, and smooth softshells were much less abundant than their counterpart. In most years, smooth softshells were not even collected in southeast Iowa despite a concerted effort to sample them. This is likely related to the type of habitat in which traps were set. Catch of both softshell species may have been higher if a greater proportion of traps were set in interior and large river habitats. Regardless such relationships are worthy of further scrutiny as more data is collected. Iowa's turtle harvest regulations may be helping smooth softshells as catches were consistently higher from 2017-2020, whereas very few were even caught in most years pre-regulation. A decline in commercial harvest of softshells during this study (Fowler 2016-2020) may have also contributed to this finding.

W_s for the smooth softshell was, generally, the same across regions. Small individuals were not well-represented in the standard weight equation; thus, its predictive capability is limited to turtles in the 4.0 to 11.0 in. size classes. Efforts at capturing smaller individuals will help strengthen the equation; however, doing so may prove challenging as small individuals may be difficult to capture in turtle traps. Efforts at capturing hatchlings and juveniles on sandbars may need to be investigated.

Red-eared sliders and map turtles (non-harvestable) had length-weight relationships with similar slopes to Iowa's harvestable turtle species (western painted turtle, common snapping turtle, spiny softshell, and smooth softshell). Sliders and maps were not collected in adequate numbers across regions to allow evaluation of whether the standard weight equation was similar throughout the state; however, the limited data available suggest that the equations may be consistent. Further data collections will allow more definitive comparisons.

Similarity in length-weight relationships for turtle species collected in this study is noteworthy. The morphological differences among species can be great, like those between common snappers and softshells, yet length-weight relationships are analogous. It is somewhat predictable that turtle species with like physical characteristics had the most homogeneous length-weight relationships. Although regression analysis suggested a single model is valid for describing the length-weight relation across numerous species, one must use caution as such a model would likely underestimate values for common snapper and overestimate values for softshells. To this end, models for families or single species may be most pertinent, depending upon the situation.

In summary, many of Iowa's harvestable turtles (common snapping turtle, spiny softshell, smooth softshell) may be exhibiting the effects of harvest pressure in combination with a number of other factors, which pose threats to their continued existence. Ernst and Lovich (2009) stated that the worst of these may be loss of habitat; moreover, they commented that an animal simply cannot live if its habitat has been eliminated. Buhlman and Gibbons (1997) found that 35.5% of turtle populations in the southeast U.S. are facing serious threats dues to environmental damage to river systems. Vandewalle and Christiansen (1996) had previously noted this phenomenon in regards to Iowa turtle populations.

The western painted turtle may be Iowa's single harvestable species that is exhibiting little impact due to harvest. Commercial harvest of this species has historically been much less than that of the common snapper and softshells (Fowler 2020), although the level of recreational harvest of this species is uncertain. Despite this uncertainty, some authors have questioned how painted turtle populations will respond to harvest over time (Gamble and Simmons 2004). Increasing harvest of paints due to changing markets or market value would elevate concerns associated with this species. The protection afforded paints in Iowa by newly implemented bag limits (1 per day) and a closed season (May 15-July 15) will aid in the conservation of this species.

Given smaller overall numbers of common snapping turtles as compared to paints is typical (Ernst and Lovich 2009), concern would seemingly surround the status of snapper populations subject to static or increasing levels of harvest. The common snapping turtle has been the most harvested species in the state of Iowa since 1987 (Fowler 2020). Turtle maximum size in southern Iowa is reduced from that in northern regions which may indicate a harvest effect. One would expect these large size classes to be represented in southern climates given that snappers grow more slowly in the north; however, they are absent. The fact that intermediate to large size classes (even the most well-represented) of snappers do not differ greatly in magnitude may also suggest an effect of harvest. Market value may dictate a male of adequate size is removed from populations. Reduced or missing size classes of large females may have serious consequences in terms of reproduction and recruitment. Considering large females are more fecund and contribute more offspring to turtle populations (Ernst and Lovich 2009), it is legitimate to ponder whether the reproductive capability of smaller female snappers is enough to sustain common snapper populations long-term.

Spiny and smooth softshell populations may be of the most concern. Investigations of escapement of male softshells from turtle traps is worthy of attention. Conversely, if males are not escaping from turtle traps then one must ponder why they are under-represented in samples. Escapement of females is less of a concern, especially for large individuals. Large softshells are, however, no more abundant than their smaller counterparts in samples. Given large softshells (exclusively female) are targeted for harvest due to their market value, one could gather that harvest is negatively affecting softshell populations. Newly enacted regulations regulating softshell harvest should help what appears to be an imperiled genus in Iowa. As smooth softshells are much less abundant than their congener, their status is likely more concerning.

The DNR's recently enacted turtle harvest regulations are aimed at conserving and, hopefully, restoring a portion of Iowa's turtle populations. Assessing the status of Iowa's harvestable turtles over a five-year time period (2016-2020), and for only four years since harvest regulations were implemented in 2017 was challenging. These populations may require many years to show signs of recovery resulting from harvest regulation changes. Note that turtle hatchlings produced in the first year of this study may not have even reached sexual maturity. Turtles exhibit healthy longevity, i.e., high life expectancy. Species such as the common snapping turtle may live 50 years or longer (Ernst and Lovich 2009), and Iowa females may not mature for 6-7 years (Christiansen and Burken 1979). Similar life history traits are observed for Iowa's other harvestable species. These characteristics along with low reproductive output and high nest and hatchling mortality make it doubtful that significant changes in Iowa's turtle population demographics would result solely from recruitment of new offspring into existing populations over the short study duration.

Countless sources of variability affect daily catch rates and, thus, estimates of annual catch. The likelihood of observing stable catch trends post-regulation was unlikely. Consider that a point-of-reference (catch trends spanning a similar time period of liberally-regulated harvest before 2017) was unavailable for most regions. Crews in southeast and southwest Iowa did begin turtle collections prior to 2016 allowing for trend analysis and comparisons over approximately a decade; however, these trends must still be interpreted with caution. The timespan in which catch data was collected in these regions is still low overall; thus, a single datapoint can leverage trends and impact conclusions. Despite aforementioned challenges, stability in catch trends were observed for all harvestable turtles in southern regions from 2017-2020; albeit more clearly for some species versus others. More restrictive regulations and decreased market demand are likely operating simultaneously to benefit turtle populations (Fowler 2016-2020). Maintaining regulations in light of an ever-changing commercial market is critical. During periods of robust market activity, regulations will serve as the primary limiting factor in regards to harvest and sustaining Iowa's turtle populations.

Smooth softshell catch during the study period was consistently low but, even so, one might ascertain that catches have generally been higher and stable since 2017. Paints outnumbered common snappers in collections over twofold during the study period, yet historically the bulk of commercial harvest has consisted of the latter species (Fowler 2020). Regulations can only help to alleviate this discrepancy in harvest apportionment. The fact that female common snapping turtle size distributions were dominated by intermediate-sized turtles is concerning because large females are more fecund and yield greater clutch mass (Ernst and Lovich 2009), and large specimens of either sex are increasingly rare. The predominance of intermediates on the future condition of Iowa snapper populations are unclear, but one might surmise a negative effect on reproductive rates. Softshells have historically been the second-most harvested Iowa species, but only compose a small fraction of sample collections since 2016; moreover, smooths were overwhelmingly the least represented of the two species. Uniform female size distributions are distressing as the absence of a preeminent breeding size class may have impacts on the long-term sustainability of populations. It may be justified to consider whether harvest of softshells, especially smooths, should be permitted.

This five-year study suggests that concerns exist for many of Iowa's harvestable turtles. Despite active monitoring of populations for only a decade in some regions, and just four years after establishing a harvest season and catch limits statewide, early signs of population stability (conceivably resulting from more stringent regulations, declining market trends, and reduced commercial harvest) were observed. It would be beneficial for Iowa's turtles to maintain harvest regulations and monitor any further population changes. Additional data collections will help confirm whether currently observed trends for harvestable species can be sustained or whether population characteristics change over time. Adjustments to turtle harvest regulations should only be considered if scientific data suggest reasons for reevaluation and modification.

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