# Survey Methodology for the Detection of Wood Turtles (*Glyptemys insculpta*)

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Wood Turtles (*Glyptemys insculpta*) are difficult to survey because their use of aquatic and terrestrial environments varies spatio-temporally. Existing survey methodology is highly variable and typically involves searching for Wood Turtles within water and on land 0 to >20 m from the shoreline from spring to autumn. The mobility of Wood Turtles suggests that detection is likely influenced by distance surveyed from water and the amount of vegetation, which varies by season. To determine an ideal survey methodology for the Wood Turtle, we recorded distances from a waterway of 31 radio-tagged turtles at Canadian Forces Base, Gagetown, New Brunswick, in 2003 and 2004. Ordinal logistic regression was used to determine the probability of finding male or female Wood Turtles with increasing distance from water at different times of day or season. Sex and time of day were not significant factors in detecting Wood Turtles. Season was a significant factor, with highest probability (69%) of finding Wood Turtles at a distance of 0–10 m of a waterway up to July 1 (corresponding to pre-nesting and nesting periods), compared to probabilities of <10% for any 10-m distance between 10 m and 50 m from a waterway. After July 1, the highest detection probability (50%) was at distances greater than 50 m from a waterway. We recommend that Wood Turtle surveys for environmental impact assessments and population monitoring be conducted on warm days (i.e., 10–25°C) within 10 m of waterways up to July 1.

Key Words: Wood Turtle; *Glyptemys insculpta*; survey methodology; detection; monitoring; New Brunswick

Wood Turtles (*Glyptemys insculpta*) exist in discontinuous populations in the northeastern United States from Michigan to Maine and south to Virginia (Ernst and Lovich 2009). In Canada, they are found in parts of south-central Ontario and southern Quebec (Desroches and Rodrigue 2004; Committee on the Status of Endangered Wildlife in Canada 2008*), New Brunswick, and Nova Scotia (McAlpine and Gerriets 1999; Gräf *et al.* 2003; Biggar 2008*) and are designated threatened nationally (Committee on the Status of Endangered Wildlife in Canada 2008*), endangered in Ontario (Ontario Wood Turtle Recovery Team 2009*), and vulnerable in Quebec (Équipe de rétablissement des tortues du Québec 2005*). In the United States, they are listed as imperiled or vulnerable in 15 of 17 states (NatureServe 2013*).

Because the Wood Turtle is a listed species, surveys to establish the presence of Wood Turtles are often included in environmental assessments and regulatory permitting for new development projects and road construction (e.g., AMEC 2002*; MacGregor and Elderkin 2003*; Saumure 2007*). Road mortality is a major threat to Wood Turtle viability (Gibbs and Shriver 2002; MacKinnon *et al.* 2005; Steen *et al.* 2006, 2012) because the extensive terrestrial movements of Wood Turtles bring them into contact with roads and exceed the traditional, narrow (e.g., 15 m) riparian buffer protection zones often required in forested and agricultural landscapes (Tingley *et al.* 2009). Accurate information on the presence of Wood Turtles could be applied to mitigating development projects and influencing the alignment and design of new roads (Langen *et al.* 2012).

Survey methodology for turtles is often based on counts of basking or road-killed animals or capture in specially designed traps (Gordon and MacCulloch 1980; Lindeman 1999; Haxton 2000; Summer and Mansfield-Jones 2008). Unless they are nesting, semi-aquatic turtle species, such as Painted Turtles (*Chrysemys picta*), Northern Map Turtles (*Graptemys geographica*), and Snapping Turtles (*Chelydra serpentina*), generally remain in or next to a waterway (Gamble and Simons 2004; Carrière and Blouin-Demers 2010; Patterson *et al.* 2012; Steen *et al.* 2012), resulting in a more defined and restricted survey area and increased confidence that detection is likely within a set distance from water.

Species that are more terrestrial, such as the Wood Turtle and the Bog Turtle (*Glyptemys muhlenbergii*), are more difficult to survey because a large proportion of the population does not bask near water and they travel unpredictable distances from water (Carter *et al.* 2000; Morrow *et al.* 2001). Wood Turtles, for example, have been recorded 300–600 m from waterways in seven studies (Tingley *et al.* 2009), and, in one study, 32% of relocations were >50 m from water (Arvisais *et al.* 2002).

Difficulties in detecting the often camouflaged Wood Turtle are compounded by the spatio-temporal variability in the species' use of water and terrestrial habitat. Within a 24-hour period, basking Wood Turtles will return to water as the ambient temperature drops, and they may not leave the water until later the following morning (Harding and Bloomer 1979; Daigle 1997; Arvisais *et al.* 2002).

Use of water also varies by season and sex; Wood Turtles often remain near waterways during the spring and autumn, but move further from water during midsummer (Farrell and Graham 1991; Kaufmann 1992; Arvisais *et al.* 2002, 2004). Female Wood Turtles are known to move greater distances than males and through different habitats, presumably to find an appropriate nesting location and for post-nesting foraging (Obbard and Brooks 1980; Gibbs and Shriver 2002; Steen *et al.* 2006; Walde *et al.* 2007). For example, 95% of male locations in an agri-forest site in Nova Scotia were within 43 m of a waterway but only 65% of female locations were within 43 m of a waterway (Tingley *et al.* 2009). Overall, the likelihood of an individual being detected in a survey could vary greatly by time of day, season, and sex.

Survey methodologies for Wood Turtles are not standardized. Most researchers capture Wood Turtles in spring during a short period of three weeks characterized by warm ambient temperatures prior to the "green-up" of vegetation (e.g., Arvisais *et al.* 2004; Walde *et al.* 2007). However, population surveys and monitoring are conducted by numerous methods and over different seasons.

Throughout its range, surveys for the Wood Turtle have been conducted during spring (Quinn and Tate 1991; Saumure and Bider 1998; Arvisais *et al.* 2002; Dubois *et al.* 2008), autumn (Compton *et al.* 2002; Greaves and Litzgus 2007), or multiple seasons (Jones *et al.* 2012). The width of the survey area varies. Some surveys begin in water or from the shoreline and extend 10, 20, or 30 m inland (Saumure and Bider 1998; Arvisais *et al.* 2002; Hunsinger 2002*; Committee on the Status of Endangered Wildlife in Canada 2008*; Jones *et al.* 2012*; M. Pulsifer, Nova Scotia Department of Natural Resources, personal communication, 2012). The United States Forest Service recommends a survey using three people, one person on either side of the waterway surveying the banks, and one on foot, or possibly a canoe, in the centre of the river (Bowen and Gillingham 2004*). A standardized survey protocol being developed for the Wood Turtle in New England requires one or two observers with non-overlapping tracks searching within 10 m of a shoreline 1 km in length for 2 hours, three times within a three-week period (Jones *et al.* 2012*). The number of surveyors over an area 10–15 m from a stream in Quebec varied between one and ten people (Arvisais et al. 2002), although most surveys are now conducted by a person on each shore and one in a canoe (Daigle 1996*).

The lack of standardized survey methods raises concern about the efficacy of environmental impact surveys, long-term monitoring, and comparisons among regions. The value of environmental impact assessments is predicated on proper survey techniques that can detect rare species; failure to detect is a concern because mitigation or avoidance practices typically are not applied if the presence of rare species is not confirmed.

Given the mobility of Wood Turtles, we predicted that survey distance from the waterway would strongly influence detection probability. We also predicted that season would be an important factor in detection because vegetation growth (and the potential concealment of Wood Turtles) increases from spring to autumn.

In this paper, we use independent locations from a population of radio-tagged Wood Turtles to determine the probability of detecting a Wood Turtle under different conditions, separate from observer bias associated with vegetation or search effort. Our intent is to establish the importance of standardizing methodology for surveying Wood Turtle populations.

## Methods

*Study area*

A total of 31 Wood Turtles was captured and marked in order to assess movement in three waterways on Canadian Forces Base Gagetown, New Brunswick (45°40'N, 66°20'W), during the spring and autumn seasons in 2003 and 2004 (May 1–October 1). We marked 27 adults (14 males and 13 females) and 4 juvenile Wood Turtles for identification using a shell notching system (Cagle 1939) and radio-telemetry devices (Model AI-2F juveniles; 12 g juveniles; 30 g adults; Holohil Systems Ltd., Carp, Ontario) on the right posterior scute (University of New Brunswick Animal Care Committee permit 04017).

Adults were defined as having >14 annuli on carapacial scutes and secondary sexual characters (Lovich *et al.* 1990; Farrell and Graham 1991; Walde *et al.* 2003). Our results pertain to adults and large juveniles (i.e., >100 mm carapace length (CL)). Carapace length in the adult sample ranged from 165 to 241 mm. One Wood Turtle had a carapace length of 164 mm but was considered to be a juvenile based on the number of rings (10) and lack of secondary sexual characteristics. Our sample of juvenile Wood Turtles was <10 years old with a carapace length range of 100–164 mm.

Initial captures of Wood Turtles were made using a two-person visual survey within 10 m of a waterway. Although our marked population was captured near shore, we believe it was representative of the larger population because literature indicates that there is no evidence of a separate Wood Turtle population beyond 10 m; individual Wood Turtles frequently move near and far from waterways and captures within 10 m would contain turtles using habitat beyond 10 m (Arvisais *et al.* 2002, Walde *et al.* 2007, Tingley *et al.* 2009). Wood Turtles were located a minimum of once per week between 0800 and 1800. A subset of six adult Wood Turtles (three males and three females) was tracked hourly for a 24-hour period up to and after

July 1 in 2004, as part of a project on influence of temperature on habitat use. Air and water temperature were recorded hourly.

The survey period up to July 1 (early season: May 1–July 1; $n$ = 133 relocations) corresponds to the pre-nesting and nesting period, and the survey period after July 1 (late season: July 2–October 1; $n$ = 214 relocations) corresponds to the post-nesting period known to influence Wood Turtle movement and habitat use (Arvisais *et al.* 2002; Compton *et al.* 2002). Nesting Wood Turtles were removed from analyses. Distance to water was measured using measuring tape; when Wood Turtles were further from water, GPS (Garmin Model 72) and GIS-based mapping were used. Data on distance from water were categorized as within water, in one of five 10-m increments to 50 m (0–10, 10.1–20, 20.1–30, 30.1–40, 40.1–50 m), and beyond 50 m. We divided days into five 2-hour segments beginning at 0800 and ending at 1800: 0800–10:00 (morning), 1001–1200 (late morning), 1201–1400 (early afternoon), 1401–1600 (late afternoon), and 1601–1800 (evening).

*Statistical analyses*

We conducted ordinal logistic regression using Minitab 16 (Minitab 16 Statistical Software 2010*) to determine the expected proportion of sightings at a certain distance compared to all other distances, and depending on three parameters (sex, season, and time of day). Distance was treated as the response, and each parameter was tested using separate ordinal logistic regressions. Estimated effects from the ordinal logistic regression represent the probability of finding a Wood Turtle within a specific parameter at a specific distance from shore compared to finding a Wood Turtle at all other distances. For example, using sex as a parameter and for male turtles specifically

$$\ln\left(\frac{\textit{Probability (sighting a male turtle at certain distance or closer)}}{\textit{Proability (sighting a male turtle at any other distance)}}\right)$$

We tested the significance of the parameters (sex, season, and time of day) against a $\chi^2$ distribution to determine whether any parameter had a significant effect on the distance from water when Wood Turtles were relocated. We used the program R version 2.13.1 (R Development Core Team 2011*) to verify the results and created a contingency table using counts of individuals, coding them by sex, season, time of day, and distance.

## Results

Sex ($P$ = 0.67) (Figure 1) and time of day ($P$ = 0.99) (Figure 2) were insignificant in determining the probability of detecting Wood Turtles with increasing distance from the water. However, season was a significant factor ($P$ = 0.00) (Figure 3), with the highest probability of detection up to July 1 (69%) occurring within 10 m of a waterway (Figure 3, Table 1). The probability of finding Wood Turtles up to July 1 remained between

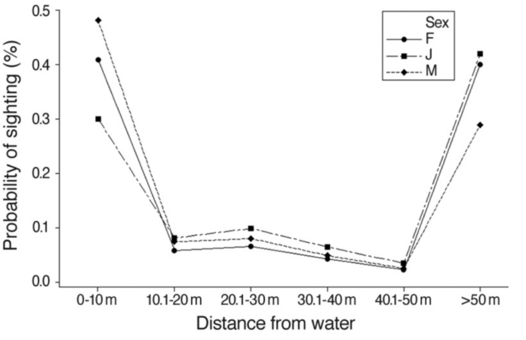


FIGURE 1. Probability of adult male, adult female, and juvenile Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, May 1–October 1, 2003 and 2004.

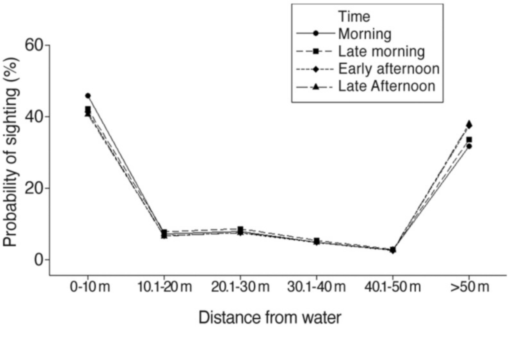


FIGURE 2. Probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, during different time periods of the day, May 1–October 1, 2003 and 2004. Early morning = 0800–10:00, late morning = 1001–1200, early afternoon = 1201–1400, late afternoon = 1401–1600.

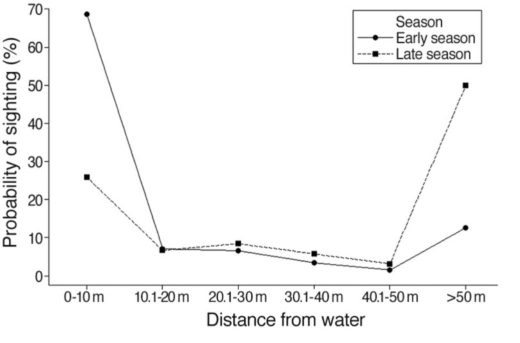


FIGURE 3. Probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, in early (up to July 1) and late (after July 1) seasons of 2003 and 2004.

TABLE 1. Percent probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, up to July 1 and after July 1, 2003 and 2004.

| | Up to July 1 | After July 1 |
|---|---|---|
| 0–10 m | 68.6 | 25.9 |
| 10.1–20 m | 7.2 | 6.7 |
| 20.1–30 m | 6.6 | 8.5 |
| 30.1–40 m | 3.4 | 5.8 |
| 40.1–50 m | 1.6 | 3.2 |
| >50 m | 12.6 | 49.9 |

2% and 7% for any 10-m distance from a waterway between 10 m and 50 m, and the probability increased to 12.6% beyond 50 m (Figure 3, Table 1). After July 1, the highest probability of sightings (50%) occurred at distances greater than 50 m from a waterway (Figure 3, Table 1). The probability of a Wood Turtle being present within 10 and 50 m of a waterway remained between 3% and 9%, and it increased to 26% for areas less than 10 m from a waterway (Figure 1). A total of 13.3% of all Wood Turtles was located in water. The longest distance a Wood Turtle was recorded from a waterway or known water body was 574 m.

Although sex had no significant effect on the probability of detecting Wood Turtles, there was a general trend for females to be further than males from waterways after July 1 (Figure 4). Time was also statistically insignificant, although, in the early season, there is a suggestion of increasing distance moved from waterway during the day (Figure 5).

Movements by the subsample of six Wood Turtles monitored for two 24-hour periods suggested that temperature affected the daily distance that the Wood Turtles moved from water. The average night-time (1700–0500) water temperature was 5.2 Celsius degrees (SD 0.9) warmer than the average nighttime air temperature up to July 1 (7.8°C, SD 1.1). At night, all six Wood Turtles moved to water, with three staying in small stagnant pools 15 m from a waterway and three Wood Turtles spending up to 6 inactive hours in the main river (12 m in width).

During this period up to July 1, when the water temperature is warmer than the air temperature, the Wood Turtles were significantly closer to water at night (average distance 7.0 m, SD 3.6) than they were in the daytime (14.6 m, SD 4.7; *t* test; $P = 0.01$). After July 1, the average nighttime air temperature (15.0°C, SD 0.8) was 2.4 Celsius degrees (SD 0.9) colder than the average water temperature; during this period, five of six Wood Turtles did not return to water at night. The average distance from water was >100 m further than in the period up to July 1 and was similar between daytime (136 m, SD 21.8) and nighttime (125 m, SD 32.4; $P = 0.5$).

The onset of daily movement by the subsample of Wood Turtles was highly variable, with earliest activity at 0630 and no movement recorded after 2030.

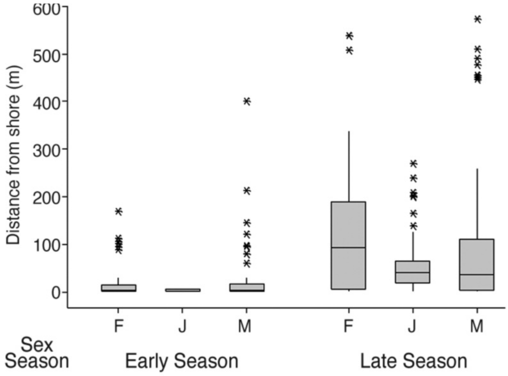


FIGURE 4. Distance from waterway of radio-tagged adult female (F), juvenile (J), and adult male (M) Wood Turtles (*Glyptemys insculpta*) in Canadian Forces Base Gagetown, New Brunswick, Canada, in early (up to July 1) and late (after July 1) seasons, 2003 and 2004. Boxes represent 50% of data, with median represented by centre line. Vertical line is the remaining upper and lower 25% of data, and asterisks represent outliers.

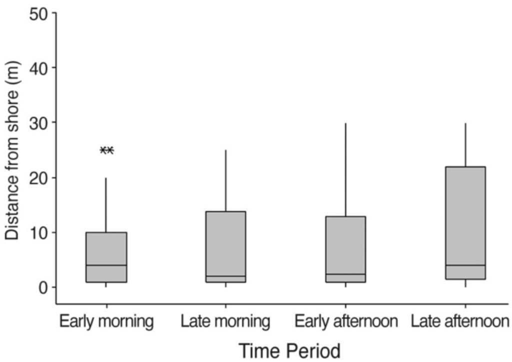


FIGURE 5. Distance from waterway by time of day of radio-tagged Wood Turtles (*Glyptemys insculpta*) in the 2003 and 2004 active season, Canadian Forces Base Gagetown, New Brunswick, Canada. Early morning = 0800–10:00, late morning = 1001–1200, early afternoon = 1201–1400, late afternoon = 1401–1600. Boxes represent 50% of data, with median represented by centre line. Vertical line is the remaining upper and lower 25% of data, and asterisks represent outliers.

Average onset of movement was mid-day (1130, SD 61 minutes). Average straight-line distance moved in 2-hour periods by males was 15.1 m (SD 5.4) up to July 1 and 19.4 m (SD 6.3) after July 1, and average straight-line distance moved by females was 1.25 m (SD 0.4) up to July 1 and 8.8 m (SD 3.1) after July 1. Basking occurred between 0845 and 1445. When temperatures exceeded 25°C, Wood Turtles typically moved to sheltered areas after 1400.

## Discussion

The main variables that influenced the probability of detecting a Wood Turtle in this study were distance from water and season. Wood Turtles were distributed from 0 to over 300 m from waterways, but most were near water; 74% of radio-tagged Wood Turtles were found in a zone from inside the waterway to 10 m inland, and 48% were between the shoreline and 10 m inland.

Our results are similar to those recorded elsewhere. In an agricultural landscape in Nova Scotia, approximately 40% of male and female Wood Turtle relocations were within 20 m of water, and many were within a shrub riparian buffer strip 10 m wide (Tingley *et al.* 2009). In Pennsylvania, the average distance of relocated Wood Turtles from a waterway was 16 m (range 0–250 m) (Ernst 2011).

It is apparent that a survey conducted close to the shoreline has the potential to successfully locate Wood Turtles. However, a near-shore survey likely would be biased towards detecting males. The recorded width of habitat containing 95% of marked Wood Turtles is 235 m for females compared to 43 for males (Tingley *et al.* 2009) and 188 m for females compared to 61 for males (Tuttle and Carroll 2003). Females move farther from shore than males and spend less time in water than males (Gibbs and Shriver 2002; Tuttle and Carroll 2003; Steen *et al.* 2006; Walde *et al.* 2007). Much of the extended female movement relates to nesting behaviour, but even post-nesting females may reside further from water (Tuttle and Carroll 2003; this study).

The large numbers of Wood Turtles regularly occurring beyond 10 m represents valuable data, and it is necessary to survey at greater distances from water if the goal is to document most of the population or most females. In Nova Scotia, 60% of relocated males were between 20 and 60 m from water (Tingley *et al.* 2009). Surveys that would cover 95% of known movements may require survey widths of 150–235 m (Arvisais *et al.* 2002; Tingley *et al.* 2009). In the current study, detection probability up to July 1 for both sexes combined was highest at 0–50 m from the waterway. However, extending the distance surveyed from the shoreline affects staff and budget issues, which in turn affect survey frequency and the ability to perform long-term monitoring. Our surveys required two people approximately 1 hour to cover 1 km of shoreline 0–10 m from the waterway; the extra 40 m in width required for a late-season survey would require 5 hours/km, or 10 person-hours.

Close proximity to water was most prevalent up to July 1, as has been recorded in other studies (e.g., Carroll and Ehrenfeld 1978; Harding and Bloomer 1979; Arvisais *et al.* 2002). Wood Turtles typically hibernate in rivers and streams (Greaves and Litzgus 2007, 2008), and movement is minimal in the spring when air temperature is below 3°C or water temperature is below 6°C (Ernst 1986). The limited movement may also be due to mating behaviour and a proportion of females staying near nesting sites (Harding and Bloomer 1979; Bowen and Gillingham 2004*; Walde *et al.* 2007; Ernst and Lovich 2009).

Similar to other studies (i.e., Harding and Bloomer 1979; Committee on the Status of Endangered Wildlife in Canada 2008*), nesting sites in this study were made in June on gravel sandbars in, and adjacent to, meandering waterways (Graham Forbes, unpublished data). In later summer, Wood Turtles move further from waterways, likely in search of food and facilitated by warmer nighttime air temperatures (Quinn and Tate 1991; Kaufmann 1992; Arvisais *et al.* 2002). In this study, Wood Turtles were less likely to occur near water after July 1 (i.e., 27% within water to 10 m from the waterway, and 22% from 0 to 10 m), and a survey after July 1 would need to cover habitat 0 to 50 m from the waterway in order to achieve a 50% probability of detection, compared to a 69% probability when conducting a survey of habitat 0 to 10 m up to July 1.

Time of day was not a strong predictor of detection in this study, but results from the subsample of Wood Turtles showed enough temporal movement to suggest that time of day will affect detection. Wood Turtles often rest in waterways at night and move inland to forage during the day (Kaufmann 1992; Arvisais *et al.* 2002; this study). Surveys conducted near water in the morning would therefore detect Wood Turtles leaving the water and basking near shore. Surveys conducted only later in the day should extend further inland than 10 m from the water.

Wood Turtles are more likely to be out of water and active on land during warm conditions (Ernst 1986; Farrell and Graham 1991). Overcast days will limit the number of basking Wood Turtles, and this may affect the number of Wood Turtle sightings. Wood Turtles will estivate when ambient temperature exceeds 25°C (Ross *et al.* 1991; this study) and thus are less likely to be detected if they are not moving or are concealed under protective cover.

Individual Wood Turtles with a carapace length of less than 100 mm were not radio-tagged; therefore, our results relate to detection of older juveniles and adults (Tuttle and Carroll 2005a). Hatchling Wood Turtles have different environmental cues, movement patterns, and habitat use than adults (Tuttle and Carroll 2005b; Castellano *et al.* 2008), and our results do not apply to hatchlings or young juveniles.

The probability of detection in this study does not directly account for the influence of vegetation, which would be an issue later in the season. In the study site, small areas (e.g., <1 $m^2$) of vegetation-free ground typically would be used by basking Wood Turtles, but these bare spots became harder to detect as grass grew higher. Sandbars and adjacent fields became heavily vegetated by grass >1 m high, and by the end of June it was no longer possible to detect Wood Turtles efficiently. Although not tested in our study, trained dogs have proven successful in locating Desert Tortoises (*Gopherus agassizii*) and Eastern Box Turtles (*Ter-*

*rapene carolina*) concealed in vegetation (Nussear *et al.* 2008; Kapfer *et al.* 2012). If trained dogs were widely used to detect Wood Turtles, this could greatly increase the period of survey. Initial efforts using dogs to find Wood Turtles in Nova Scotia suggest the method is promising (S. Mockford, personal communication, 2013).

Escape behaviour would also influence detection. Deep vegetation surrounding a stream will conceal an immobile species of small turtle possessing a dark, mud-covered carapace. But turtles also may avoid detection by moving; a Wood Turtle can detect an approaching predator from several metres away, giving it time to retreat to the water or hide further under the vegetation (Peterson 1966). Whether a turtle hides or flees may be related to habitat type, because Saumure and Bider (1998) found that Wood Turtles in forest sites escaped to waterways and those in agri-forest sites remained still. Wood Turtles are one of the faster species of turtle, with speeds reaching 0.32 km/h (Woods 1945). This study did not assess these variables, and it would be informative to develop correction factors for distance sampling methods, as has been done for the Desert Tortoise (Freilich *et al.* 2000; Nussear and Tracy 2007).

In conclusion, expectations of equal probability of detecting a Wood Turtle or most members of a population of Wood Turtles within a narrow strip in any month or time of day are not warranted. If the goal of a survey is to establish the presence of this species at risk, then we recommend that surveys be conducted before July, prior to vegetation growth, and when ambient air temperature exceeds the temperature of the water (in our area this was when ambient air temperature exceeded 10°C). Increasing the survey width from 10 m to 20 m from the waterway gained only a 7% increase in probability of detection, and the extra effort beyond a survey from 0–10 m does not seem justified. Although 13% of our relocated Wood Turtles were in water, we suspect that detection in water, due to varying depth and turbidity, would be highly variable. Surveys in water are not recommended unless the entire survey area is composed of shallow, narrow, and clear streams (e.g., Saumure and Bider 1998). A larger number of surveyors will yield a better population estimate; however, the numbers must be kept reasonable to ensure a similar number of surveyors can be maintained each year in any long-term monitoring project.

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