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Original Research Article

# Endangered species protection and evidence-based decision-making: Case study of a quarry proposal in endangered turtle habitat

Gabriella M. Zagorski [a], Douglas R. Boreham [b], Jacqueline D. Litzgus [a, *]

[a] Department of Biology, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario, Canada
[b] Northern Ontario School of Medicine, 935 Ramsey Lake Road, Sudbury, Ontario, Canada

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A B S T R A C T

Surface mining practices can negatively impact turtles through degradation of wetlands and surrounding upland habitat, alteration of movement corridors, increased risk of nest and turtle predation, and direct mortality. These impacts, in turn, can cause changes in sex ratios and population demography, which may ultimately lead to population declines and extirpation. Using radio-telemetry, GPS data loggers, and capture-mark-recapture surveys over two field seasons, we described the demography of, and identified critical habitat for, a population of endangered Blanding's turtles (*Emydoidea blandingii*) inhabiting an area of interest for development of a trap rock quarry in Ontario, Canada. We captured 56 turtles and estimated population size to be 80±18 turtles, and density to be 1.84 turtles/ha, which is among the highest reported densities for the species. Daily distances moved and home range sizes were generally smaller than conspecific values reported in the literature, suggesting that habitat quality was high as turtles did not need to move much to acquire necessary resources. We identified 15 nesting sites and 12 wetlands that housed overwintering turtles, both considered by government to be critical habitats with lowest tolerance to destruction. We mapped our spatial data based on the application of legislated provincial and federal recovery guidelines, and the results indicate that the quarry proposal should be rejected if the spirit of the law is upheld given that at least 63% and at most 100% of the proposed quarry area is categorized as endangered species habitat.


## 1. Introduction

An estimated 61% of turtle species are threatened with extinction or are already extinct (Gibbons et al., 2000; Lovich et al., 2018; Rhodin et al., 2018). Turtle life history characteristics limit the ability of populations to recover from anthropogenic threats as most species are long-lived with delayed sexual maturity and long generation times (Ernst and Lovich, 2009). Turtle populations are especially vulnerable because of their low fecundity and low recruitment, and even a small loss of adults can lead to population declines and extirpation (Congdon et al., 1993; Innes et al., 2008; Keevil et al., 2018). Adult survivorship, especially of females, is arguably one of the most important factors contributing to population persistence (Congdon et al., 1993; Heppell, 1998; Enneson and Litzgus, 2008). Habitat loss is the primary threat to turtles (Gibbons et al., 2000;

* Corresponding author.
*E-mail address:* jlitzgus@laurentian.ca (J.D. Litzgus).

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Rhodin et al., 2018), therefore description and quantification of home ranges, and nesting and overwintering sites (i.e., critical habitats; SARA, 2002) are essential to habitat and species protection. Because individual populations occur in different habitats, population-specific spatial data cannot always be effectively extrapolated among populations, necessitating local data collection to effectively inform decision making.

Quarrying is a type of surface mining that destroys turtle habitat (COSEWIC, 2016). Wetlands may become degraded from water discharge, changes in surface or groundwater flow, and chemical or sediment contamination (Azous and Horner, 2001; Tulloch Environmental, 2017). Terrestrial habitat may be destroyed by blasting, and turtles may be directly killed by excavation equipment or vehicles entering and exiting construction and operation zones (Azous and Horner, 2001; Steen et al., 2006; COSEWIC, 2016). The creation of quarry access roads and areas of finely crushed gravel may attract nesting females, increasing the risks of turtle and nest mortality and predation (Steen et al., 2006; ECCC, 2018). Many biological and legislative factors need to be considered when constructing and operating quarries in areas containing Species At Risk (SAR) turtles. Political factors should be excluded if endangered species laws are upheld for their intended purposes, which are to protect SAR and their habitats, and to facilitate their recovery (SARA, 2002; ESA, 2007).

The purpose of our study was to apply endangered species legislation to ecological data to inform decision-making about resource extraction. We examined a population of the endangered Blanding's turtle (*Emydoidea blandingii*; van Dijk and Rhodin, 2011) inhabiting Crown (i.e., public) Land in Algoma District, Ontario where a trap rock quarry is proposed. The objectives of our study were to (1) collect population demography data to quantify abundance, (2) collect spatial ecology data to quantify home range size and movements, and (3) use the spatial data to delineate critical habitats under provincial (Ontario) and federal (Canada) endangered species legislation, to provide a quantitative data-driven approach to decision-making about the quarry permit. We also discuss the challenges associated with data that may or may not support development in SAR habitat.

## 2. Methods

### 2.1. Habitat characterization and critical habitat

Under the Endangered Species Act (ESA) in Ontario, general habitat descriptions are created for species likely to be affected by human activities, and are intended to provide scientific evidence-based habitat protection (OMNRF, 2013). The general habitat description for Blanding's turtles divides used habitats into categories in order of least to most tolerant of alteration (OMNRF, 2013). Category 1 includes nesting and overwintering sites, plus a 30-m buffer, and is considered least tolerant of alteration. Category 2 is the used wetland complex and any waterbodies within 500 m of a species' occurrence, and is considered moderately tolerant to alteration. Category 3 is an area between 30 and 250 m from an occurrence buffering the suitable wetlands and waterbodies, and is considered most tolerant to alteration. The Ontario ESA is enforced on both public and private lands (ESA, 2007).

At the federal level in Canada, protection of critical habitat falls under the Species At Risk Act (SARA) which applies on federal lands, including military bases and First Nations lands (SARA, 2002). Critical habitat for Blanding's turtles was defined in a recent recovery strategy (ECCC, 2018). Nesting sites are given a 150 m terrestrial buffer, and wetland complexes in the 2 km radial distance of an observation receive a 240 m terrestrial buffer (ECCC, 2018). All areas surrounded by the terrestrial buffer that fall inside the 2 km radial distance from a turtle observation are defined as critical habitat units which should be protected from development (ECCC, 2018).

### 2.2. Study site

The study site (46°N, 82°W) is located on relatively pristine Crown Land in Algoma District, Ontario to which provincial legislation applies (ESA, 2007), and also sits within the Robinson-Huron Treaty Lands (1850) of Canada's First Nation peoples to which federal legislation applies (SARA, 2002). Human disturbance at the site includes wells placed to monitor ground water levels, ATV trails and a few small areas where test blasting for the quarry has occurred. The proposed quarry licensed area is 115 ha with an extraction area of 68.3 ha (Tulloch Environmental, 2017). The habitat includes a combination of rocky outcrops, mixed forest and wetlands. Common wetland types include open marshes, wet meadows, fens, vernal pools and treed swamps.

### 2.3. Population demography

Mark-recapture data were collected from June 2017 to November 2018. During the turtle active season (late April to September), surveys for Blanding's turtles were conducted 5 times per week by a minimum of 2 and up to 6 researchers. Sites were accessed using canoes, by walking around the edges or through wetlands, to hand capture individuals. Individual-specific data (body size, sex, and age category) were collected. All turtles were marked using marginal scute notching (Cagle, 1939), sexed using secondary sex characteristics (Ernst and Lovich, 2009), measured with calipers (±0.1 cm, Haglof Model CF59729), weighed using Pesola spring scales (±10 g), photographed, and any deformities recorded. Turtle capture locations (latitude, longitude) were recorded with a handheld GPS unit (Garmin GPSMap 64s), converted to UTM coordinates, and inputted into ArcGIS 9.2 (ESRI, 2006). Population size was estimated using the Lincoln-Peterson model calculated by hand. We opted to use the Lincoln-Peterson model, recognizing it assumes a closed population, because of the short duration of our mark-recapture surveys relative to the great longevity of Blanding's turtles (Congdon et al., 1993). Population density was calculated by dividing population size by area of wetlands where turtles were found. We did not include deep water (i.e., centers of lakes with water depth > approx. 5 m), terrestrial habitat or nesting sites in this calculation, as Blanding's turtles prefer shallow water and are mostly found in wetlands (COSEWIC, 2016).

### 2.4. Spatial ecology

Spatial data were collected from June 2017 to November 2018 using radio telemetry and miniature GPS data loggers placed on a subset of captured male and female Blanding's turtles. A total of 29 different Blanding's turtles were monitored with VHF radios (Advanced Telemetry Systems Inc., Isanti, MN; models R1655, R1650 and A2850) across the 2017–2018 and 2018–2019 field seasons. Gravid females ($N = 11$) were outfitted with GPS loggers (Lotek PinPoint Beacon Tag-240) to identify nesting sites. Each turtle was radio-located approximately 2 times per week throughout the active season, once per week in the fall, and once per month during the winter to confirm overwintering sites. Data collected included GPS coordinates (latitude, longitude) and behaviour (e.g., nesting, hibernating).

#### 2.4.1. Home ranges and daily distances moved

We calculated home range size using 100% Minimum Convex Polygons (MCPs; ha), and then calculated 95% kernel density estimates (Rowe et al., 2009; Edge et al., 2009, 2010; Laverty et al., 2016) with a smoothing factor (h) that resulted in kernel home range sizes being equal to the 100% MCP (Row and Blouin-Demers, 2006) for each turtle's annual home range size using functions created in RStudio (R Core Team, 2017). Home ranges were calculated only for turtles that were tracked every 2–3 days for 3 months or more during the active season (April–October). We tested for differences in mean home range sizes between the sexes using a Mann-Whitney *U* test. We also compared our calculated home range sizes to those published for other Blanding's turtle populations.

Daily distance moved (DDM; m/day) was calculated in RStudio for turtles that were tracked every 2–3 days for a minimum of one field season (May–October) with some individuals being tracked continuously for up to 23 months. DDM was calculated as the distance moved between consecutive radio-locations divided by the number of days between these consecutive tracking events. We compared mean DDM between the sexes using a *t*-test. We also compared our calculated DDM to those published for other Blanding's turtle populations.

#### 2.4.2. Nesting and overwintering sites

We gathered nest site data over two nesting seasons (2017 and 2018). GPS data loggers were deployed on female turtles when they were gravid with shelled eggs (as indicated by inguinal palpation), and retrieved and offloaded once eggs were no longer detectable by palpation (with the exception of 2 loggers that could not be retrieved until 14 August and 12 October). If a female was gravid for more than 7 days (expected battery life of programmed GPS loggers), the logger was replaced with a freshly-charged logger. Data from the GPS loggers were downloaded and tabulated in Excel. Nesting sites were confirmed by ground-truthing and visual inspection. If nesting sites were not found, GPS logger data were used to make the best estimate using GPS points in combination with habitat type (rocky outcrops) and VHF telemetry data. Distance travelled from water to nest site (m) was measured in ArcGIS. To quantify how far females travelled to nest, the distance from the wetland of origin was measured. If wetland of origin was known, the straight-line distance was measured from the nest to the wetland of origin. When the wetland of origin was unknown, the straight-line distance from the nest to the nearest waterbody was measured.

Overwintering areas were identified using VHF telemetry data collected from 24 different Blanding's turtles from September to December of 2017 and September 2018 to May 2019. Turtle location points were loaded into ArcGIS and the entire wetland where one or more hibernating turtles were identified was labelled as an overwintering area.

### 2.5. Provincial and federal mapping

Maps were created to delineate critical habitat using both the provincial and federal habitat protection documents (OMNRF, 2013; ECCC, 2018). All nesting sites found with GPS loggers, VHF transmitters, or by opportunistic nesting observations were recorded, and UTM coordinates for these locations were mapped in ArcGIS. The buffer tool was used to create a 30 m minimum buffer and a 250 m maximum buffer around each nest location as per the general habitat description for Blanding's turtles (Category 1 habitat; OMNRF, 2013). A buffer of 240 m was delineated around nesting sites to define federal critical habitat (ECCC, 2018). The ArcGIS polygon tool was used to create a polygon around overwintering wetlands and the buffer tool was applied to create a 30 m buffer around these wetlands as per the general habitat description for Blanding's turtles (OMNRF, 2013).

## 3. Results

### 3.1. Population demography

Blanding's turtles were found in almost every wetland, waterbody and creek surveyed (21 aquatic habitats had turtles/23 habitats surveyed). Male to female sex ratios were approximately equal ($\chi^2 = 1$, df = 1, $p = 0.4$; Table 1), and we captured one juvenile. A total of 56 Blanding's turtles were captured at the proposed quarry site, with 31 recaptured at least once. If a turtle

**Table 1**
Population ecology and mean ± standard deviation morphometric data for Blanding's turtles (*Emydoidea blandingii*) captured at a proposed trap rock quarry site in Algoma District, Ontario.

| Population metric | Value |
|---|---|
| Turtles captured (recaptures) | 56 (31) |
| Estimated population size | 80 |
| Body mass (g) | |
| Males | 1574.89 ± 143.51 |
| Females | 1432.68 ± 167.93 |
| Midline carapace length (cm) | |
| Males | 22.71 ± 0.80 |
| Females | 21.62 ± 0.61 |
| Midline plastron length (cm) | |
| Males | 20.18 ± 0.68 |
| Females | 20.33 ± 0.78 |
| Male: Female | 27:28 (+1 juvenile) |

was recaptured at any point in either of the 2017–2018 or 2018–2019 field seasons, not using radio telemetry, it was counted as a recapture. Estimated population size was 80 (95% CI ± 18) turtles. The area of wetlands used by turtles was approximately 43.0 ha, yielding a population density of 1.8 turtles/ha.

### 3.2. Spatial ecology

#### 3.2.1. Home ranges and daily distances moved

Home range sizes did not differ significantly between the sexes ($U = 45$, df = 2, $p = 0.2$; Fig. 1A). The turtle with the largest home range was a male (69.1 ha). Daily distances moved also did not differ significantly between sexes ($t = 0.73$, df = 16, $p = 0.47$; Fig. 1B). The turtle with the greatest DDM was an adult female (61.5 m/day).

#### 3.2.2. Nesting and overwintering sites

In the 2017 field season, we found 1 gravid female on 2 June 2017 and she nested on 11 June 2017. In the 2018 field season, the first gravid female was found on 2 June 2018 and the first female nested between 12 and 15 June 2018. Of the 12 GPS loggers deployed, 2 did not produce data due to researcher error. A total of 15 nesting sites were identified using GPS loggers, radio telemetry and nesting surveys; all of which were on rocky outcrops, which is common nesting habitat for freshwater turtles in the geographic region (Litzgus and Brooks, 1998; Litzgus and Mousseau, 2006; Markle and Chow-Fraser, 2014). Each nest site showed multiple signs of nesting activity including test-pitting and depredated nests, and one site had 4 different Blanding's turtle nests in an area approximately 1 m × 0.3 m. All nests were laid in rock crevasses where soil depth was approximately 10–30 cm. Turtles moved an average of 278.2 ± 132.7 m from their home wetland to nest. Of the 10 turtles with retrievable GPS logger data, nesting migrations took between 2 and 14 days with an average of 6 ± 4 days.

We identified 12 wetlands that housed overwintering turtles. A total of 47 individual turtles were observed in overwintering sites in the 2017/2018 and 2018/2019 winters. Of the 39 turtles whose overwintering sites were confirmed in the 2017/2018 season, 22 individual's overwintering sites were also found in the 2018/2019 season, and 13/22 (59%) returned to the same wetlands to overwinter in both winters. Of the individuals that did not overwinter in the same sites in both winters, distances between overwintering sites ranged from approximately 90 to 640 m. In 7 of the 47 (15%) overwintering observations, turtles were overwintering in areas where no other turtle was found overwintering. We cannot know with certainty that these sites were used by individual turtles as other turtles may have been present but just not detected. We found that 40 of the 47 (85%) overwintering observations were in wetlands where other turtles were also found hibernating. Water depth in overwintering sites ranged from 30 to 150 cm before ice formation. All turtles used overwintering sites within their active season wetlands or within 240 m of their active season wetlands.

### 3.3. Provincial and federal mapping

Habitat maps were created using the provincial legislation's 30 m minimum and 250 m maximum buffers (Fig. 2). Total categorized habitat using the 30 m buffer was 66.6 ha (62.6% of the 115 ha of land in the proposed quarry). Of the total categorized habitat, 14.8 ha (12.9% of the 115 ha quarry) was Category 1 habitat, 26.2 ha (22.8% of the 115 ha) was Category 2 habitat, and 25.6 ha (22.3% of the 115 ha) was Category 3 habitat when the minimum buffer was applied. Using the 250 m maximum provincial buffer, 114.8 ha (100% of the 115 ha) was categorized habitat, and Category 3 habitat increased to 73.8 ha (64.2% of the proposed 115 ha). A map was also created using the federal legislation's 240 m buffer around turtle occurrences (Fig. 3) which showed that 113.9 ha (99.9% of the 115 ha quarry) was categorized as critical habitat for Blanding's turtles.

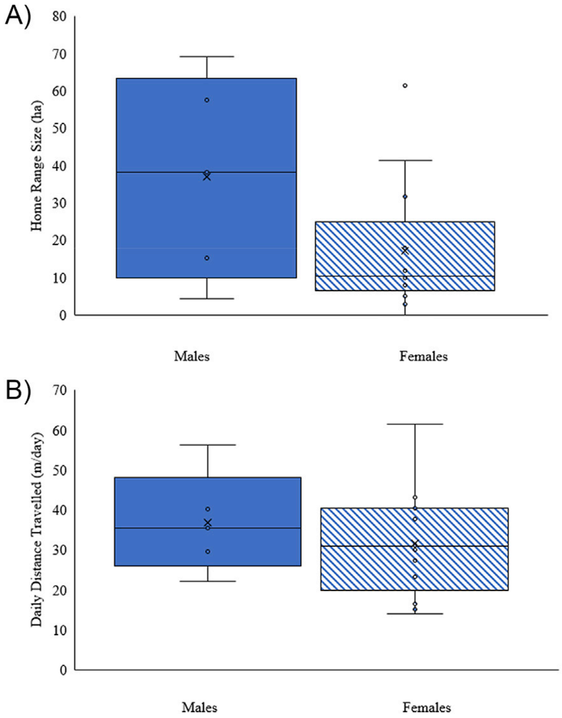


**Fig. 1. A)** Home range sizes and **B)** daily distances moved by male ($N = 5$) and female ($N = 13$) Blanding's turtles (*Emydoidea blandingii*) in Algoma District, Ontario. Home range sizes ($p = 0.20$) and daily movements ($p = 0.47$) did not differ between the sexes. X indicates the mean, horizontal line indicates the median, filled box indicates inter-quartile range, and whiskers indicate the highest and lowest observations.

## 4. Discussion

### *4.1. Population demography*

We found a large number of Blanding's turtles at our study site. Our calculated population density (1.8 turtles/ha) is the highest reported for Blanding's turtles in Ontario, followed by a population in Southern Ontario with a density of 1.4 turtles/ha (COSEWIC, 2016). Of the other 19 populations listed in the COSEWIC (2016) report for which density was calculated, 14 reported densities ranging from only 0.05 to 0.6 turtles/ha with an average of 0.2 ± 0.08 turtles/ha (COSEWIC, 2016). That abundance was greater at our site relative to other locations in the country likely reflects the relatively pristine nature of our study area, indicating it may not be the best location for a trap rock quarry if Blanding's turtle protection is prioritized as per the ESA and habitat description (OMNRF, 2013).

### *4.2. Spatial ecology*

Blanding's turtles in our study generally had smaller home range sizes and daily movements than turtles in other studies. Blanding's turtles in our study did not move more than 240 m from their active season wetlands, other than to nest. These data are important because they support current federal and provincial legislation requiring a terrestrial buffer to protect Blanding's turtle habitat (OMNRF, 2013; COSEWIC, 2016; ECCC, 2018). Edge et al. (2010) reported annual home range sizes of turtles in Algonquin Provincial Park almost twice the size of those of our turtles, yet both populations are at northern latitudes where habitat productivity is presumably relatively low. In contrast, Millar and Blouin-Demers (2011) reported smaller home range sizes but daily movements over 4 times the distances travelled by turtles in our study, even though they tracked turtles over a shorter time period on Grenadier Island, a more southern location in Ontario in a heavily developed area. Daily movements of Blanding's turtles in Algonquin Provincial Park (Edge et al., 2010) were approximately double the size of those in our study. The study site in Algonquin Park, where logging takes place and where human recreational use is high, was adjacent to human development, and therefore not as pristine as our study site. We presume our turtles may be moving less because habitat quality is high such that turtles did not need to move much to acquire necessary resources, but we did not quantify habitat quality.

We identified multiple nesting and overwintering sites, both considered Category 1 critical habitats least tolerant to destruction (OMNRF, 2013). A total of 15 nest sites were identified, 10 of which were found using GPS loggers. Rowe and Moll (1991) and Millar and Blouin-Demers (2011) found gravid females making average movements of approximately 900 m from their wetland of origin to nest. Our turtles moved 3 times less (approx. 278 m) to reach nesting sites, again suggesting that

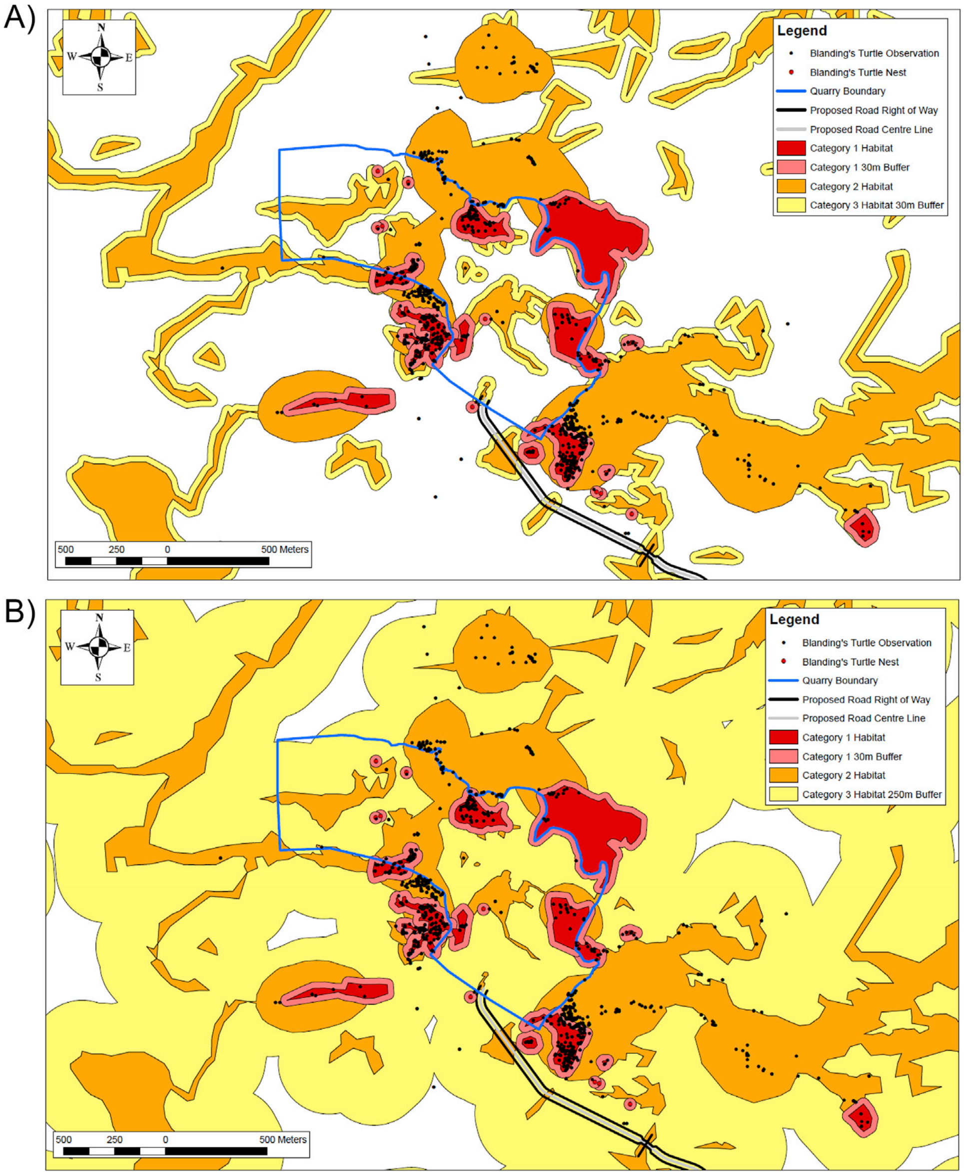


**Fig. 2. A)** Blanding's turtle (*Emydoidea blandingii*) habitat categorization map with a 30 m terrestrial habitat buffer as per provincial habitat description minimum, and **B)** 250 m terrestrial habitat buffer as per provincial habitat description maximum (OMNRF, 2013). The proposed quarry location is outlined in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

habitat resources are in close proximity, likely because the habitat matrix is relatively pristine. Many of the Blanding's turtles in our study exhibited communal hibernation and fidelity to overwintering sites. Newton and Herman (2009) suggested that Blanding's turtles return to the same overwintering sites each year to increase mating opportunities; they found at least 46 turtles overwintering in 7 sites, a number similar to our observations. We also observed mating aggregations at overwintering sites (Zagorski, 2019). Edge et al. (2010) found turtles overwintering in bogs, fens and marshes while we found turtles overwintering in marshes and swamps. Seburn (2010) suggested that turtles will sometimes use active season habitat as overwintering habitat, as we observed in some cases; however, only protecting areas where turtles have been observed basking can result in a lack of protection for overwintering sites.

### *4.3. Conservation implications*

At the time of submitting this manuscript, the quarry application was still pending approval from the provincial government regulator (OMNRF). In the interest of transparency and evidence-based decision-making, we willingly shared our

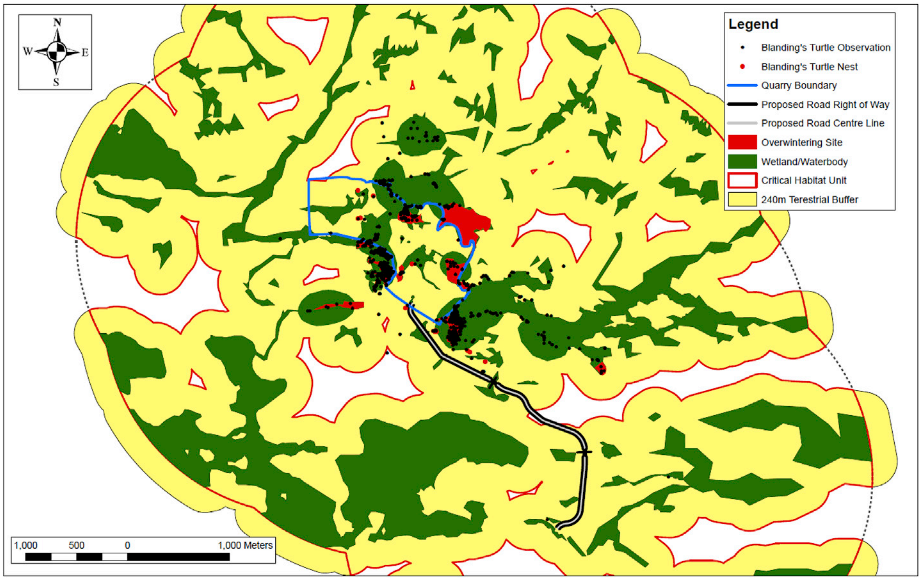


**Fig. 3.** Blanding's turtle (*Emydoidea blandingii*) critical habitat unit map as per the federal recovery strategy. Nesting sites are given a 150 m terrestrial buffer, and wetland complexes within the 2 km radial distance of an observation have a 240 m terrestrial buffer (ECCC, 2018). All areas surrounded by the terrestrial buffer that fall inside the 2 km radial distance from a turtle observation are defined as critical habitat units (ECCC, 2018). The proposed quarry location is outlined in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

data with the regulator, the quarry company, and their retained environmental consultant; we also extended an invitation to collaborate on field data collection. Upon seeing our data, the quarry company and their consultant launched a defaming attack on our careers by widely disseminating, in writing, accusations of academic misconduct, conflict of interest, and data fabrication. After several exchanges between lawyers, a letter of apology and retraction of the accusations was received from the consultant (but not the quarry company). It is our understanding that the process to apply for development permits in Ontario involves the developer hiring an environmental consultant to collect SAR data (and other data) at the proposed development site. This could be perceived as a conflict of interest and could be avoided by collaboration with academic researchers who collect focused data at arms-length from the regulator and developer. Our mapping results, based on both the provincial or federal legislation (Figs. 2 and 3), indicate that the quarry proposal should be rejected if the spirit of the ESA and SARA are upheld, given that at least 63% and at most 100% of proposed quarry area is categorized as endangered species habitat with low tolerance to disturbance, but it remains to be seen whether science, politics, or money will prevail in the quarry permit decision.

If the quarry is permitted, our study could serve as the “before” period of a Before-After-Control-Impact (BACI) study as we also collected demographic and spatial data at a control site (Zagorski, 2019). Long term BACI studies are recommended to examine effects of environmental change (Lesbarrères and Fahrig, 2012; Smokorowski and Randall, 2017). Without this experimental approach, changes in abundance and movement patterns would be missed during development (Price et al., 2011). BACI designs have been conducted in a road ecology context (e.g., Baxter-Gilbert et al., 2015; Colley et al., 2017; Markle et al., 2017), but few if any studies have been conducted for surface mining impacts. Overall Benefit Permits (OBP) allow for development in SAR habitat if the provincial Minister has the opinion that an overall benefit to the species will be achieved in a reasonable amount of time, that other alternatives have been considered, and that steps have been taken to minimize the impact on members of the species (ESA, 2007; OMNRF, 2012). Oftentimes, projects are approved before enough prior research has been done on habitats where SAR are present, resulting in poorly-informed mitigation and little to no overall benefit for the species. OBPs present an opportunity for scientists to conduct BACI studies to assess the effectiveness of mitigation measures and suggest improvements before, as well as after, the development is complete. BACI studies also can be used to influence current and future legislation regarding development in SAR habitats.

Our case study does not solely apply to Blanding's turtles in Canada. We are advocating a data-driven evidence-based approach that can be used in any area where development is proposed in SAR habitat, and where mitigation measures are required. Delineating critical habitat is essential for the protection of any SAR, especially those that use numerous habitat types across different life stages. Once critical habitat is identified, areas that are intolerant of development can be avoided and areas where the species will not be affected, or will be minimally affected, can be selected for development. Enforcing legislation during development projects is critical for the conservation of SAR, as is the use of scientific evidence to make decisions about development.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2019.e00751.

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