Population size and spatial ecology of Blanding’s turtle (Emydoidea blandingii) in South March Highlands, Ottawa, Canada

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<td>Hasler, Caleb; University of Illinois, NRES Robinson, Kevin; Dillon Consulting Limited, Stow, Nick; City of Ottawa, Planning and Growth Management Department, Infrastructure Services and Community Sustainability Taylor, Shawn; Dillon Consulting Limited,</td>
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Population size and spatial ecology of Blanding’s turtle (*Emydoidea blandingii*) in South March Highlands, Ottawa, Canada

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Running Page Head: Ecology of Blanding’s turtle near Ottawa, Canada

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Abstract

Between 2010–2011, an arterial road was constructed within provincially significant wetlands in the South March Highlands (SMH) located in Ottawa, Ontario, Canada. The wetlands and adjacent upland areas were determined to be sensitive habitat for Blanding’s turtles (*Emydoidea blandingii* (Holbrook, 1838)) during the approval and permitting process and a population study was required as part of the road construction project. The study consisted of a four-year mark-and-recapture program and a movement study of radio-tagged adult turtles. General findings included the identification of 27 adult males and 55 females and a population estimate of 93 adults (95 % CI; 86–118). A 1:2.32 male to female sex bias was also found. Mean home range size was 19.06 ha and tagged turtles moved on average more per observation in 2013 (191.40 m compared to 89.75 m and 123.04 m in 2011 and 2012, respectively). Previously reported differences in movement patterns between males, females, and gravid females were not observed. The SMH Blanding’s turtle population should be closely monitored as urban development continues in the area, which may further reduce the population size. Understanding the biology of imperiled populations across species ranges is necessary to promote conservation and adaptive wildlife management.

Keywords: POPAN Formulation, Home Range, Radiotelemetry, Urban Development, Population Estimate, Freshwater Turtles
Introduction

Understanding the unique characteristics of different populations of endangered species aids in conservation and protection (Crandall et al. 2000), especially in support of adaptive management by stakeholders (Fontaine 2011) and when a species’ biology differs across its range (Ernst et al. 1994). Population estimates offer managers support when setting conservation targets (e.g., Garshelis and Hristienko 2006) and population-specific estimates of survivorship and fecundity can be used in population viability analyses to understand extinction risks, sensitivity, and minimum viable population sizes (Shaffer 1981; Boyce 1992). Furthermore, determining area-specific use of habitat and movement behaviours such as home range size, further aids managers in protecting sufficient suitable habitat for long-term population viability (Fordham et al. 2014).

The Blanding’s turtle (Emydoidea blandingii (Holbrook, 1838)) is a threatened species that uses terrestrial and aquatic habitats, mainly upland forests and wetlands with abundant vegetation (Ross and Anderson 1990; Rubin et al. 2001b; Bury and Germano 2003; COSEWIC 2005; Congdon et al. 2008; Beaudry et al. 2009; Edge et al. 2010; Refsnider and Linck 2012). Across much of its range the species is at-risk due to habitat destruction, fragmentation, and decreases in habitat quality, mainly due to urban expansion and road development (Rubin et al. 2001b; Hartwig 2004; Rubin et al. 2004; COSEWIC 2005; Attum et al. 2008). Also, adult mortality frequently occurs for populations near anthropogenic development because females moving between resident wetlands and nesting sites, and roaming males, are killed by vehicle traffic (Beaudry et al. 2008, 2010). Due to low fecundity and frequent mortality of adults, populations of Blanding’s turtle are at risk of decline (Congdon et al. 2008) and many American states and Canadian provinces where Blanding’s turtle is known to occur consider the species either threatened or endangered and protect them under legislation (Nanjappa and Conrad 2011).
A population of Blanding's turtle was reported in the South March Highlands, located on the western edge of the City of Ottawa’s (the City) urban boundary. Urban development has occurred for the past thirty years and continues to remove sensitive habitat features and alter landscapes. The City completed the extension of a main arterial road through the South March Highlands in 2011 to service existing and future development. Because Blanding's turtles are protected in the Province of Ontario by the *Endangered Species Act (2007)*, the approval authority required the construction of a novel wildlife guide system consisting of fencing and terrestrial culverts to prevent turtles from crossing the road at grade (Taylor et al. 2014). Additionally, the authority required a four-year study of the local Blanding's turtle population to determine the population size and distribution of turtles throughout the South March Highlands. The goal of this study was to report on the findings of the population estimate and movement study to support local and international practitioners in developing conservation priorities for freshwater turtles. The main questions of the study were: 1) what is the size of the Blanding's turtle population; 2) are there equal numbers of males and females; and, 3) do movement behaviours and home range sizes differ among the sexes?

**Materials and Methods**

**Study Area**

The South March Highlands (SMH) is an 895 ha forest and wetland complex on the western edge of the suburbs of Ottawa, Ontario, and is bounded by a mix of urban and rural roads (Brunton 2008). The SMH is an extension of a largely undeveloped ridge to the west, the Carp Hills, from which it has become somewhat isolated due to intervening rural, subdivision development. Substantial suburban expansion has occurred over the past thirty years in the eastern portion of the SMH. Municipal infrastructures such as the extension of Terry Fox Drive have occurred in and around the SMH and are presumed to have impacted the SMH Blanding's turtle population.
Mark-and-recapture Program

The mark-and-recapture program began in the fall of 2010 and ended in the summer of 2013. In 2010, sampling was limited to only two weeks of marking due to delays. In 2011, beginning in May and ending in August, a 6-week marking period was followed immediately by a 6-week recapture period. In 2012 and 2013, recapture occurred in May, June, and July. During 2011, 2012, and 2013, mark-and-recapture of hand caught turtles during radio tracking sessions occurred into the late fall when turtles were observed while traversing the study area. Sampling effort totalled 2,360 trap days.

Turtles were captured using baited hoop traps. Trap sites were selected based upon accessibility, as well as appropriate water depths to ensure that the uppermost portion of the trap would remain a minimum of 15 cm out of the water to allow turtles to have access to air. The trapping locations covered a large portion of the SMH area, centered on wetlands, creek corridors and ephemeral pools. Furthermore, Blanding's turtles that were observed in the field were caught by hand and used in the study. Upon removal from the hoop trap, or capture in the field, turtles were placed in a dark cloth bag to reduce stress. Sex was determined, which is easily done via visual inspection of the plastron and beak (Ernst et al. 1994) and two methods of permanent identification were applied: scute notches were used for quick visual identification (Cagle 1939), while Passive Integrated Transponder (PIT) tags (Biomark, Boise ID, 12 mm, 125 kHz) were used as a permanent method (Buhlmann and Tuberville 1998). Gravidity was assessed using palpation and size allowed for distinction between adults from juveniles (only turtles with carapace lengths > 18 cm were included in the study). Subsequent recaptures were recorded by noting location, date and time, and specimen number. After processing, each turtle was returned to the same location where it was captured and released on land.
Radio Tagging and Tracking

Twenty-three Blanding’s turtles were tagged with radio transmitters (Table 2) using similar methods to Innes et al. (2008). The radio transmitters (Sigma Eight, Newmarket, Ontario, TX-P5-E-1200, 1200 mAh, 15 g) were attached to the posterior end of the carapace and the transmitters used did not exceed 5% of the turtle weight. Turtles were released within a few meters of the location from where they were initially trapped. Presumably due to tag failure, emigration, or removal from the study area, five radio-tagged turtles were never observed post-release or were observed less than five times (Table 2). These turtles have been excluded from the analysis of radio tracking data. Transmitters were tracked using an Icom (Osaka, Japan) IC-R20 communications receiver and an omni-directional Yagi 3-element antenna three times a week between May and September. Less frequent tracking occurred in the early spring and late fall. Most locations were determined by “zero-gain” tracking and positioned using a hand-held GPS. Where possible, positions were estimate from land as to not disturb the tagged turtles.

Data Analysis

The number of mark-and-recaptured turtles in 2011 (including turtles caught during the shorten sampling period in fall of 2010), 2012, and 2013 (Table 1) were inputted into the Program MARK (Gary C. White, University of Colorado). A Jolly-Seber model (POPAN formulation) was used to estimate population size and probabilities of survival and capture. The POPAN formulation is an adoption of the Jolly-Seber estimation made by (Schwartz and Arnason 1996) (Figure 1). Only adult Blanding’s turtles were used in the model, due to the adult sampling bias (adult turtles were observed more often than juveniles and hatchlings because of a sampling bias related to the trapping technique) (Congdon et al. 2001).

The ratio of males to females was compared to a theoretical ratio of 1:1 using a chi-squared goodness of fit test using the Yates correction for continuity. The test was
completed using the program R (R Development Core Team 2010) and significance was tested at $\alpha = 0.05$.

Movement ecology of turtles was summarized by calculating minimum distance travelled (MnDT) and home range (HR) size. MnDT is a simple measurement of mobility and is the annual sum of the distance between sequential observations. Individuals were monitored for multiple years and sampling sizes were unequal therefore MnDT has been analyzed and reported as “MnDT per observation”. HR size was calculated using minimum convex polygons (MCP; Hayne 1949). Using 95% MCP is a robust method for determining the size of an animal’s HR size (Row and Blouin-Demers 2006) and is calculated by using the outer most positions (Hayne 1949). Comparisons were made between the different reproductive statuses (male, female, gravid female) and year due to differences found by Millar and Blouin-Demers (2011). Each metric was compared using two-way repeated measure ANOVAs (MDT). The R package “adehabitat” version 1.8.14 (Calenge 2006) was used to create MCPs and calculate area. Statistical analyses were completed using the program R (R Development Core Team 2010) and significance was tested at $\alpha = 0.05$.

Results

Population Estimate and Sex Ratio

The overall adult population estimate was calculated to be 93 adult Blanding’s turtles (95 % CI 86–118). The total number of males estimated to be within the SMH was 28 males (27–36) and 65 females (59–82), resulting in an adult sex ratio of 1:2.32 (M:F) that was statistically different from 1:1 ($\chi^2 = 14.72$, D.F. = 1, $P < 0.001$). Since the POPAN formulation was used, final probabilities of survivorship and catchability cannot be estimated (Schwartz and Arnason 1996). The mean probability of survivorship across sampling years for females was 0.89 (S.D., ± 0.12)
and 0.87 (± 0.18) for males. The mean probability of catchability across sampling years for females was 0.83 (± 0.25) and 0.82 (± 0.25) for males.

Radio Telemetry

On average tagged turtles moved greater distances per observation in 2013 than in 2011 and 2012 (Figure 2; two-way repeated measures ANOVA; \( F = 0.28, 6.01; \) D.F. = 2, 2; \( P = 0.006 \)). MnDT per observation did not vary with reproductive status. Mean MnDT per observation in 2011 was 89.75 m (± S.E. 16.07), 123.04 m (± 19.26) in 2012, and 191.40 m (± 29.60) in 2013. HR size did not differ by year or by reproductive status (Figure 3). The mean HR for all tracked turtles was 19.06 ha (± 6.37). Lastly, two tagged gravid females were found dead over the course of the study (Table 2), one was killed by a vehicle while crossing a road to the east of the SMH (Turtle 0-2) and the other was found dead of unknown causes within the SMH (Turtle 2-8).

Discussion

Population Estimate

The final population estimate of 86–118 adult Blanding’s turtle was small when compared to population estimates conducted within protected areas (Herman et al. 1994; Pappas et al. 2000; Congdon et al. 2001; Lang 2004; Rubin et al. 2004; Ruane et al. 2008), but was larger than two populations studied near urban areas (Rubin et al. 2004). To compare the SMH population estimate to other Blanding’s turtle population estimates, the SMH had ~0.14 adults per ha, while a 19-year study in Michigan found twice the number of adults per ha at ~0.29 (Congdon et al. 2001) and a Nova Scotia study found fewer than 0.01 adults per ha (Herman et al. 1994). In comparison to other studies completed near urban areas, the SMH population estimate is between two populations studied near Chicago, which had 0.06 and 0.20 individuals per ha (Rubin et al. 2004). As a general rule, small and isolated
populations of Blanding’s turtle are a conservation challenge as few isolated
individuals can cause low genetic variability (Shaffer 1981; Mockford et al. 2005).
However, this may not be such a concern for the SMH population of Blanding’s
turtle, as even small populations have been found to have equal genetic diversity
when compared to larger populations (Rubin et al. 2001a). Small populations are
also at greater risk of extinction from catastrophic events and simple stochastic
processes (Boyce 1992).

An important characteristic of a population model is the estimated survivorship,
especially for small populations. Survivorship, along with other demographic
variables, can be used to determine the minimum population size or rate of
extinction (Shaffer 1981; Boyce 1992). In the SMH, mean survivorship of females
and males were 0.89 and 0.87, respectively. As such, these estimates suggest that
several adults each year are dying and since mortality rates of only 2–3 % result in
poor population viability (Congdon et al. 1993), the SMH population is likely at risk
of extinction. Evidently, two tagged gravid turtles were found dead over the course
of the study and given that the Blanding’s turtle life history dictates that females are
the limiting factor with respect to population size (Congdon et al. 1993; Congdon et
al. 2001), every effort should be taken to prevent further female mortality.

The SMH Blanding’s turtle population has a female sex-biased, as more than two
females for every male were calculated to be present. Female sex-biased Blanding’s
turtle populations have been found in other studies (Ross 1989; Congdon and Van
Loben Sels 1991; Pappas et al. 2000; Ruane et al. 2008) and may be due to
temperature-dependent sex determination (Gutzke and Packard 1987) and females
choosing warmer nesting sites (Ruane et al. 2008), as offspring are more likely to be
female when exposed to higher nest temperatures. Another possibility is that the
sampling period was bias towards females, as reproductive females tend to be more
active than males during June, which was when most of the sampling was conducted
(Millar and Blouin-Demers 2011). Given that female Blanding’s turtles are at a
heightened risk to road mortality than males (Beaudry et al. 2008, 2010), a female-skewed sex bias may promote population resilience in impacted habitats.

Movement behaviours

Movement behaviours and HR sizes of tagged Blanding’s turtles in the SMH did not differ based on reproductive status. A recent study by Millar and Blouin-Demers (2011) conducted in the St. Lawrence Islands National Park, Ontario, found gravid females moved significantly more than males and had larger HRs than both males and non-gravid females. In the case of the SMH, tagged turtles moved shorter distances, but had similar HR sizes to the St. Lawrence River population. These differences between the two studies may be due to the length of the two studies, as our study spanned 29 months, which is 13 more months than St. Lawrence study. It may be that the interannual variation among individuals observed reduced the likelihood of finding movement pattern differences between turtles of different reproductive status, which has been reported elsewhere (Grgurovic and Sievert 2005; Schuler and Thiel 2008; Fortin et al. 2012).

The HR sizes of tagged SMH Blanding’s turtles ranged considerably, with some turtles having HR sizes as small as a few hectares and others having HR sizes equalling 25 – 50 % of the total area of the SMH; however, the overall mean was similar to other reported HR sizes for Blanding’s turtle. Several other studies have measured HR size in Blanding’s turtle using similar methods and have found mean HR sizes for turtles dwelling in protected areas typically around 5-40 ha (Rowe and Moll 1991; Piepgras and Lang 2000; Innes et al. 2008; Schuler and Thiel 2008; Millar and Blouin-Demers 2011), and similarly, HR sizes for turtles in suburban areas ranged from 5-22 ha (Rubin et al. 2001b; Grgurovic and Sievert 2005).

Limitations
Several limitations of the study reduce the interpretability of the data. The SMH has limited fencing (Taylor et al. 2014) and animals can move freely to other suitable habitat; however, the density of roads and surrounding development, limits the likelihood that turtles frequently immigrate or emigrate from the SMH. Other limitations include the sampling technique. Traps could only be placed in areas where sufficient water levels allowed for the safe deployment (for samplers and for turtles) of traps. It is possible that areas with deep open water and shallow puddles were under sampled. As stated in the methods, turtles were captured and sampled when observed outside of traps, thus reducing the potential sampling bias. Lastly, because females have a tendency to move more than males (Millar and Blouin-Demers 2011), females may have had a higher encounter rate with the sampling gear, and therefore caught more frequently than males, which was also observed by Congdon et al. (1993). Overall, by separating the sexes in the population estimate, the effect of the bias is weakened; however, the estimate may have still underestimate the number of male Blanding's turtles.

Conclusions

Estimating population size and understanding the spatial ecology of imperiled species is important for determining conservation targets and goals. The SMH population is at a point where particular actions could increase the population size to levels more indicative of protected areas. However, if actions are not taken, and given the survivorship estimates, the SMH population could be at risk of extirpation in a relatively short time. Key actions to protect adult females may include construction of more wildlife crossings and ensuring habitat connectivity. Further mark-and-recapture should continue and focus on refining the population estimate for the purpose of calculating population-specific rates of survivorship, fecundity, immigration, and emigration that could be used to conduct a population viability analysis specific to the SMH. Should further radio telemetry study occur, increasing the number of tagged individuals each year may allow for more appropriate comparisons to be made with other studies.
Acknowledgements

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Literature Cited


Tables

Table 1. Number of Blanding’s turtles (*Emydoidea blandingii* (Holbrook, 1838)), by sex, marked and recaptured during 2011 (includes four turtles marked in 2010), 2012, and 2013.

<table>
<thead>
<tr>
<th>Time</th>
<th>Total Number of Individuals Captured (male, female)</th>
<th>Number of Marked Individuals Captured (male, female)</th>
<th>Number of Unmarked Individuals Captured (male, female)</th>
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<td>Occasion 1) Marking period in 2011</td>
<td>45 (15, 25), includes four turtles (2, 2) captured in fall 2010</td>
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<td>Occasion 2) Recapture period in 2011</td>
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<td>21 (7, 14)</td>
<td>24 (6, 18)</td>
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<td>Occasion 3) Recapture period in 2012</td>
<td>39 (10, 29)</td>
<td>28 (7, 21)</td>
<td>11 (3, 8)</td>
</tr>
<tr>
<td>Occasion 4) Recapture period in 2013</td>
<td>35 (13, 22)</td>
<td>27 (10, 17)</td>
<td>8 (3, 5)</td>
</tr>
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Table 2. Details related to radio-tagged Blanding’s turtle (*Emydoidea blandingii* (Holbrook, 1838)). (Obs. = observations, MnDT = minimum distance travelled, MCP = size of minimum convex polygon)

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<th>Sex</th>
<th>Monitoring Start Date</th>
<th>Monitoring End Date</th>
<th>Number of Days Monitored</th>
<th>#Obs.</th>
<th>MnDT (m)</th>
<th>MCP (ha)</th>
<th>Notes</th>
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<td>GF</td>
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<td>10/10/2013</td>
<td>136</td>
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<td>3556</td>
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*Found to be gravid; suspected tag failure*
Figure Captions

Figure 1. Conceptual model (Jolly-Seber-POPAN formulation) used to estimate population size.

Figure 2. Minimum distance travelled (MnDT; m) per observation by year and by reproductive status. Mean measurements of females (black; \( n_{2011, 2012, 2013} = 3, 3, 3 \)), gravid females (light gray; \( n_{2011, 2012, 2013} = 4, 4, 5 \)), and males (dark gray; \( n_{2011, 2012, 2013} = 4, 6, 5 \)) with standard error bars have been shown. Tagged Blanding’s turtles (Emydoidea blandingii (Holbrook, 1838)) moved more in 2013 than in 2011 and 2012 (two-way repeated measures ANOVA; F= 0.28, 6.01; DF = 2, 2; P = 0.006).

Figure 3. Area of home range calculated using minimum convex polygons (ha) consisting of 95 % of observations. Mean measurements of females (black; \( n_{2011, 2012, 2013} = 3, 3, 3 \)), gravid females (light gray; \( n_{2011, 2012, 2013} = 4, 4, 5 \)), and males (dark gray; \( n_{2011, 2012, 2013} = 4, 6, 5 \)) with standard error bars have been shown. Home range size did not differ between years, or by sex. The dashed line represents the overall mean of 19.06 ha.

Figure

See attached file.
Figures

\[ b_1 \rightarrow \Phi_1 \rightarrow \rho_1 \rightarrow \text{Mark (2011)} \rightarrow N_1 \]

\[ b_2 \rightarrow \Phi_2 \rightarrow \rho_2 \rightarrow \text{Recapture 1 (2011)} \rightarrow N_2 \]

\[ b_3 \rightarrow \Phi_3 \rightarrow \rho_3 \rightarrow \text{Recapture 2 (2012)} \rightarrow N_3 \]

\[ b_4 \rightarrow \Phi_4 \rightarrow \rho_4 \rightarrow \text{Recapture 3 (2013)} \rightarrow N_4 \]

\( \Phi_i \) = probability of a turtle surviving between occasion \( i \) and \( i + 1 \)

\( \rho_i \) = probability of capture at occasion \( i \)

\( b_i \) = probability at occasion \( i \) of a turtle entering the population from a “super” population

\( N_i \) = population size at time \( t \).