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Ecology of a Recently Discovered Population Segment of Blanding's Turtles, *Emydoidea blandingii,* in Barren Meadow and Keddy Brooks, Nova Scotia

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Blanding's Turtles in Barren Meadow Brook and Keddy Brook are part of the Pleasant River population, the easternmost population currently recognized in Nova Scotia. Previous genetic analysis demonstrated restricted gene flow among the populations of Nova Scotia. The conservation of this genetic diversity is important to reduce genetic drift and bottleneck effects in these populations. Between 2006 and 2008, the population in Barren Meadow Brook and Keddy Brook was estimated using visual surveys, trapping, and radio-tracking. Over the three years, surveys yielded 69 individuals (14 females, 22 males, 29 juveniles, 4 undetermined). Capture-mark-recapture analysis using the Chapman variation of Petersen formulas for bi-census yielded population estimates of 88 Blanding's Turtles. The sex ratio did not deviate significantly from 1:1. Applying minimum convex polygon (MCP) and kernel methods to radio-tracking data yielded preliminary estimates of home range size and location for males and females. Females had larger homes ranges, probably because of the limited availability of nesting sites in Barren Meadow and Keddy Brooks. New overwintering sites and three new nesting sites were identified. Home ranges of males did not overlap, and males seemed to show territorial behaviour. An expanded sample, particularly of males, is needed to improve the assessment of home ranges, movements, and behaviour. To date, conservation efforts in this population have focused on females. If home ranges of males in an expanded sample also do not overlap, then conservation of this population requires closer scrutiny of males and their population genetic structure.

Key Words: Blanding's Turtle, *Emydoidea blandingii*, population status, ecology, Nova Scotia.

Southwestern Nova Scotia contains three small, genetically distinguishable populations of Blanding's Turtles, *Emydoidea blandingii*, at the northeastern periphery of the species' range (Mockford et al. 1999). These populations have been isolated since the end of the Hypsithermal Interval ~4500 years ago (Bleakney 1958). Mockford et al. (2007) concluded they should be considered evolutionarily significant units (ESU) based on the reduced gene flow among the Nova Scotia populations and their long genetic isolation from the remainder of the species' range.

The landscapes that support the populations in Nova Scotia vary both structurally and in the level of protection they receive. The population in Kejimkujik National Park of Canada occurs on federally regulated land and is therefore protected, and the McGowan Lake populations occur in a combination of private and provincially regulated land, much of which has been designated for conservation (McNeil, 2002). The Pleasant River population, which includes the Blanding's Turtles in Barren Meadow Brook and Keddy Brook, occurs in a mixed-use working landscape that is afforded less formal protection. The primary threats to Blanding's Turtle in Nova Scotia are human-induced mortality and loss and fragmentation of habitat. Limited migration has been observed among these populations (Herman et al. 1995; personal observation, JL). This may lead to further isolation of existing populations, and the deleterious effects associated with inbreeding and genetic drift could eventually lead to their extinction (Herman et al. 1995, 1999*).

The Blanding's Turtles in Barren Meadow Brook and Keddy Brook form a discrete component of the Pleasant River population. Previous genetic analysis suggested restricted gene flow between the Barren Meadow Brook and Keddy Brook population and the Pleasant River population (Toews 2005*). More detailed analysis of these populations is needed for the further evaluation of the diversity within, and gene flow among, these populations. The objectives of this study were to determine abundance, sex ratio, age distribution, seasonal movement patterns, and home range size for the

understudied Barren Meadow Brook and Keddy Brook population.

Study Area and Methods

The study sites, Barren Meadow Brook (44°26'N, 64°48'W), Keddy Brook (44°25'N, 64°50'W), and the surrounding wetlands, lie within the Medway River drainage basin, in the municipality of Colpton, Lunenburg County, in southwestern Nova Scotia (Figure 1). The study area is divided into three main sites: Barren Meadow Brook, Keddy Brook, and Shingle Lake. The species is associated with shallow water, submerging and emergent vegetation, and deep organic sediments (Ross and Anderson, 1990). In Nova Scotia, the distribution of Blanding's turtle closely parallels that of highly coloured acid waters and peaty soils (Power *et al.*, 1994). Barren Meadow Brook and Keddy Brook were chosen because this area is at greatest risk of disturbance. Barren Meadow Brook and Keddy Brook are in a mix of Crown and privately owned land that supports forestry and outdoor recreational activities. Human settlement and agriculture comprise the principal disturbance regimes.

At first capture, individuals were marked with a unique notch code, following standard procedure used in Kejimkujik National Park (Power 1989). Morphological measurements (maximum straight-line carapace, maximum plastron length and width, weight, tail length pre- and post-cloaca) were recorded for each individual that was encountered during visual surveys or trapped, and morphological, age, and sex data were recorded when they were equipped with radio-transmitters. On older juveniles and adults, sex was assessed using pre-cloaca tail length. Age was determined by counting plastron rings, as described in Lefebvre et al. (2011).

Inventory

Three methods were employed to survey the population: visual surveys, trapping, and radio-telemetry. Visual surveys and trapping occurred between May and September of each year; radio-telemetry was carried out throughout the year.

Visual surveys involved walking parallel to the brooks and searching the open areas from the bank to the edge of the woody vegetation. Effort is estimated in person-hours. At each encounter, the identity of the Blanding's Turtle (notch code noted when present) and location (Universal Transverse Mercator coordinates) determined using a handheld Garmin GPS unit were recorded.

The study area was systematically trapped for 1229 trap-nights between 2006 and 2008, with most effort (934 trap-nights) in 2006; additional trapping in areas not sampled previously occurred in 2007 (245 trap-nights) and 2008 (50 trap-nights). Trapping sessions were composed of a minimum of 25 trap-nights (e.g., five traps for five days) employing baited hoop traps (3 cm mesh and 30 cm mouth) (Bourque 2006), checked daily. Sardines in soy oil were used as bait and were changed every three days (McNeil 2002; Caverhill 2006).

Ten to 15 individuals (males, females, and juveniles) per year were equipped with radio-transmitters and their positions were recorded as often as possible (every one to three days) to assess movements. Subadults and adults were equipped with AI-2F (28 g) transmitters and juveniles were equipped with PD-2 transmitters (3.8 g) (Holohil Systems, Carp, Ontario). All individuals were tracked with an Osprey receiver (HR2600DLT with data logger telemetry, H.A.B.I.T. Research Ltd., Victoria, British Columbia) equipped with a Yagi 3-prong folding directional antenna. Transmitters were affixed to the carapace with PC-7 epoxy paste (Protective Coating Co., Allentown, Pennsylvania). The data were analyzed to determine home range sizes and activity centres.

Analysis

Population size was estimated using the Chapman variation of the Petersen estimator for bi-census method (Ricker 1975; Borchers et al. 2002; Skalski et al. 2005). Sex ratio and age distribution were calculated. Deviation from a 1:1 sex ratio was tested using χ^2. Daily movements of radio-tracked turtles were mapped using ArcGIS 9.2 software (ESRI, 2006*). Home ranges of males, females, and juveniles were estimated using the kernel and minimum convex polygon (MCP) methods in the ArcGIS package Hawth's Tools v.3.27, at 95% of sightings (location points). Differences in the sizes of home ranges were tested with a unilateral *t*-test between sexes and with ANOVAs between years using the Tukey test with Holm's correction (Holm, 1977; 1979). Home ranges were calculated for four seasonal activities over the calendar year: dispersal (1 April–1 June), nesting (2 June–3 July), summer activity (4 July–7 September), and overwintering (8 September–31 March).

Results

During the study, 69 different individuals were identified. In 2006, 39 Blanding's Turtles (25 marked in previous studies and 14 unmarked) were encountered a total of 84 times (72 captures by traps, 12 captures by visual surveys). In 2007, 41 individuals, including 17 new individuals for this population, were handled a total of 76 times (42 captures by traps and 34 by visual surveys). No Blanding's Turtles were captured in trapping sessions in 2008, but visual surveys provided 13 captures. The population was estimated at 87.8 individuals (C.I. 13.9 at 95%). The sex ratio was not significantly different from 1:1 ($\chi^2 = 0.18$, df = 1, $P = 0.18$). Nearly two-thirds (40 of 65) of the Blanding's Turtles were <30 years old, and nearly one-third (18 of 65) were ≤10 years old (Table 1).

In 2006, 183.5 hours were expended tracking 11 Blanding's Turtles (6 females, 3 males, and 2 juveniles) during the active period (April to September). With the bulk of the trapping already done, more effort (240

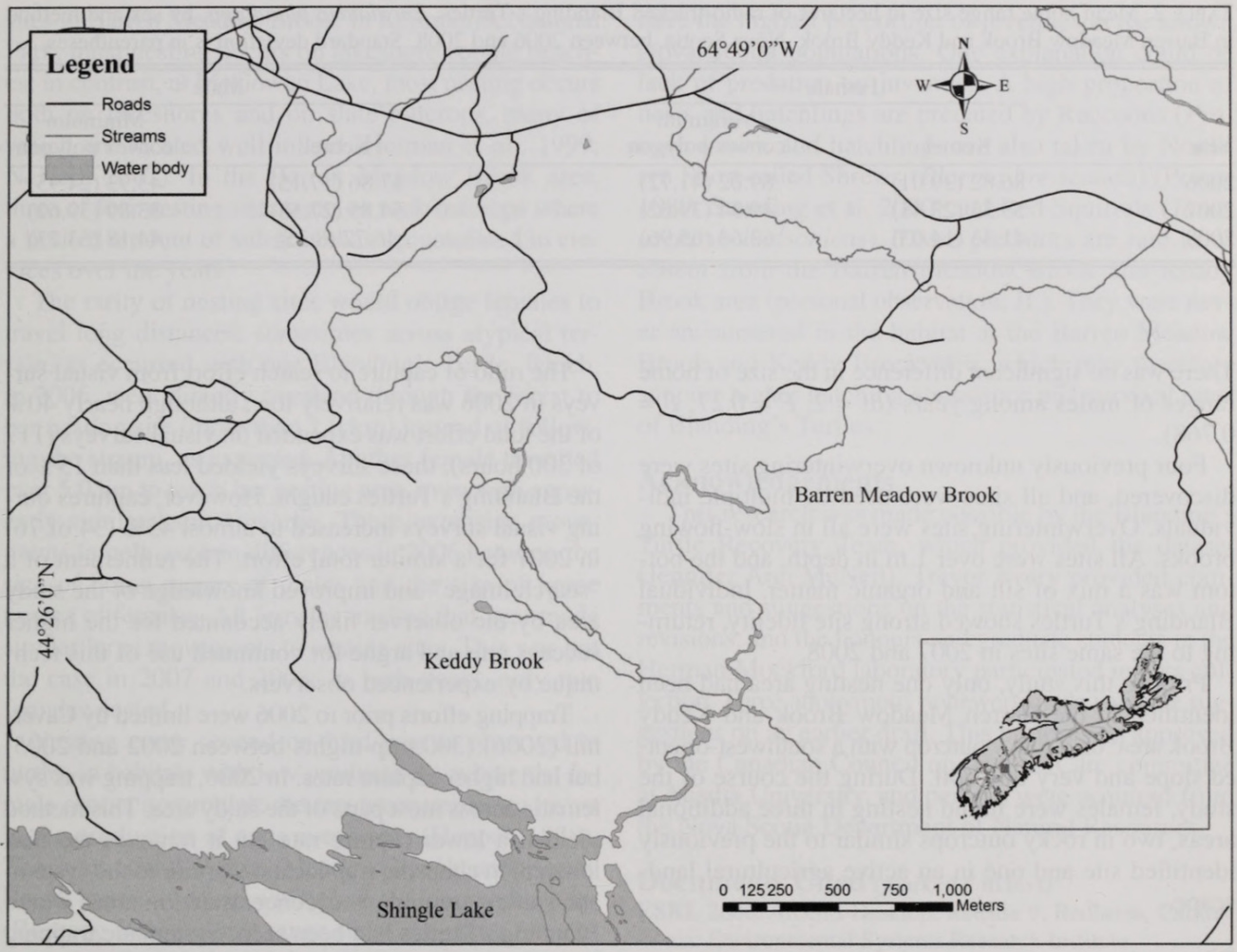

FIGURE 1. Map of the study sites (Barren Meadow Brook, Keddy Brook, and Shingle Lake) in Lunenburg County, Nova Scotia.

TABLE 1. Captures of Blanding's Turtles, *Emydoidea blandingii,* by age category and sex in Barren Meadow Brook and Keddy Brook, Nova Scotia, between 2006 and 2008.

Age category (years)						
Juvenile			Adult		Undetermined	
Young juvenile (0–10)	Old juvenile (11–18)	Sub-adult (>18 but not sexually active)	Male	Female		Total
18	8	3	22	14	4	69

hours) was dedicated to radio-tracking in 2007: 14 Blanding's Turtles (7 females, 5 males, and 2 juveniles) were radio-tracked throughout the year. In 2008, 14 Blanding's Turtles (6 females, 7 males, and 1 juvenile) were radio-tracked throughout the year, but the overall effort was reduced (140 hours) in order to spend more time monitoring nesting. Some individuals were tracked for more than one year.

In 2006, home range size differed significantly between the sexes (Table 2). Female home ranges were larger when estimated by both multiple convex polygon ($t = 20.51$, df = 7, $P < 0.001$) and kernel methods ($t = 2.00$, df = 7, $P < 0.05$). Home range sizes of males and females did not differ in 2007 (multiple convex polygon $P = 0.366$; kernel $P = 0.54$) or 2008 (multiple convex polygon $P = 0.24$; kernel $P = 0.18$).

Home ranges were compared among the three years separately for each sex. Female home ranges differed significantly among years (df = 2, $F = 7.743$, $P < 0.001$) and were significantly larger (Tukey test with Holm's correction) in 2006 than in 2007 (df = 1, $t = -3.32$, $P = 0.005$) and 2008 (df = 1, $t = -3.62$, $P = 0.002$).

TABLE 2. Mean home range size in hectares of radio-tracked Blanding's Turtles, *Emydoidea blandingii*, by sex and method in Barren Meadow Brook and Keddy Brook, Nova Scotia, between 2006 and 2008. Standard deviation is in parentheses.

	Female		Male	
Year	Kernel	Minimum convex polygon	Kernel	Minimum convex polygon
2006	86.82 (39.01)	89.02 (41.72)	47.86 (17.15)	43.93 (24.95)
2007	53.33 (23.41)	40.34 (39.62)	54.85 (27.58)	33.89 (39.62)
2008	41.33 (14.03)	63.63 (65.96)	46.72 (8.35)	44.18 (53.73)

There was no significant difference in the size of home ranges of males among years (df = 2, $F = 0.27$, $P = 0.768$).

Four previously unknown overwintering sites were discovered, and all sites were used by multiple individuals. Overwintering sites were all in slow-flowing brooks. All sites were over 1 m in depth, and the bottom was a mix of silt and organic matter. Individual Blanding's Turtles showed strong site fidelity, returning to the same sites in 2007 and 2008.

Prior to this study, only one nesting area had been identified in the Barren Meadow Brook and Keddy Brook area: on a rocky outcrop with a southwest-oriented slope and very thin soil. During the course of the study, females were found nesting in three additional areas, two in rocky outcrops similar to the previously identified site and one in an active agricultural landscape.

Discussion

Prior to this study, 34 individuals had been identified in inventories carried out in Barren Meadow Brook and Keddy Brook. Systematic trapping and surveying in the current study identified 35 additional individuals, more than doubling the known population. This number falls within the estimate of the population, suggesting that most of the population has now been accounted for. The majority of Blanding's Turtles captured in the study site were ≥5 years old. Barren Meadow Brook and Keddy Brook contain more than 10% of the estimated adult population of Blanding's Turtles in Nova Scotia (Herman et al. 2004*), and this area has the highest ratio of juveniles to adults.

The 1:1 sex ratio is consistent with other studies in which Blanding's Turtle habitat is isolated from main roads, which are a major cause of mortality in female turtles (Desroches and Picard 2005; Steen et al. 2006). If and when logging and mining activities are resumed in the Barren Meadow Brook area, the locations of roads should be carefully planned to reduce effects on nesting females and to facilitate the movement of Blanding's Turtles between seasonal use areas. Blanding's Turtles nest occasionally on road shoulders (Power 1989; McNeil 2002; Desroches and Picard 2005; Caverhill 2006), and this makes both females and hatchlings vulnerable to increased mortality from vehicle traffic.

The ratio of capture to search effort from visual surveys in 2006 was relatively low; although nearly 40% of the total effort was expended on visual surveys (117 of 300 hours), these surveys yielded less than 15% of the Blanding's Turtles caught. However, captures during visual surveys increased to almost 45% (34 of 76) in 2007 for a similar total effort. The refinement of a "search image" and improved knowledge of the study area by the observer likely accounted for the higher success rate and argue for continued use of this technique by experienced observers.

Trapping efforts prior to 2006 were limited by Caverhill (2006) (300 trap-nights between 2002 and 2005) but had higher capture rates. In 2006, trapping was systematic across most parts of the study area. This method yielded a lower capture rate but it removes the bias inherent in choosing trap locations; prior to the systematic survey, trapping was concentrated in areas where Blanding's Turtles had been seen. Systematic trapping also yielded captures in areas previously thought unproductive and identified previously unknown travel routes.

The estimated mean home range for males was larger than for Blanding's Turtles in Wisconsin and Massachusetts (Ross and Anderson 1990; Grgurovic and Sievert 2005), but it was similar to estimates from Minnesota (Piedgras and Lang 2000). Mean home range size in Barren Meadow Brook and Keddy Brook was influenced by one individual, whose home range was 1.6 to 3 times larger than that of other males. Even with such a large home range, activity centres among males did not overlap, except during communal activities such as mating and overwintering. This behaviour was consistent with observations by Ross and Anderson (1990).

Some previously unreported aggressive behaviours were observed during mating. Older males chased, mounted, and dominated smaller or younger males, forcing them to flee. The mean home range size for males was smaller than for females; this would be expected if a male is defending a territory from other males. This behaviour has never been reported elsewhere in Blanding's Turtles.

The mean home range size for females was much larger than has been observed in Wisconsin and Massachusetts (Ross and Anderson 1990; Grgurovic and Sievert 2005). This may reflect a paucity of nesting

sites in Barren Meadow Brook. In Kejimkujik National Park, most nesting occurs on lakeshore cobble beaches; in contrast, at McGowan Lake, most nesting occurs both on lakeshores and on slate outcrops, many of which are located well inland (Herman et al., 1999; NcNeil, 2002). In the Barren Meadow Brook area, three of four nesting sites were on rock outcrops where a limited amount of substrate has accumulated in crevices over the years.

The rarity of nesting sites would oblige females to travel long distances, sometimes across atypical terrain, as occurred with one Blanding's Turtle, which, in 2006, went directly overland through the forest to her nesting site (more than 1.0 km) instead of following the stream, as expected. Another female travelled over 5.0 km to reach her nesting area, even with apparently similar habitat nearby. These extensive movements largely explain differences in 2006 between the size of home ranges of males and the size of home ranges of females. All females tracked that year made similar large movements to nesting sites. This was not the case in 2007 and 2008; in both years, only two females nested.

Nesting every second or third year is observed in turtles in habitats with low productivity, where the female cannot accumulate the resources needed to invest in the production of eggs every year (Heppell 1998). The area round Barren Meadow Brook and Keddy Brook is mostly a fen, with relatively low productivity (Bourque 2006). Home range sizes of nesting females were significantly larger than the home range sizes of non-nesting females ($t = 4.84$, df = 9, $P < 0.001$), and this finding supports the hypothesis that a paucity of nesting sites adds to the energetic costs of reproduction. This could, in turn, explain the lower frequency of nesting in this population.

Overwintering sites are critical for Blanding's Turtles, particularly in Nova Scotia, which is at the northern limit of the species' range. Because they commonly overwinter for six months or more, the Blanding's Turtles in Nova Scotia spend half of their lives or more at overwintering sites. During unseasonably warm winter temperatures, Blanding's Turtles often become locally active at these sites, and they have even been observed mating in mid-January (Newton and Herman 2009). In the Barren Meadow Brook and Keddy Brook area, Blanding's Turtles were observed using communal overwintering sites, a behaviour that is widely reported for this species (Sajwaj and Lang 2000; Ultsch 2006; Newton and Herman 2009). Communal overwintering provides an opportunity for mating early in the spring, before production and fertilization of eggs.

The number and quality of nesting sites are much lower in the Barren Meadow Brook and Keddy Brook area than in the areas that support the other Nova Scotia populations. The productivity of the habitat is also low. Yet Barren Meadow Brook and Keddy Brook have the highest proportion of juveniles in the known Nova Scotia populations. One explanation could be lack of predation on juveniles. A high proportion of nests and hatchlings are predated by Raccoons (*Procyon lotor*), and hatchlings are also taken by Northern Short-tailed Shrews (*Blarina brevicauda*) (Power 1989; Standing et al. 2000) and Red Squirrels (*Tamiasciurus hudsonicus*). These predators are rare in or absent from the Barren Meadow Brook and Keddy Brook area (personal observation, JL). They were never encountered in the habitat at the Barren Meadow Brook and Keddy Brook area, which may therefore support higher hatching abundance and survival rates of Blanding's Turtles.

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