Emerging Patterns in Population Structure and Trap Efficacy After Three Years of a Survey of Western Painted Turtles (*Chrysemys picta bellii*, Gray, 1830) in Marshall County, South Dakota

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Abstract: Turtles are long-lived and globally declining, but relatively little is known about the natural history of many turtle species. Even amongst relatively well-studied species, there is a paucity of information for some habitats and long-term population trends are lacking. Here we report the results from the first three years of an intended long-term population survey of Western Painted Turtles (*Chrysemys picta bellii*) in the prairie highlands of the Coteau des Prairies, South Dakota. Turtles were sampled using basking traps, hoop traps, and dip nets. Catch per unit effort varied between years, but not significantly so, and hoop traps significantly outperformed basking traps. Population estimates calculated using the Schnabel Index decreased over the three years of the study; although this could accurately represent a decreasing population, it is likely the result of small sample sizes. The adult sex ratio was slightly skewed toward females, but not significantly so. Our results underscore the need to study wide-ranging species, such as the Painted Turtle, in all habitats within their range using multiple sampling techniques.

Introduction

Turtles are perhaps one of the most threatened vertebrate groups (Lovich et al. 2018, Rhodin et al. 2018), and due to their range of ecological roles the reduction or loss of turtle populations are likely to greatly impact many habitats in a variety of ways (Lovich et al. 2018). Their long generation time and low dispersal ability are thought to render turtles particularly sensitive to human disturbance on the individual, population, and community levels (reviewed in Butler 2019). A recent review (Rhodin et al. 2018) concluded that 35% of chelonian species are Critically Endangered or Endangered according to International Union for Conservation of Nature (IUCN) criteria. Of the 57 species of turtles, tortoises, and sea turtles in North America, 14 species are considered Endangered or Critically Endangered, including pond turtles like the *Emydoidea blandingii* Holbrook (Blanding's Turtle) and *Clemmys guttata* Schneider (Spotted Turtle). Others, like *Chrysemys picta* Schneider (Painted Turtle), are considered to be Species of Least Concern (Van Dijk 2011).

Painted Turtles are small, semi-aquatic, omnivorous habitat generalists that are widespread across North America, mostly in habitats with slow-moving water (Ernst and Lovich 2009). They are largely diurnal, basking on any available surface or object to increase body temperature in order to support activity and physiological functions (Schwarzkopf and Brooks 1985). Courtship and mating in northern populations are typically from March to mid-June, with egg-laying in June and July (Ernst and Lovich 2009). Hatchlings hatch in the fall and overwinter in the nest in northern populations, emerging from the nest in the spring (Gibbons and Nelson 1978). The incubation temperature in the nest determines the

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sex of individual hatchlings, with males produced at cooler temperatures (Rhen and Lang 1998). The adult sex ratio in a population can fluctuate widely between years, but long-term studies often report a 1:1 ratio (Zweifel 1989). Some locations are known to have a skewed sex ratio, however (e.g. Koper and Brooks 1998).

Despite being a well-studied species, there is still much to learn about the Painted Turtle (Lovich and Ennen 2013). Current information in the Coteau des Prairie highlands of South Dakota relies on bycatch data (Moos and Blackwell 2016, 2017) and voucher specimens (Davis 2023) rather than dedicated turtle surveys. Given known sex and age-class biases in trapping methods (Gamble 2006, Tesche and Hodges 2015), it is likely that these data do not accurately represent actual population demographics (Koper and Brooks 1998, Tesche and Hodges 2015). Changes in human habitat use are known to affect physiological (Mota et al. 2021) and demographic characteristics in Painted Turtles (Eskew et al. 2010). Furthermore, variation in climatic variables such as temperature and rainfall has been shown to affect both the population sex ratio and the phenology of Painted Turtle reproduction (Hedrick et al. 2021, Powell et al. 2023) which could have important long-term implications on turtle populations. Accurate population data are critical to establish a baseline for future evaluations of anthropogenic influences on turtle populations.

In 2020 we began what is intended to be a long-term survey of *Chrysemys picta bellii* Gray (Western Painted Turtles) in Marshall County, SD. We used 3 capture techniques to collect basic demographic information, in order to:

1) Gather data on population structure, particularly sex ratio and age class (hatchling, juvenile, adult).
2) Examine trapping efficacy of the 3 most common capture techniques.
3) Estimate local population size.
4) Establish a baseline for long-term assessment of Western Painted Turtle populations in the Coteau des Prairie habitat.

Materials and Methods

The Clear Lake watershed is a mix of pastureland and cropland, and the lake itself is primarily used for recreation (South Dakota Game, Fish and Parks [SDGFP] 2015). Clear Lake has a surface area of ~473 ha, 12.2 km of shoreline length, and is eutrophic with relatively good nitrogen (<0.2 mg/L) and phosphorus levels (0.013 mg/L), especially when compared to the regional average (Clear Lake Betterment Association 2016). The lake is fed by 2 inlets, one from Long Lake in the north and the other from North Red Iron Lake to the east (Fig. 1). The study site is located where the unnamed stream that drains from North Red Iron Lake enters Clear Lake (45.695469, -97.340790). At this point the stream widens and flows through a culvert under Marshall County Rd 10, but just upstream is relatively undisturbed, surrounded by a complex riparian habitat that contains emergent and overhanging vegetation and ample woody debris that can be used by turtles for basking. In contrast, the lake itself is surrounded by a mix of public and privately-owned land and is subject to a relatively high degree of anthropogenic activity, especially when compared to both Long Lake and North Red Iron Lake. Specifically, in 2010 Clear Lake had a total of 207 houses lining its shores (Helms 2010) compared to the other two lakes which do not appear to have any human-built structures nearby (Google 2023). The estimated fishing pressure on Clear Lake in 2019 was 12,179 angler hours from May through August (SDGFP 2020).

In 2020, we deployed 2 basking traps (71 cm x 71 cm x 30 cm Sundeck trap #840879 from Heinsohn's Country Store, www.texastastes.com) and 2 hoop traps (91 cm diameter, 3 hoops, 3.8 cm mesh, ~180 cm long from Memphis Net & Twine, #TN315) on the afternoon of 15 June and checked them each day at approximately the same time until we removed them on 9 July. One hoop trap was removed on 18 June due to extensive damage. Dip netting was also carried out each day immediately prior to checking traps. On 14 June 2021 and 23 June 2022 we deployed 4 basking and 4 hoop traps for 7 continuous days. We added 2 mini hoop traps (30 cm diameter, 60 cm long from SF Fishing, #CN001M) in 2022 to determine whether they would increase our capture rate. All trap types were baited with canned sardines packed in soybean oil.

Captured turtles were given individual marks using a non-toxic, oil-based paint marker as per Kornilev et al. (2012), weighed, and measured for straight-line carapace length (SCL). The sex of turtles with SCL greater than 50 mm was determined by the length of the foreclaws and location of the cloaca relative to the edge of the carapace (Ernst 1971), and turtles smaller than 50 mm SCL were considered to be juveniles and were not sexed. We photographed each carapace and plastron to record shell patterning and for long-term identification (Cooley et al. 2013).

Statistical analyses

Catch per unit effort (CPUE) was calculated as (number of turtles caught in basking and hoop traps) divided by (number of traps x number of hours each trap was deployed) for the number of turtles per trap-hour (turtles/trap-hr). Due to the complexity of the habitat, turtles caught by hand or dipnet were the result of opportunistic encounters rather than structured searches; therefore, we did not calculate CPUE for these capture types.

Figure 1. Aerial photo of Clear Lake, Marshall County, South Dakota, including North Red Iron Lake and the location of the study site (https://www.arcgis.com/apps/mapviewer/index.html?layers=10df2279f9684e4a9f6a7f08febac2a9).

The CPUE for hoop traps and basking traps by year was compared using the nonparametric Kruskal-Wallis test. Chi-square analyses were used to determine whether there was a significant difference in the sex of turtles caught in each trap type, and to see if there was an association between year and number of each sex.

Population estimates were calculated using the Schnabel method, which incorporates multiple samples (Krebs 1999). Each day of the sampling period within a year was considered a sample and used to generate a population estimate. Given the very small number of between-year recaptures so far (one from 2020 to 2021, and another from 2021 to 2022), we have not generated a population estimate using each year as a sample.

Results

We recorded a total of 140 captures across the 3 years (Table 1), with 58% caught in hoop traps, 22% in basking traps, 16% using dipnets, and the rest by hand (2021) or mini hoop traps (2022). We captured and marked a total of 108 individual turtles, of which 44 were male, 53 female, and 11 were juveniles of undetermined sex (Table 2), and females comprised 55% of the total number of adults captured. In 2020 56.5% of the adults captured were female, in 2021 48.5% were female, and in 2022 61.1% were female. There was not a statistically significant association between the sex of the turtles and the year ($X^2 = 0.874$, df = 2, p-value = 0.646).

Table 1. Total number of captures per year and by capture method, including recaptured turtles. “Other” indicates turtles that were caught by hand in 2021 and in mini hoop traps in 2022.

Year	Total	Hoop	Basking	Dipnet	Other
2020	54	26	25	3	0
2021	56	34	3	17	2
2022	30	21	3	3	3
Total	140	81	31	23	5

Table 2. Total number of turtles captured, number of new adult captures each year by sex, recaptured turtles, catch per unit effort (turtles/trap-hr) by trap type, and the proportion of males and females captured in each trap type.

Year	Males (%)	Females (%)	Recaptures	Total captures	Hoop CPUE	Basking CPUE	Total CPUE	Basking % female/male	Hoop % female/male
2020	20(43.5)	26(56.5)	8	54	0.040	0.022	0.028	64.0/36.0	50.0/50.0
2021	17(51.5)	16(48.5)	12	56*	0.051	0.005	0.028	66.7/33.3	44.1/55.9
2022	7(38.9)	11(61.1)	12	30	0.032	0.005	0.018	100.0/0	47.6/52.4
Totals	44(45.4)	53(54.6)	32	140	0.040	0.013	0.025	67.7/32.3	46.9/53.1

*includes 11 juveniles

Total CPUE across all years and trap types was 0.025 turtles per trap hour, with higher success in hoop traps (0.040) versus basking traps (0.013; Table 2). Yearly total CPUE was calculated for individuals captured in hoop and basking traps only and did not differ between years (Kruskal-Wallis $X^2 = 1.333$, df = 2, p-value = 0.513). Hoop traps were significantly more effective at catching turtles compared to basking traps (Table 2) (Kruskal-Wallis $X^2 = 5.622$, df = 1, p-value = 0.0177).

Of the turtles captured in basking traps, more were female, while hoop traps caught slightly more males (Table 2). However, there was no statistically significant association between sex and trap type ($X^2 = 3.111$, df = 1, p-value = 0.0778). We were less effective at catching adult turtles using dipnets (Table 1), although all of the juveniles in our sample were captured in 2021 using this method.

The estimated population size, based on the number of recaptured turtles within each year's sample, ranged from 136 turtles (72.6 to 320.2 95% CL) in 2020 to 26 turtles (14.1 to 52.9 95% CL) in 2022 (Fig. 2).

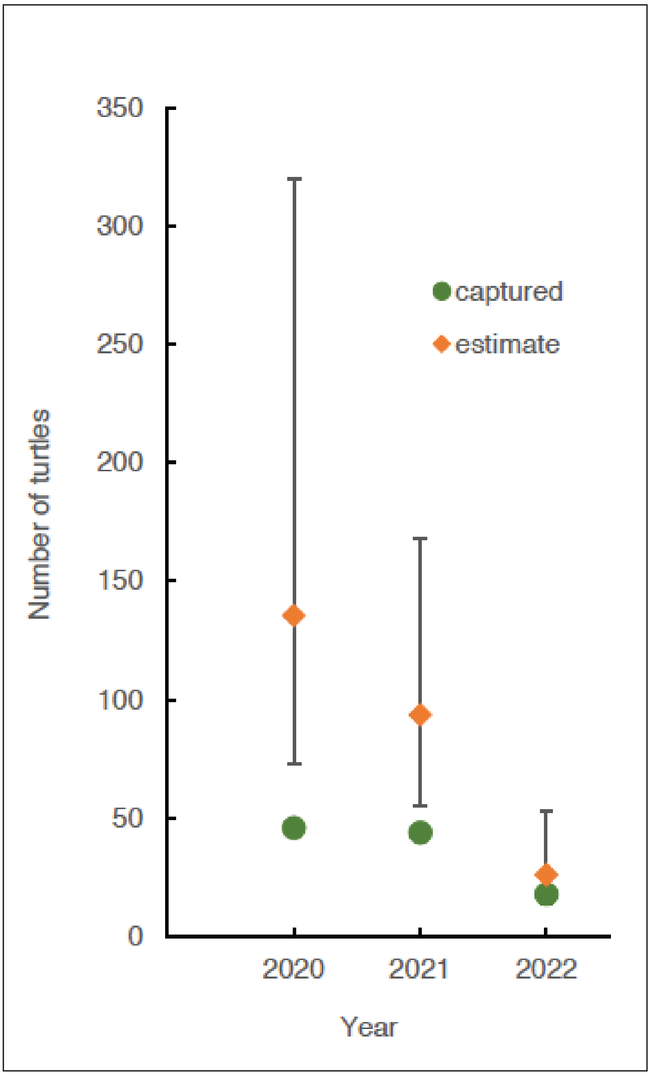

Figure 2. Population estimates with 95% confidence limits using the Schnabel method and actual number of turtles captured in 2020 to 2022 at the Clear Lake study site.

Discussion

An understanding of natural history, population dynamics, and the ability of any species to adjust to environmental changes while coexisting with human disturbance is necessary for species management and conservation. Relatively little is known about the natural history of many turtle species. Basic population surveys can provide valuable information about demographics, habitat use, and movement between habitat types. The most common methods for sampling populations of freshwater turtles are basking traps and hoop traps. Other studies on Painted Turtles have reported sex and age-class biases in trapping methods, which have the potential to lead to inaccurate estimates of sex ratios and population demographics (e.g., Gamble 2006, Koper and Brooks 1998, Tesche and Hodges 2015). We analyzed our results to determine whether or not they followed a similar pattern; that is, to produce more turtles in basking traps and a male-biased sex ratio (e.g., Gamble 2006).

Although the number of turtles we captured per trap-hour was similar to that reported in other studies (e.g., Bandas 2003, Gamble 2006, Moos and Blackwell 2016), our CPUE by trap type differed from other reports in terms of which trap type was more effective. The overall CPUE for our basking traps was 0.013, compared to 0.040 for our hoop traps (Table 2). In contrast, Gamble (2006), sampling Painted Turtles in central Minnesota, found that basking traps had an average CPUE of 0.068, while the average for hoop traps was 0.029. A study by McKenna et al. (2001) in Ohio failed to capture any Painted Turtles in baited hoop traps but reported a CPUE of 0.107 for basking traps. And while Tesche and Hodges (2015) did not report CPUE, they did conclude that hoop traps were less effective than basking traps across all age and sex classes of Painted Turtles captured in their study in British Columbia.

Although there was no statistically significant association between sex and trap type, our results also differ from previous studies in the direction of sex bias of trap types. Sixty-eight percent of the turtles we found in basking traps were female, while our hoop traps had a slight male bias (48% female); both males (81%) and females (65%) were captured more often in hoop traps. Gamble (2006) captured more males than females in both trap types, while Tesche and Hodges (2015) report a bias for males in basking traps over hoop traps and no significant difference between trap types for females. Multiple sources have suggested the possibility that male trap bias is due to the attraction of males to traps that already contain females (reviewed and tested by Frazer et al. 1990), or the ability of female turtles to escape hoop traps (Frazer et al. 1990), although it may be due to an actual male bias in a particular population (Gamble 2006).

Overall we captured more adult female Painted Turtles than adult males (55% females), resulting in a slightly, but not significantly, female-biased sex ratio. Others have also reported an adult sex ratio close to 1:1 (Bandas 2003, Zweifel 1989). However, some found more females, such as Tesche and Hodges (2015, 64% female); Koper and Brooks (1998, 75% female) and Moldowan et al. (2018, 78% female), while others more males (Gamble 2006, 29% female; Moos and Blackwell 2016, 33 to 43% female). There is certainly a great deal of variation in the reported adult sex ratio from one location to the next, even within the same study (Moos and Blackwell 2016 throughout South Dakota, although all were male-biased), and between years at the same location (Ernst and Lovich 2009, Zweifel 1989). A larger sample size generated by including more traps at additional locations throughout Clear Lake, and combining these data with trapping results from future years, will allow us to describe trends in the adult sex ratio of this population over time with greater accuracy and confidence.

A number of factors could lead to the differences in patterns of bias in trap efficacy and sex ratio between our results and others. For example, although we have attempted to compare our data primarily to other studies of Western Painted Turtles in the Midwest, our study location differs from typical prairie potholes in having an abundance of woody debris. Painted Turtles are capable of using a wide range of substrates for basking (Ernst and Lovich 2009), but a large selection of easy to access and familiar structures could mean our basking traps are less attractive, and therefore less effective, than they would be in more open aquatic habitats.

Another factor is that of the seasonality of turtle behavior and the timing of field work. Our sampling took place in mid-June through early July, while others in the Midwest sampled early summer through late summer or autumn (Bandas 2003, Gamble 2006, Moos and Blackwell 2016), although not continuously at one location. Turtles may move to different habitats within the lake environment depending on changes in mate searching, egg laying, foraging, temperature relations, and energy use. For example, during the cooler spring and fall, turtles may bask more than in the warmer summer (Gamble 2006). In addition, females may bask more in the early summer than males due to the increased energetic demands of egg development and nesting behavior (Carriére et al. 2008, Krawchuk and Brooks 1998) and so occupy a site with plentiful basking opportunities more than males during our field season in June. Mating behavior in this species takes place both in spring and autumn (Ernst and Lovich 2009), so another possibility is that males have more incentive to curtail basking and return to the water to court females (Carriére et al. 2008). Both Moos and Blackwell (2016) and Moldewan et al. (2018) found an increase in the proportion of males in the sample, and therefore an increase in male activity, from summer into autumn. We captured more males in hoop traps than basking traps, suggesting that the males were spending more time in the water. And while our basking traps did catch more females than males, we caught more females in hoops than basking traps. It is possible that given the abundance of basking sites to choose from, the likelihood of any of the turtles using our basking traps was reduced.

Painted Turtle population age structure is known to skew towards adults due to the relatively high mortality and potentially lower catchability of hatchlings and juveniles (Ernst and Lovich 2009). The proportion of the population comprised of juveniles can vary over time, depending on nesting and hatching success (Zweifel 1989). However, the capture methods used clearly influence the number of juveniles in the sample; we captured nearly all juveniles in 2021 using dipnets. Whether this represents higher juvenile survivorship in 2021 due to decreased predation or increased hatching success, or can be explained by changes in juvenile distribution between years, should be further investigated. Dip netting typically results in more hatchlings and juveniles than trapping (Ream and Ream 1966, Tesche and Hodges 2015). Approximately 10% of our sample were juveniles, close to that reported by Gamble (2006), although he did not include dip netting so most of the juveniles in his study were captured in basking traps. The mesh size of our basking and hoop traps would allow hatchlings and small juveniles to easily escape, so changing to a smaller mesh size and spending more time dip netting should increase the number of juveniles in our sample and provide a clearer picture of the age structure of this population.

There is a wide range in reported Painted Turtle population density estimates, due in part to differences in capture methods and in the estimates of the area actually occupied by turtles (Zweifel 1989). For example, in his survey of Painted Turtles occupying a series of small ponds in New York, Zweifel (1989) reports an average total density of 137 turtles/ha, with a range of 71-193/ha, and a possible maximum of 560 turtles/ha in the largest pond. Koper and Brooks (1998) report on a population of Painted Turtles of known size, consisting of 110 individuals occupying a 1.7 ha pond (65 turtles/ha). Although our study site is only a small part of Clear Lake, we can look at the capture rate and density of turtles at this location as representative of the entire population. The stretch of inlet where we sampled has an aquatic surface area of approximately 0.13 ha, so the density of turtles occupying this site ranged from 138 turtles/ha in 2022 to 354/ha in 2020 (with an average density of 277/ha), which falls within the very large range of population densities reported for this species. However, possibly the most appropriate comparison for the number of turtles captured in this study is to Moos and Blackwell (2016) who recorded Painted Turtle by-catch in modified fyke nets in Clear Lake. Based on supplemental data provided by Moos and Blackwell (2016), they captured between 11 (0.025 turtles/trap-hr CPUE) and 92 turtles (0.213 CPUE) across the 6 years of their study. Although they did not sample in the inlet habitat where we had our traps, our annual total capture totals fit in the same range.

While our estimated turtle population size declined from 2020 to 2022, the relatively low number of turtles captured and small percentage recaptured during each year produced population estimates with wide error bars. That, and the very low number of turtles we have recaptured between years so far, suggests that we are encountering a different subset of the total population each year. The Schnabel method, like the Petersen method, assumes constant population size, random sampling, and equal catchability (Krebs 1998). Although the Painted Turtles in Clear Lake could be considered a closed population, we were sampling in one location within the lake habitat and turtles could easily enter and leave our sample site. Marked turtles were observed more than a mile away from the sample site (pers. obs.), indicating the turtles roam widely and utilize a large portion of Clear Lake. However, it is likely that some of these turtles were occupying the sample site more consistently than others, violating the assumption of equal catchability. Expanding our sampling to include more locations around Clear Lake will help to minimize violating these assumptions.

Turtle populations, especially ones that are limited in size, are likely to vary in size and population structure annually (Zweifel 1989). Therefore, there is a need to establish long-term monitoring to separate year-to-year variation in population size, due to nesting and hatching success, for example, from long-term demographic trends. Short-term fluctuations in population size could also be due to patterns of movement between overwintering habitat and active season habitat. Painted Turtles are known to move between water bodies, seasonally and in response to habitat changes (Ernst and Lovich 2009). Moos and Blackwell (2016) examined the relationship between annual turtle catch rates and a number of weather variables, and found a negative correlation to winter precipitation. In the Prairie Pothole Region, which includes the Coteau des Prairie highlands, most ponds and lakes are primarily filled by snowmelt and rain and changes in precipitation result in shifts in suitable habitat (Johnson et al. 2005). In South Dakota, Painted Turtles overwinter in permanent water bodies that are sufficiently deep to avoid freezing (Davis 2023). A larger proportion of turtles in a population could leave the overwintering site in the spring when higher winter precipitation has created a greater number of suitable active season habitats. In addition, higher precipitation resulting in more water bodies suitable for overwintering could mean that fewer turtles return to the target water body for the winter, and therefore there are fewer turtles available for capture in the spring (Moos and Blackwell 2016). Our preliminary data support this proposed relationship between precipitation and turtle occupancy, in that our CPUE may be related to the previous 6 months' precipitation; however, more than 3 years of data are needed to fully investigate this relationship.

In addition to factors that legitimately affect turtle population size and structure, we would like to underscore the importance of minimizing trapping bias. These data are routinely used to generate population estimates and therefore guide regulatory decisions. Under or over sampling one part of the population can lead to inaccurate or misleading population inferences, compounding potential issues of small sample sizes. Despite this, Tesche and Hodges (2015) found that freshwater turtle population surveys still frequently use only one trap type and fail to discuss potential trap bias. The considerable between-trap and inter-year variation in turtle capture rates in our study further supports the use of multiple trap types.

Finally, we hope this serves as a baseline for long-term assessment of Western Painted Turtle populations in the Coteau des Prairie habitat. Although Painted Turtles are widespread and well-studied in many locations (e.g., Tesche and Hodges 2015, Zweifel 1989), local parameters and population dynamics may vary greatly (Ernst and Lovich 2009). Filling in the large geographical gaps in our knowledge of this species will allow us the opportunity to examine geographic variation and assess the effects of human-turtle interactions in this habitat.

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