Sex-biased seasonal capture rates in Painted Turtle (*Chrysemys picta*)

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Abstract
We examined captures of Painted Turtle *(Chrysemys pict*a) in Algonquin Provincial Park, Ontario, Canada, during the understudied summer–autumn transition period (August–September). The proportion of captured male turtles increased relative to the proportion of females during the late summer and early autumn sampling period, leading to male-biased capture rates in a population with a strongly female-biased sex ratio. We consider explanations for the capture bias in relation to sex-specific activity patterns and briefly discuss the implications of sampling period on the outcome of population structure studies.

Key words: Activity patterns; breeding; capture; *Chrysemys picta*; mating; Painted Turtle; seasonality; sex ratio; population studies; Algonquin Park

Introduction
Painted Turtle (*Chrysemys picta*) is among the most-studied freshwater turtles of North America (Lovich and Ennen 2013). The species' wide longitudinal and latitudinal geographic range (Hecnar 1999; Ernst and Lovich 2009) and relative abundance have supported a large volume of ecological, life history, and population biology studies (e.g., Wilbur 1975; Zweifel 1989; Congdon *et al.* 2003; Browne and Hecnar 2007; Lovich and Ennen 2013).

Much research on Painted Turtle biology has focussed on its active season, which extends from approximately May through August, depending on local regional climate. The overwintering period has also been subject to considerable study, given the unique physiological adaptations of adult and hatchling Painted Turtles to low dissolved oxygen and cold temperatures (Storey *et al.* 1988; Crocker *et al.* 2000; Costanzo *et al.* 2004; Rollinson *et al*. 2008). In contrast, research on Painted Turtle during the transition period between active season and overwintering has been largely neglected. Using observational study of Painted Turtles in Algonquin Provincial Park, south-central Ontario, we report on sex-biased captures during the understudied summer–autumn transition period and consider explanations for the bias in relation to sex-specific activity patterns.

Methods
Research on the biology of Painted Turtles at the Algonquin Wildlife Research Station, near the species' northern range limit, has been ongoing since 1978 under the leadership of R.J.B. and J.D.L. Observational and experimental study on the mating system of Painted Turtles took place during late summer and early autumn 2013 (Moldowan 2014). Aquatic transects at Wolf Howl Pond (45°34'N, 78°41'W), Algonquin Provincial Park, were surveyed by canoe, and turtles were captured by hand and dip net. Between 10 and 44 Painted Turtles (mean = 24) were captured on 19 sampling occasions between 8 August and 24 September 2013 (Julian dates 220 through 267). Sampling was conducted between 1000 and 1600 on clear days with little wind. All observed individuals, regardless of activity (e.g., basking, free swimming, bottom walking), were targetted for capture.

Following capture, the sex of the turtles was recorded based on the presence or absence of sexually dimorphic characters (foreclaw elongation, carapace height, body size, and head shape morphology; Ernst and Lovich 2009; Moldowan *et al.* 2016, 2017). Individuals were counted only once during each sampling occasion. All captured individuals were marked members of the long-term study.

The population under study has a sex ratio of 0.29:1 male:female (Samson 2003; R.J.B. and J.D.L. unpubl. data). To test for a shift in sex ratio during the summer–autumn transition period, we conducted a linear regression analysis with Julian date as the predictor variable and sex ratio as the response variable. We also conducted a χ^2 test to verify that the sex ratio of turtles sampled in this study was reflective of the population sex ratio at large. Finally, linear regression was used to test whether sample size (predictor) affected sex ratio (response) among the captured turtles across all 19 sampling occasions. Findings were considered statistically significant at $\alpha < 0.05$.

Results

The proportion of captured male Painted Turtles significantly increased relative to the proportion of captured females during the late summer and early autumn sampling period (Figure 1). Painted Turtles captured during the summer–autumn transition period demonstrated a significant increase in male:female sex ratio ($R^2 = 0.60$, $F_{1,17} = 24.74$, $P < 0.001$), ranging by nearly an order of magnitude from 0.12 to 1.10 (Figure 2). The sex ratio of all turtles captured or recaptured across the 48-day sampling period was 0.39 male:1 female (129 male and 334 female captures/recaptures) and did not differ statistically from the expected ratio (i.e., the population sex ratio; Samson 2003; R.J.B. and J.D.L. unpubl. data) of 0.29:1 ($\chi^2_1 = 0.45$, $P = 0.57$). Size of the captured sample was not a significant predictor of sex ratio ($R^2 = 0.02$, $F_{1,17} = 0.33$, $P = 0.58$).

Discussion

Our seasonal capture records indicate differences in activity levels between male and female Painted Turtles during the summer–autumn transition period. Male Painted Turtles remain active later in the year than females. These observations are consistent with seasonally male-biased activity in Pond Slider (*Trachemys scripta*; Morreale *et al.* 1984; Thomas *et al.* 1999), Snapping Turtle (*Chelydra serpentina*; Brown and Brooks 1993), and a Virginia population of Painted Turtles (Mitchell 1988). Morreale *et al.* (1984) and Thomas *et al.* (1999) have hypothesized that by extending the length of their active season, males can increase mate-searching activities, improve their chances of mating, and thereby potentially increase their reproductive fitness.

Across its range, Painted Turtle has two breeding periods, one at the beginning (spring) and one at the end (late summer and autumn) of the active season (Sexton 1959; Gibbons 1968; Ernst 1971a,b; Moll 1973; Licht *et al.* 1985; Gist *et al.* 1990; Ernst and Lovich 2009). Temperature (Ernst 1971a; Ganzhorn and Licht 1983; Licht and Porter 1985) and/or photoperiod (Mendonça 1987; Thomas *et al.* 1999) serve as the proximate mechanism(s) triggering the onset of reproductive cycling in temperate turtles. Across the geographic range of Painted Turtle, a gradient in the timing of reproductive activity is expected because of latitudinal differences in the length of the active season (Christiansen and Moll 1973; Moll 1973; Thomas *et al.* 1999). In Algonquin Provincial Park, the active (growing) season for ectothermic vertebrates is short, with an average of 115–125 frost-free days per year (OMAFRA 2013). Thermal and energetic constraints imposed by a northern climate on reproduction (Koper and Brooks 2000; Rollinson and Brooks 2007, 2008) may force female Painted Turtles to reduce the duration of their active season relative to that of males to conserve energy. Late summer and early autumn (August–Septem-

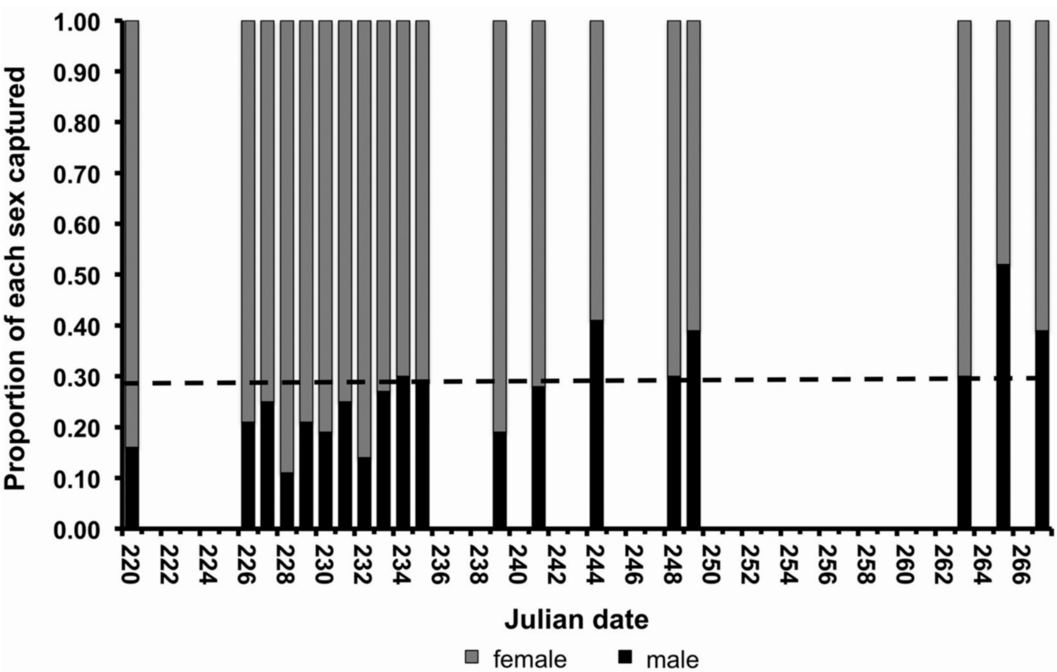

FIGURE 1. Proportion of captured Painted Turtles (*Chrysemys picta*) by sex during late summer and early autumn (8 August to 24 September 2013) in Algonquin Provincial Park, Ontario, Canada. The dashed line represents the expected proportion of males to females (0.29:1) based on the population sex ratio (Samson 2003; R.J.B. and J.D.L. unpubl. data).

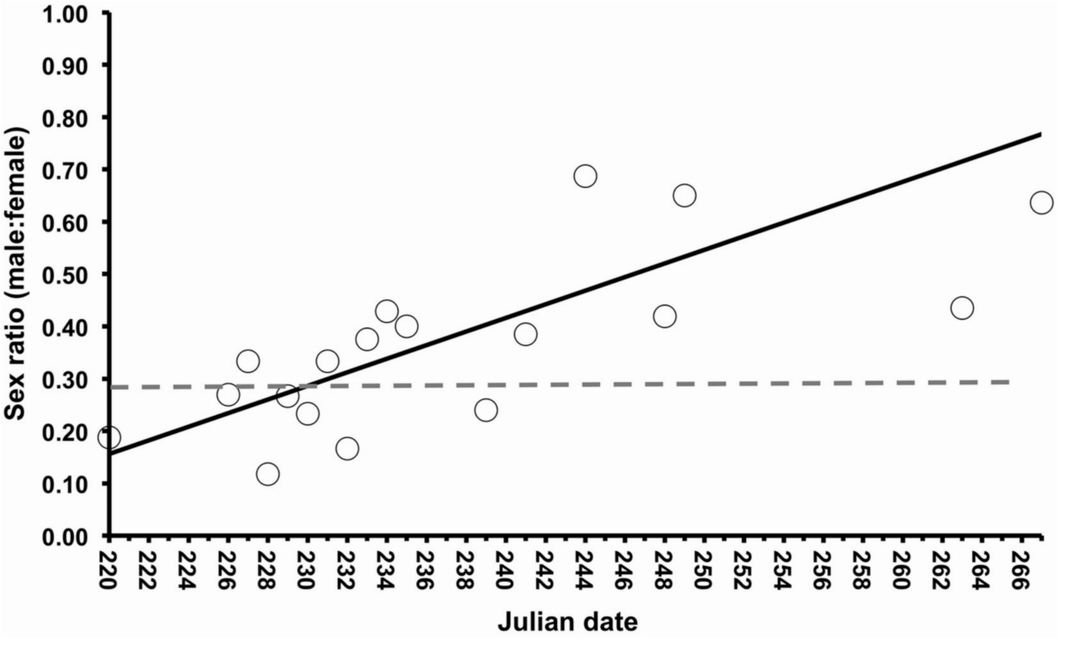

FIGURE 2. Increasing male bias in the sex ratio of captured Painted Turtles (*Chrysemys picta*) in Algonquin Provincial Park, Ontario, Canada, during the late summer–early autumn transition period, 8 August to 24 September 2013 ($y = 0.013x - 2.6926$, $R^2 = 0.60$). The dashed line represents the population sex ratio 0.29:1, male:female (Samson 2003; R.J.B. and J.D.L. unpubl. data).

ber) are energetically taxing times, as female Painted Turtles invest in follicular growth (Gibbons 1968; Congdon and Tinkle 1982; Mitchell 1985; Rollinson and Brooks 2007). Concurrently, male Painted Turtles undergo an increase in testis size from July to September (Gibbons 1968; Moll 1973; Congdon and Tinkle 1982) and an apparent increase in reproductive behaviour relative to females. Despite a reduction in female activity during summer–autumn transition, males may still secure mating opportunities by adopting coercive reproductive tactics (Moldowan 2014). Long-term sperm storage in Painted Turtle promotes multiple mating opportunities throughout the year and can lead to high reproductive success among males that successfully mate (Pearse *et al.* 2002; McGuire *et al*. 2011, 2014).

Our findings highlight the fact that sampling period can have considerable influence on measures of population structure (e.g., sex ratio) of Painted Turtle because of sex-specific activity patterns (Ernst 1971c; Mitchell 1988). Thus, those conducting demographic studies must be aware of sampling biases imposed by time of year. It is unlikely that our observed shift in male and female catchability is simply an artefact of sampling method (Ream and Ream 1966; Koper and Brooks 1998) because we used a consistent capture method over a relatively short sampling period, and our sample size did not affect sex ratio. Furthermore, our study site has been sampled annually for decades, with sampling occurring over many consecutive weeks during spring population inventories (May) and nest monitoring (June), making it unlikely that turtles became exceptionally wary or demonstrated avoidance behaviour during autumn sampling. An increasing frequency of male conspicuousness (Figures 1 and 2) and reproductive activity (Moldowan 2014) provide evidence that late summer and early autumn is an important breeding period in this northern population of Painted Turtles.

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