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Has the Eastern Red-backed Salamander (*Plethodon cinereus*) Declined in Ontario?

David C. Seburn[1, 3] and Erin Mallon[2]

[1]Seburn Ecological Services, 2710 Clarenda Street, Ottawa, Ontario K2B 7S5 Canada
[2]Ontario Nature, Suite 612, 214 King Street West, Toronto, Ontario M5H 3S6 Canada
[3]Corresponding author: davidseburn@sympatico.ca

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Amphibians are known to be declining around the world. Although often only reported for frogs, declines among salamanders are also known to be occurring. In Ontario, for example, citizen science monitoring indicates the Eastern Red-backed Salamander (*Plethodon cinereus*) has not been found in the last 20 years in many areas where it was historically known to occur. To test whether this decline is real or the result of lack of recent observations, we conducted targeted surveys in 25 grid squares with no recent records of the species and confirmed the presence of the Eastern Red-backed Salamander in 84% of these squares. It made up 90% (183 of 202) of all six species of salamanders encountered and was also the first salamander species detected in 90% of the squares. The median number of cover objects needed to detect a species was 34 (range 1–145) for Eastern Red-backed Salamanders, 129.5 (range 34–204) for Blue-spotted Salamanders (*Ambystoma laterale*), and 154 (range 6–187) for Spotted Salamanders (*Ambystoma maculatum*), and these detection rates differed significantly ($H = 9.46$, $P < 0.01$). Our study suggests that Eastern Red-backed Salamanders have not declined. We caution researchers using citizen science data that a lack of sightings of a "cryptic species" does not mean a species has declined.

Key Words: Eastern Red-backed Salamander; *Plethodon cinereus*; amphibian decline; Ontario

Introduction

Amphibian populations are known to be declining around the world (Wake and Vrendenburg 2008; Collins and Crump 2009; Collins 2010), and a global assessment of all known amphibian species concluded that a third were threatened with extinction (Stuart *et al.* 2004). Although amphibian declines are often associated only with frogs, salamanders are also declining with at least two apparent extinctions (Rovito *et al.* 2009). Salamander declines have been reported in Europe (van der Sluijs *et al.* 2013), Central America (Rovito *et al.* 2009), and North America (Bank *et al.* 2006; Means and Travis 2007). Declines have been observed in both aquatic (Wheeler *et al.* 2003; Lowe 2012) and terrestrial salamanders (Maerz *et al.* 2009; Caruso and Lips 2013). Some species have even declined within protected areas where habitat loss has not been an issue (Bank *et al.* 2006). The cause of many of these declines remains uncertain, although newly emerging diseases (Bosch and Martínez-Solano 2006; Martel *et al.* 2014), pollution (Bank *et al.* 2006), invasive species (Maerz *et al.* 2009), habitat loss (Arntzen 2015), and climate change (Parra-Olea *et al.* 2005; Caruso *et al.* 2014) or some combination of factors are all probable.

Salamander declines are important because these amphibians are a critical component of forest ecosystems. For example, the biomass of woodland salamanders is substantial and in some areas can be greater than that of birds or small mammals (Burton and Likens 1975). Salamanders are significant predators of forest floor invertebrates, and their loss from forest ecosystems could alter invertebrate diversity and soil dynamics as well as carbon and nutrient cycling (Davic and Welsh 2004; Best and Welsh 2014), although not all salamander removal experiments have detected significant changes (e.g., Hocking and Babbitt 2014).

The Ontario Reptile and Amphibian Atlas (ORAA; Ontario Nature 2016) is documenting the current distribution of amphibians and reptiles across Ontario, using 10-km by 10-km grid squares, modeled after the provincial Breeding Bird Atlas (Cadman *et al.* 2008). The ORAA is a citizen science project that relies on volunteer observers, researchers, and land managers to report sightings. Currently, over 3000 people have contributed over 350 000 records. The atlas database builds on the Ontario Herpetofaunal Summary (Oldham and Weller 1989), started in 1984, which includes historical records from published literature, unpublished government reports, and museum records. The overall goal of the ORAA is to document occurrences of herpetofauna across Ontario and identify trends in distribution.

Data from the ORAA suggest that salamanders have declined significantly. For example, there are no recent records (defined as the last 20 years) of the Eastern Red-backed Salamander (*Plethodon cinereus*) from over 400 grid squares where it was historically known to occur.

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Such absences could indicate that this species has been extirpated from more than 40 000 km^2. To assess whether the apparent decline is real or a result of lack of observations, we conducted targeted surveys of salamanders in 25 grid squares that lacked recent reports of Eastern Red-backed Salamanders. Although there are similar trends for other woodland salamanders, we selected the Eastern Red-back Salamander as the target species as it is typically more common, often accounting for more than 90% of individuals in salamander surveys in northeastern North America (Degraaf and Yamasaki 1992; Moore 2005; Pearce and Venier 2009).

Methods

We selected a study area west of Ottawa and north of Peterborough because a large number of ORAA grid squares in this region lacked recent reports of salamanders and also contained numerous parcels of easily accessible public land. Within this area, we identified grid squares with historical records from the ORAA (before 1995) of the Eastern Red-backed Salamander, but with no recent records (from 1995 onward). Historical records included citizen science observations, records obtained by the ORAA from published papers, government reports, and museum records. For each grid square with a historical record, we determined whether it contained accessible public land (provincial parks or Crown land). The presence of public land was determined by using Google Maps (2015) for provincial parks and the Ontario government's Crown Land Use Policy Atlas (MNRF n.d.) for Crown land. For each square containing public land, we determined the last year of observation for all other woodland salamander species. Priority was given to squares with multiple species of salamanders but only historical records, but an effort was also made to include squares from across the region.

We drove along roads adjacent to (or on) public land to select sites with suitable habitat for woodland salamanders (predominantly deciduous or mixed woods). Selected sites were surveyed in a standardized manner to ensure consistency of results. The two authors, both experienced field biologists, searched under appropriate cover objects (woody debris such as branches, small logs, bark, and anthropogenic debris, such as boards or sheet metal) for 1 h (two person-hours). Cover objects were carefully replaced as accurately as possible to minimize disturbance to the microhabitat. Surveys were stopped before 1 h elapsed if all historically reported salamander species had been detected.

We recorded the number of cover objects searched in each square, the number of cover objects searched to first detect each species, as well as the number of individuals of each species. The location (determined using a handheld Global Positioning System unit), date, time, and weather conditions were recorded for each survey. At four sites, only one biologist (D.C.S.) conducted the surveys and, in these cases, the survey was conducted over 2 h to compensate for the reduction in surveyors. Some Blue-spotted Salamanders (*Ambystoma laterale*) encountered in this study may have been unisexual polyploids. Given that polyploids must co-occur with Blue-spotted Salamanders, the presence of apparent Blue-spotted Salamanders is evidence that the species occurs at the site (Bogart and Klemens 2008). The median number of salamanders per square includes only squares with full, 1-h surveys and does not include squares where the species was not detected. We did not include squares where the Eastern Red-backed Salamander was not detected because it is possible it was not present. Our interest was in how many cover objects must be searched, on average, to detect each species when it is known to be present.

The non-parametric Kruskal-Wallis test was used for statistical comparisons using Minitab 8.3 (Minitab Inc., State College, Pennsylvania, USA). QGIS 2.0 (QGIS 2017) was used for data mapping.

Results

From 15 July to 18 September 2015, we surveyed 25 grid squares that lacked recent records of the Eastern Red-backed Salamander: 12 within provincial parks and 13 on Crown land. All but three squares were surveyed from 11 to 18 September. Substantial rainfall occurred on the weekend of 12–13 September and soils under cover objects were damp to wet for the following week when most of our surveys were undertaken. Eastern Red-backed Salamanders were detected in 21 of the 25 squares (Figure 1). The four squares where Eastern Red-backed Salamanders were not detected were not spatially clustered. Five other species of salamanders were detected in seven or fewer squares (Table 1). The median number of species detected in squares where full surveys were conducted was two (range 0–3, $n = 17$). Although the other salamander species were detected in few grid squares, at least 50% of the species detections resulted in the first recent report of the species in the square (Table 1).

There was no significant difference between the date of the last historical observation of Eastern Red-backed Salamanders in squares where we detected them (median date 1988, range 1977–1994) and squares where we did not detect them (median date 1987, range 1984–1993; $H = 0.01$, $P > 0.9$).

Eastern Red-backed Salamanders made up 90% (183 of 202) of all salamanders encountered. Considering the three most common species, the median number of individuals per square was eight for Eastern Red-backed Salamanders (range 2–37, $n = 13$), one for Blue-spotted Salamanders (range 1–2, $n = 3$), and one for Spotted Salamanders (*Ambystoma maculatum*; range 1–1, $n = 6$).

We surveyed 3876 cover objects in the 25 grid squares. A median of 205 (range 148–272) cover objects were checked per square when full surveys were conducted. Eastern Red-backed Salamander was the first species detected in 90% (19 of 21 squares) of the squares where they were found. For species found in

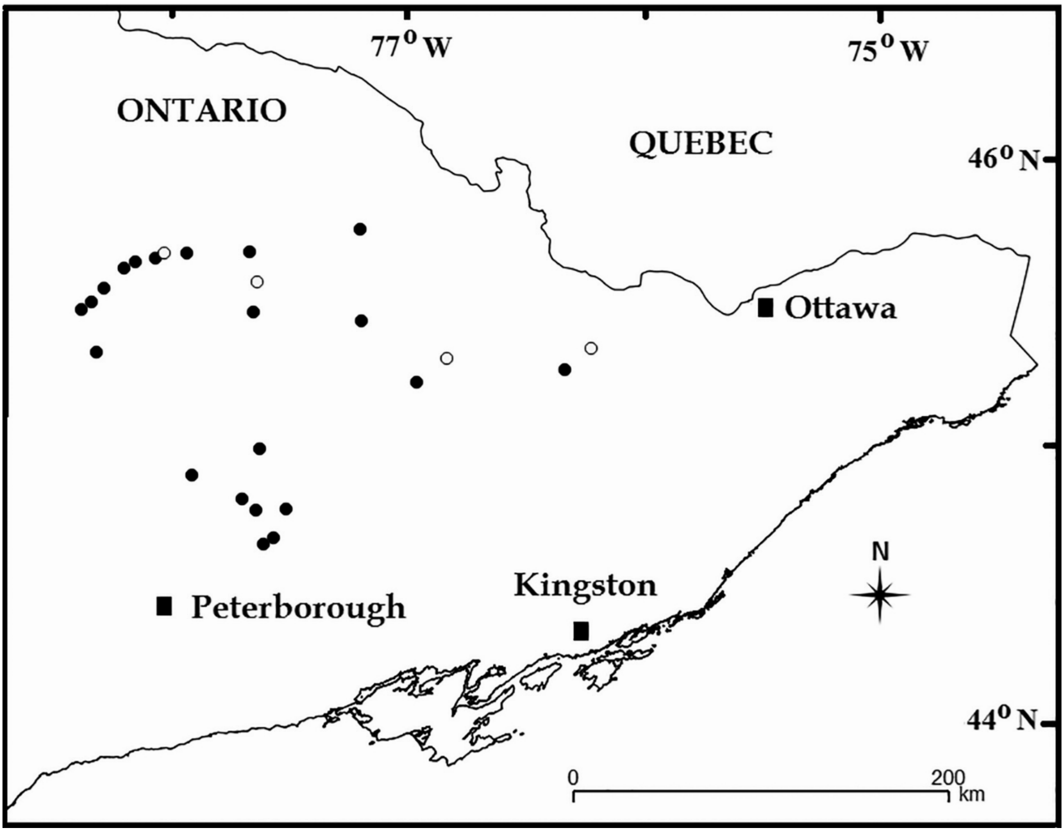

Figure 1. Location of salamander survey sites in Ontario. Solid circles indicate sites where Eastern Red-backed Salamander (*Plethodon cinereus*) was detected and open circles indicate where the species was not detected.

TABLE 1. Salamanders detected during surveys in 25 grid squares (10-km × 10-km) in Ontario in 2015. Squares with first recent record indicates the number of squares where this observation was the first recent (last 20 years) report of the species.

Species	Detected, no. squares	First recent record, no. squares (%)	No. found	Maximum no./square
LUNGLESS SALAMANDERS				
Red-backed Salamander (*Plethodon cinereus*)	21	21 (100)	183	37
Four-toed Salamander (*Hemidactylium scutatum*)	1	1 (100)	1	1
Northern Two-lined Salamander (*Eurycea bislineata*)	2	1 (50)	4	3
MOLE SALAMANDERS				
Blue-spotted Salamander (*Ambystoma laterale*)	4	2 (50)	5	2
Spotted Salamander (*Ambystoma maculatum*)	7	5 (71)	7	1
NEWTS				
Eastern Newt (*Notophthalmus viridescens*)	2	2 (100)	2	1

four or more squares, the median number of cover objects checked to detect a species was 34 for Eastern Red-backed Salamanders (range 1–145, $n = 21$), 129.5 for Blue-spotted Salamanders (range 34–204, $n = 4$), and 154 for Spotted Salamanders (range 6–187, $n = 7$), and these detection rates were significantly different ($H = 9.46$, $P < 0.01$).

Discussion

The Eastern Red-backed Salamander was easily detected in 84% of the squares we surveyed. A longer survey might have detected Eastern Red-backed Salamanders in more squares; however, detection probability for this species under natural cover objects reaches approximately 100% after 45 minutes (Otto and Roloff 2011).

Given that each grid square is 100 km^2 and that we surveyed only one small site for two person-hours, it is likely that, if we had surveyed multiple sites per grid square, we would have detected Eastern Red-backed Salamanders in an even greater percentage of squares. Thus, there appears to be no evidence that this species has been eliminated from parts of our study area. However, it is possible that the Eastern Red-backed Salamander has declined in other parts of the province as salamanders were rarely encountered in systematic amphibian surveys in southern Ontario, possibly because of widespread loss of forest cover (Hecnar 1997).

Eastern Red-backed Salamander made up 90% of the salamanders detected in this study. Other studies in Canada or the northern United States have found that Eastern Red-backed Salamanders make up at least 81% of the salamanders encountered (Bonin and Bachand 1997) and usually 90–99% of all salamanders (Degraaf and Yamasaki 1992; Moore 2005; Pearce and Venier 2009).

Eastern Red-backed Salamanders were easily detected in most grid squares, sometimes under the first cover object searched. Although salamanders are easy to find in the appropriate habitat, they are not often reported to the ORAA, where they make up only 2.5% of all amphibian and reptile observations in the last 20 years (unpublished data from the ORAA). Similarly, salamanders account for only 11% of observations contributed to the Carolina Herp Atlas and the low percentage was partially attributed to the cryptic nature of the species (Price and Dorcas 2011). Unlike most other amphibians and reptiles, salamanders are rarely encountered when not actively sought.

Citizen science has been widely demonstrated to be valuable in ecological science (e.g., Delaney *et al.* 2008; Dickinson *et al.* 2010; Ries and Oberhauser 2015). Nonetheless, it has limitations. Volunteers can overlook low-density patches of invasive species (Fitzpatrick *et al*. 2009), and the same may also be true for low-density or cryptic native species. Our results imply that many volunteers may have little interest in actively searching for salamanders. This is supported by the fact that we confirmed the presence of Eastern Red-backed Salamanders in 11 of the 12 squares surveyed within provincial parks, in easily accessible areas, usually along major hiking trails.

Although data from the ORAA are valuable in demonstrating where salamanders are known to occur, a lack of recent reports should not be assumed to indicate a current absence of the species without additional survey effort. Volunteers should be encouraged to visit squares with historical records and survey for salamanders to provide a more complete understanding of the current distribution in Ontario given the global concern over salamander declines. Our results suggest that at least 30 cover objects must be searched under to achieve a 50% probability of detecting Eastern Red-backed Salamanders at a site with suitable habitat, although more than 150 objects need to be checked to have a 50% chance of detecting some other species of woodland salamanders. We encourage individuals surveying for salamanders to record the number of cover objects checked to provide a measure of survey effort. Recording other data such as weather conditions, soil moisture under cover objects (e.g., wet versus dry), and forest type are also valuable. Great care should always be taken to replace cover objects. We also caution researchers using citizen science data that lack of records of a "cryptic species" does not mean a species has declined.

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