HERPETOFAUNA IN RONDEAU PROVINCIAL PARK, ONTARIO, CANADA: COMMENTS ON SAMPLE METHODOLOGY AND FOREST DISTURBANCE

by

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ABSTRACT

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Habitat selection in herpetofauna in Rondeau Provincial Park (RPP) around roads and human structures in built areas were described alongside recommendations on cover board material for their survey. The first objective was to ascertain differences among captures between cover board types: 1.5-inch (3.8 cm) thick, but smaller, spruce boards or 0.5-inch (1.3 cm) thick plywood boards. The second objective was to report on insights on cover board arrangement for maximum captures and appropriate seasons for herpetological surveys in the RPP region. A third objective was to determine how distance to nearest road or distance to the nearest artificial structure might influence captures. Cover boards were classified by type and frequency of capture across eight common species in RPP. Significantly higher captures than expected by the area from which all traps were drawing indicated patterns of selection. The period over which peak captures occurred was plotted for each species against temperature trends over the 2014 season. Species preferring moist habitats were attracted to a more insulating board that mimics damp microclimates; those preferring dry habitats were ready to use a less insulating plywood board. Model selection based on Akaike's Information Criterion (AIC) for small samples was used to find habitat associations for five species with sufficient captures in forest and built areas, distance to the nearest road, and distance to identified buildings in the cottage development. Roads created a significant apparent deterrent to the herpetofauna in RPP. As the climate changes, herpetofauna will be forced to change their activity seasons. The trends illustrated in RPP indicated that small, cryptic species of lizards could survive anthropogenic disturbance and even find overnight refuge in anthropogenic areas.

Keywords: Carolinian forest, cover boards, herpetofauna, resource selection, Rondeau Provincial Park

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CHAPTER 1: HERPETOFAUNA OF RONDEAU PROVINCIAL PARK

CONSERVATION OF THE CAROLINIAN FOREST IN CANADA: RONDEAU PROVINCIAL PARK

The last remnants of the Carolinian forest in Canada are within Ontario; historically the Carolinian forest covered 80% of the Carolinian zone but is now reduced to only 11% of the southwestern part of the province. As much as 90% of the original forest cover was converted to agriculture and urban development (Carolinian Canada 2004). The provincial and federal governments (alongside third-party recovery practitioners and stakeholders) encourage management and monitoring by landowners to enhance biodiversity and recreation opportunities within the remaining Carolinian forest (OPA 2006; Environment Canada 2014; OMECP 2021b). The first protected area legislated in the Carolinian forest region was Queen Victoria Provincial Park, established near Niagara Falls under the Provincial Park Act 1887; the Park is still the centrepiece of Niagara Falls tourism (Killan 1993:3-5). After creating Algonquin Provincial Park (originally Algonquin National Park), Ontario residents petitioned a new provincial park a few years later. The new Park was designated to protect a tourist resort – Rondeau Harbour's Pointe aux Pins (Killan 1993:16).

Unlike its predecessors, Rondeau Provincial Park (RPP) was developed based on its potential for opportunities for conservation and recreation, cited by the surrounding community as the top reasons for protection following a significant increase in outdoor activities for the average Ontario citizen (Killan 1993:18). Pre-2000, many studies related to park management focused on landscape ecology and population dynamics of fish and wildlife species. The management plan for RPP has been designed with now-historical data with just a few citations of more recent literature (OMECP 2021a). Whether the isolation of RPP is detrimental to gene flow between native populations is unknown. There are ongoing concerns that park officials have raised during each lease renewal that structures and activities on the Park's 200-300 leased cottage properties adversely affect habitat quality (OMECP 2021a). For cottagers and recreationists to enjoy their portion of the protected area, roadways and pathways leading to recreational features and private land within RPP are maintained by park staff. All the Park's roads, waterways, wildlife populations (especially white-tailed deer, [*Odocoileus virginianus*, Zimmermann]), invasive species, and buildings, including cottages, are assessed and monitored regularly for their effects on habitat degradation.

The southern region of Ontario is historically a mixture of tallgrass prairie and oak-savannah habitat with thick, fertile soils ideal for factory agriculture (OMNRF 2012). Throughout the mid-to-late 1800s this region was transformed into agricultural and urban settlements, whereby the savannah was left in fragments and highly disturbed (Bakowsky and Riley 1994). The current savannah remnants can be found in protected areas (such as RPP) and many railways and river bluffs. The scarcity of resources for active management of the oak-savannah makes protected areas even more critical to their conservation. The dry-soil savannah in Ontario varies widely in shrub cover and herpetofauna, depending on site history, fire regimes, and climate change (Catling and Catling 1993; Will-Wolf and Stearns 1999).

STUDY AREA: RONDEAU PROVINCIAL PARK

The southwestern portion of Ontario contains many species of trees at the northern limit of their range. Most forests in this region are small and fragmented, regenerated from intensive urbanization of the 1800s and early 1900s (Elliot 1998). The Carolinian habitat is synonymous with the Lake Erie Lowland ecoregion, where ecosystems are reminiscent of the southern United States (Kerr and Cihlar 2004). Scattered throughout the forest are Carolinian patches of black walnut (*Juglans nigra* L.), tulip trees (*Liriodendron tulipifera* L.), sycamore (*Platanus occidentalis* L.), hackberry (*Celtis occidentalis* L.), sassafras (*Sassafras albidum* (Nutt.) Nees), pin oak (*Quercus palustris* Münchh.), and red mulberry (*Morus rubra* L.), among a variety of other trees. These species can exist in this region because of their association with Lake Erie (Boutin et al. 2011).

Surrounding Lake Erie (in Ontario) is 817 ha of freshwater dune habitat, of which 86.4 ha belong to RPP (OMNRF 2012; Bakowsky and Henson 2014). This Park is not large compared to other protected areas (Killan 1993:19). It protects 11 km of beach on the western part of Lake Erie and 32.5 square km in total (Figure 1.1). It is surrounded by several kilometres of agricultural and developed lands, difficult for local wildlife to traverse. There are upwards of 70 cottages along the coastline, many of which predate the area's protected status. The main road throughout Rondeau Provincial Park and most of the cottages are immediately adjacent to forest and <150 m from the coastal dune habitat. Significant declines in tree canopy cover previously led to some efforts to regenerate historical savannah habitat in the region (Tanentzap et al. 2011).

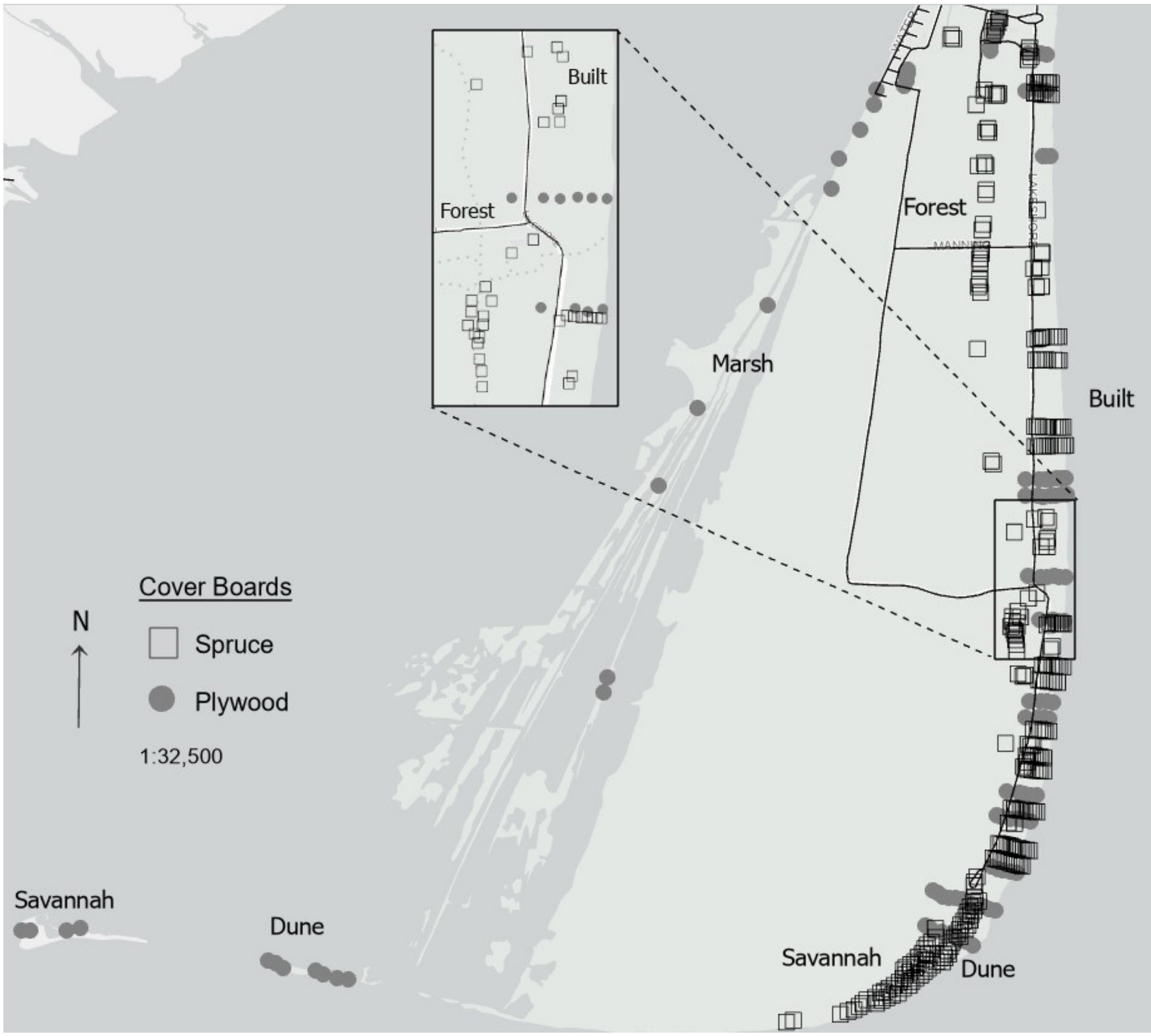

Figure 1.1. Map of Rondeau Provincial Park with cover board and road distribution. Inset shows detail on some of the transects used in Chapter 3 to compare reptile and amphibian captures in forest and built areas of the park where they are adjacent.

MONITORING HERPETOFAUNA IN RONDEAU PROVINCIAL PARK

Studying habitat associations is essential to conservation efforts and environmental assessment programs (Gibbon et al. 2000; Diele-Viegas et al. 2018). Targeted management efforts can enhance understanding of habitat use and selection, preserving populations most at risk. By incorporating herpetofauna into local conservation schemes, biodiversity can be better represented, understood, and therefore, conserved (Roll et al. 2017). Herpetofauna comprise more than half of all terrestrial vertebrates, while the primary focus of most wildlife researchers is birds and mammals (Hecnar 2009). Relative to all currently described species, herpetofauna are loosely considered adequately studied globally, yet are rarely considered in local management plans (Roll et al. 2017; Titley et al. 2017). Excluding any taxon from a management plan on any scale is to mischaracterize the ecological status of that region. This issue is magnified in the tropics but also comes to light in southern Ontario (Roll et al. 2017).

The data described by Brazeau (2016) and used in Chapters 2 and 3 of this thesis are part of an ongoing investigation of the influence of cottages on the distribution of the five-lined skink (*Plestiodon fasciatus* L.) and other herpetofauna as a means to contribute to decisions in Rondeau Provincial Park's conservation strategy. Habitat and species presence/absence surveys have been ongoing since the creation of RPP (OMECP 2021b). These surveys are the incentive for a herpetofaunal monitoring program in RPP that began in 2013. The layout of cover boards as passive traps to survey are illustrated in Figure 1.1. Chapter 2 analyses all cover boards in all habitats, whereas Chapter 3 focuses on the built areas and the forest habitat. As it is diverse, the herpetofauna community in RPP allows an indicator species approach to habitat fragmentation assessments (OMECP 2021a). An inlaid map shows some of the detail for Chapter 3 (Figure 1.1).

More observations were made of reptiles than the amphibians, with only the rare hog-nosed snake (*Heterodon platirhinos* Latreille) without sufficient data for analysis (Tables 1.1, 2.1, 2.2). The common garter snake (*Thamnophis sirtalis* L.) is the only reptile to contain no federal (SARA) or provincial (COSSARO) designation and is internationally (IUCN) considered of least concern. The Dekay's brown snake (*Storeria dekayi* Holbrook) is federally designated as not at risk. The eastern fox snake (*Pantherophis gloydi* Schmidt and Kunz) and the five-lined skink are federally considered endangered, and the eastern ribbon snake (*Thamnophis sauritus* L.) is of special concern provincially and threatened federally (Government of Canada 2021; COSSARO 2022). Spring is the most crucial season for the survival of reptiles in Ontario, with an early emergence period leading directly into the breeding season for five of the six species (Table 1.1).

The most uncommon amphibian species captured in RPP were: the American toad (*Anaxyrus americanus*, Holbrook 1836), wood frog (*Lithobates sylvaticus* Leconte), eastern newt (*Notophthalmus viridescens* Raf.), Fowler's toad (*Anaxyrus fowleri* Hinkley), and the northern leopard frog (*Lithobates pipiens* Schreb.; Table 1.2). Of these species, only the northern leopard frog is classified as not at risk by the federal Species at Risk Act (SARA). Except for the Fowler's toad (endangered), all amphibians observed in RPP do not yet have a status with the provincial Committee on the Status of Species at Risk in Ontario (COSSARO) because they are data deficient. All amphibians in RPP breed primarily in the spring and emerge before mid-May. Of the eight amphibians present during Park surveys, only the blue-spotted salamander (*Ambystoma laterale*

Hallowell), green frog (*Lithobates clamitans* Latreille), and red-backed salamander (*Plethodon cinereus* Green) have sufficient data for meaningful analysis in this thesis.

LAYOUT OF THE THESIS

This thesis will cover the following objectives: Chapter 2 will ascertain the more efficient cover board type, spruce or plywood boards, and report insights on cover board arrangement for maximum captures and appropriate seasons for herpetological surveys for the region of Rondeau Provincial Park. It will list each species, detailing life-history traits such as refuge habitat preference and seasonal emergence times and compare these details to what is known about the captures. Chapter 3 will compare captures of herpetofauna between disturbed and undisturbed forest macrosites for each species and describe whether canopy cover is a successful predictor of the presence of amphibians and reptiles using resource selection functions. Due to the nature of general descriptions across many genera, it is predicted that passive traps make for the most effective observation methods. Passive traps are highly versatile in deployment and more environmentally conscientious than alternative means. It is also predicted that more individuals across all species will choose locations less disturbed than locations of more frequent human traffic (roadways and built areas). Furthermore, species may adhere more closely to their environmental requirements than to disturbance factors within their range.

Table 1.1. Reptile species of Rondeau Provincial Park. Species in bold contained sufficient data for further analysis; END: Endangered, THR: Threatened, SC: Special concern, LC: Least concern, NAR: Not at risk, ND: No data

Species	Refuge Habitat	Capture Totals	Emergence	Breeding	Status		
					IUCN[4]	SARA[3]	COSSARO[2]
Heterodon platirhinos Eastern hog-nosed snake	Mammal burrows, loose/sandy soils, rock fissures, forests[1]	1	Mid-April[8]	Autumn, occasionally spring[6]	LC	THR	THR
Pantherophis gloydi **Eastern fox snake**	Marshes, prairies, forests[5]	39	Mid-April[5]	May and June[5]	LC	END	END
Plestiodon fasciatus **Common five-lined skink**	Wooded areas, rock outcrops, decaying wood, forest debris, woodpiles[6]	3784	Early April[9]	Spring[6]	LC	END	END
Storeria dekayi **Dekay's brown snake**	Bogs, swamps, marshes, damp woodlands, urban centres (parks, cemeteries, empty lots)[6]	343	Early spring[7]	Spring[7]	LC	NAR	ND
Thamnophis sauritus **Eastern ribbon snake**	Freshwater streams, ponds, marshes, bogs, swamps[6]	67	Early spring[7]	Spring[7]	LC	SC	SC
Thamnophis sirtalis **Common garter snake**	Meadows, woodlands, marshes, streams, drainage ditches, suburbs[6]	1203	Early spring[7]	Spring, occasionally autumn[7]	LC	ND	ND

1. Thomasson and Blouin-Demurs 2015; 2. COSSARO 2018; 3. Government of Canada 2021; 4. IUCN 2021; 5. Row et al. 2012; 6. Powell et al. 2016; 7. Canadian Herpetological Society 2021; 8. Cunnington and Cebek 2005; 9. Hecnar and M'Closkey 1998.

Table 1.2. Amphibian species of Rondeau Provincial Park. Species in bold contained sufficient data for further analysis; END: Endangered, LC: Least concern, NAR: Not at risk, ND: No data.

Species	Refuge Habitat[1]	Capture Totals	Emergence	Breeding	Status		
					IUCN[2]	SARA[3]	COSSARO[4]
Anaxyrus americanus American toad	Forest, suburbs, shallow freshwater	1	Early spring (April)[5]	Early spring[5]	LC	ND	ND
Anaxyrus fowleri Fowler's toad	Floodplains, wooded areas, suburbs, fields	4	Spring (May)[6]	Spring (May)[6]	LC	END	END
Ambystoma laterale **Blue-spotted salamander**	Forests, swamps, marshes	2195	Early spring (April)[7]	Spring[1]	LC	NAR	ND
Lithobates clamitans **Green frog**	Permanent or semi-permanent waterbodies	46	Early spring (April)[5]	Late spring (June)[5]	LC	ND	ND
Lithobates pipiens Northern leopard frog	Slow streams, marshes, bogs, ponds, lakes	8	Early spring (April)[5]	Late spring[5]	LC	NAR	ND
Lithobates sylvaticus Wood frog	Shallow freshwater, woodland streams, willow thickets	2	Early spring (April)[5]	Early spring[5]	LC	ND	ND
Notophthalmus viridescens Eastern newt	Ponds, small lakes, marshes, ditches, slow streams, damp forests	3	Early spring (April)[7]	Spring or autumn[1]	LC	ND	ND
Plethodon cinereus **Eastern red-backed salamander**	Moist mature forest, woody debris, leaf litter	135	Early spring[8]	Spring or autumn[8]	LC	ND	ND

1. Powell et al. 2016; 2. IUCN 2021; 3. Government of Canada 2021; 4. COSSARO 2018; 5. Klaus and Lougheed 2013; 6. Yagi 2015. 7. Nature Conservancy Canada 2020; 8. Canadian Herpetological Society 2021.

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CHAPTER 2: INVESTIGATING HABITAT ASSOCIATIONS FOR EIGHT SPECIES OF CAROLINIAN HERPETOFAUNA

Studies of distribution, abundance, and habitat selection in herpetofauna are complex undertakings. Many species are cryptic and have evolved to balance secretive behaviour with required daily activities (Engeman et al. 2016). The most crucial part of sampling cryptic populations is adopting an effective, efficient methodology that also captures variable phenology across different species. Any method requires an ethical design and, for most researchers, must also be inexpensive. Synthesizing data from multiple studies is one way to analyze data from various sources with new results when field research is infeasible. A standardized approach is necessary to compare research spanning several authors and years (Grant et al. 1992; Engeman et al. 2016). The challenges in standardizing across databases are the multitude of study designs and their individual biases in observations among the different researchers.

One of the most common methods of surveying herpetofauna involves live traps, including passive traps under natural or artificial cover, in the latter case often known as cover boards. Cover boards may be equally effective, less expensive, and less environmentally destructive than other capture forms (Grant et al. 1992; Sutton et al. 1999; Houze and Chandler 2002). Researchers have adapted cover boards for different scenarios, including for capturing arboreal species with artificial bark. This particular adaptation of the cover board has positive results with a much higher observation and capture rate than other methods (Nordberg and Schwarzkopf 2015). A researcher can track cover board use based on daily or weekly surveys, during which animal tracks or individuals are identified (Engeman et al. 2016). In conjunction with a method to track recaptures, cover boards can assist in estimating population size.

Forests in and around Rondeau Provincial Park (RPP) are highly disturbed by five main factors: deer browsing, cottages, roads and pathways, beach stabilization, and commercial logging. As a result, forest managers have observed significant declines in forest canopy cover, which has led to some areas regenerating historical savannah habitat (Tanentzap et al. 2011). Vegetation is considered an essential moderator of temperature and one of the most critical factors in habitat choice in squamates and amphibians (Cortés-Gómez et al. 2013; Krause Danielsen et al. 2014).

The first objective of this chapter is to ascertain differences among captures between cover board types: 1.5-inch (3.8 cm) thick spruce or 0.5-inch (1.3 cm) thick plywood boards. Some captures under natural debris will serve as a benchmark to the natural habitat. The second objective is to report insights on cover board arrangement for maximum captures and appropriate seasons for herpetological surveys in the RPP region. Cover boards will be classified by type and frequency of capture across eight more common species in RPP (listed in Table 1.3).

Variations in temperature throughout the active season may cause presence-absence to fluctuate based on target species (listed in Table 2.1). Individual species may prefer natural debris over cover boards supplied by a researcher; where natural debris may be more frequent or result in a more favourable microclimate, cover boards will have a reduced capture rate.

Small, arid-adapted, diurnal reptiles have higher capture rates with increased minimum daily temperatures (Read and Moseby 2001). For example, the common garter snake (*Thamnophis sirtalis*, L. 1758) may be found more frequently in drier, mixed-canopy forests than the ribbon snake (*T. sauritus,* L. 1766; Table 2.1). It is predicted that more captures will occur under plywood boards than spruce due to their larger size (Hecnar and M'Closkey 1998).

Table 2.1. Study species categorized by the habitat each species was located in and when each was likely to be found at Rondeau Provincial Park (RPP) in 2014.

Species	Habitat in Rondeau Provincial Park[1]	Peak activity[2]
Ambystoma laterale Blue-spotted salamander	All	Spring
Lithobates clamitans Green frog	F, S, B	Late spring
Pantherophis gloydi Fox snake	F, S, D	Mid-to-late spring
Plestiodon fasciatus Five-lined skink	All	Spring
Plethodon cinereus Red-backed salamander	F	Spring or autumn
Storeria dekayi Dekay's brown snake	F, S, B	Spring
Thamnophis sauritus Eastern ribbon snake	All	Spring
Thamnophis sirtalis Garter snake	All	Spring or autumn

1. F: forest, S: savannah, B: built areas, D: dune, All: present in all available habitats
2. Tables 1.1, 1.2

METHODS

Surveys of spruce cover boards (n = 292), plywood cover boards (n = 111) and natural debris piles (n = 37) were conducted 42 times from May to October 2014. Five broad categories were used to describe the habitat where they were placed or naturally occurred: stabilized dune, savannah, built areas, marsh, and forest (Figure 1.1). The spruce boards were untreated and 120 cm x 11.25 cm; they were set in pairs 2 m apart, and each placement site was located approximately 40 m apart. The plywood boards were untreated and 122 cm x 122 cm; they were placed singly in transects on the perimeter of RPP. The spruce board survey contained a nearly equal number in four habitats, 40 in dune, 37 in savannah, 30 in built areas, and 40 in the forest. The locations of plywood boards were unequal across habitat types, 37 boards in the dune habitat, 25 in the savannah, 20 in built areas, 19 in the forest, and 10 in the marsh. Reference areas of natural debris were searched with the same frequency as the cover boards and debris varied from small to large wood piles, including beached driftwood.

ANALYSIS

A test of habitat associations was done separately for the two types of cover boards due to differences in the number of each type and the absence of spruce boards in the marsh. Natural debris piles were reported as references only. The fox snake was not considered in calculations of habitat association due to its extensive range, allowing individuals to be drawn into any trap placed on the RPP peninsula. To estimate the minimum area over which a cover board attracts an individual of each species, their point locations were expanded to circular areas (buffers) using ArcGIS Pro (version 2.8.2); the circle radii matched those from estimated home ranges for each species (Table 2.2).

The buffers were combined between overlapping boards within the same habitat type. The total area of buffers in each habitat per species was then calculated. The total area covered by the boards within a single habitat was then divided by the total area covered by all boards across all habitats providing the proportion of total board coverage afforded to each habitat. This factor was multiplied by the number of captures by species during the entire season, giving the expected number of captures by species in each habitat. Significantly higher captures than expected by the area all traps are drawing from were tested with a Chi-squared goodness-of-fit test. Each species was plotted with the median number of captures to determine when higher-than-average captures occurred. A chi-squared goodness-of-fit test was also used to test for differences in capture success comparing plywood and spruce cover boards. The period over which peak captures occurred was plotted for each species against temperature trends over the 2014 season recorded at the Erieau (AUT), Ontario weather station (Government of Canada 2021). RStudio (version 1.4.1103) and R (version 3.6.3) were used for all analyses and graphics.

Table 2.2. Home range and its corresponding radius by species used to estimate the draw distance to the cover boards.

Species	Citations of research describing home range	Radius (m)
Ambystoma laterale Blue-spotted salamander	Individuals were tracked via radio telemetry or detected via PIT telemetry to measure a life zone extending from the edge of a breeding pool. Ryan and Calhoun 2014	150
Storeria dekayi Dekay's brown snake	An English and French literature survey using studies at least one month in duration or studies containing detailed telemetry information. Studies containing migration-only data were excluded. Displacement and introductory trials were also excluded. Macartney et al. 1988	14
Pantherophis gloydi Fox snake	A comparison of minimum convex polygons between Point Pelee National Park and Hillman Marsh Conservation Area in Southern Ontario, Canada. The study examined movement patterns and two spatial scales of habitat use patterns – home range and location. Individuals were tracked with implanted transmitters. Row et al. 2012	1200
Thamnophis sirtalis Garter snake	An English and French literature survey using studies at least one month in duration or studies containing detailed telemetry information. Studies containing migration-only data were excluded. Displacement and introductory trials were also excluded. Macartney et al. 1988	210
Lithobates clamitans Green frog	Throughout the active season, movement patterns and home ranges of green frogs were studied in Michigan from 1948-1949. Toe clippings and detailed descriptions of individuals allowed for identification using capture-recapture methods. 1221 green frogs for a total of 2056 captures were described during daytime and nighttime surveys. Martof, 1953	4.4
Plethodon cinereus Red-backed salamander	Co^{60} radio telemetry was used to track 40 individuals throughout northern Michigan. Home ranges were studied as a precursor to understanding the homing ability in this species. Home range areas were calculated three ways – polygon, circular, and elliptical. These three were based on whether the salamanders were associated with logs or tree root systems. Kleeberger and Werner 1982	2.8
Thamnophis sauritus Ribbon snake	An English and French literature survey using studies at least one month in duration or studies containing detailed telemetry information. Studies containing migration-only data were excluded. Displacement and introductory trials were also excluded. Macartney et al. 1988	50
Plestiodon fasciatus Five-lined skink	No fixed range: tracking indicates that most individuals made regular linear movements while occasionally returning to the same locations. Brazeau and Hecnar 2018	12

RESULTS

SEASONAL HABITAT ASSOCIATIONS OF REPTILES IN RONDEAU PROVINCIAL PARK

Reptile captures across all five species began in May, and most captures occurred between June and the first week of August and again mid-September (Figure 2.1). The latest emergence was the fox snake during the last week of May. The brown snake was first captured approximately one week before captures of the fox snake.

More than 50% of the fox snake captures occurred between early June and the end of July, recurring again only in mid-September. The garter snake's peak observations were between June and July, after which point, the captures varied little. Mid-to-late June through the first week of August was the peak time for captures of the ribbon snake; outside of this period, there were very few captures recorded. The five-lined skink maintained more than 50 individuals captured from the beginning of May through the last week of August, where observations fell below 50 nearly consistently until the end of the capture period in October.

Overall, spruce boards had far more captures than plywood boards (Table 2.3). Spruce boards also caught five species that the plywood boards did not capture: the eastern hog-nosed snake, American toad, Fowler’s toad, wood frog, and eastern newt. The highest number of captures for the five-lined skink occurred in the dune habitat under a spruce cover board; for the garter snake, the highest number of captures occurred under a plywood cover board. The fox snake's most frequent capture appeared in the forest under the plywood. The ribbon snake had two captures under plywood cover boards, one in the marsh and the second in the dune. The brown snake was captured equally under plywood and spruce cover boards in the marsh and savannah.

All species had strong associations with habitat (Chi-squared goodness of fit tests all significant at $p<0.01$), but in a variety of ways (Table 2.4). The five-lined skink was captured less than expected based on the area of draw to the cover boards in the forest, but double what was expected in the built areas. The garter snake had more than three times fewer captures in the forest than expected, considerably more than expected in the savannah, and just over twice as many as expected in the marsh. The brown snake had six times fewer captures than expected in the dune habitat and more than three times as many in the marsh. The brown snake was captured less often than expected in built areas and nearly three times more than expected in the savannah. The eastern ribbon snake had insufficient captures to describe habitat associations, most occurrences in the built area of RPP. Fox snake occurrences aligned with increases in temperature over a week (Figure 2.3). From September to the end of the surveys, there was only one capture of the ribbon snake. The lack of captures was associated with a rapid decline in temperature in the first week of September.

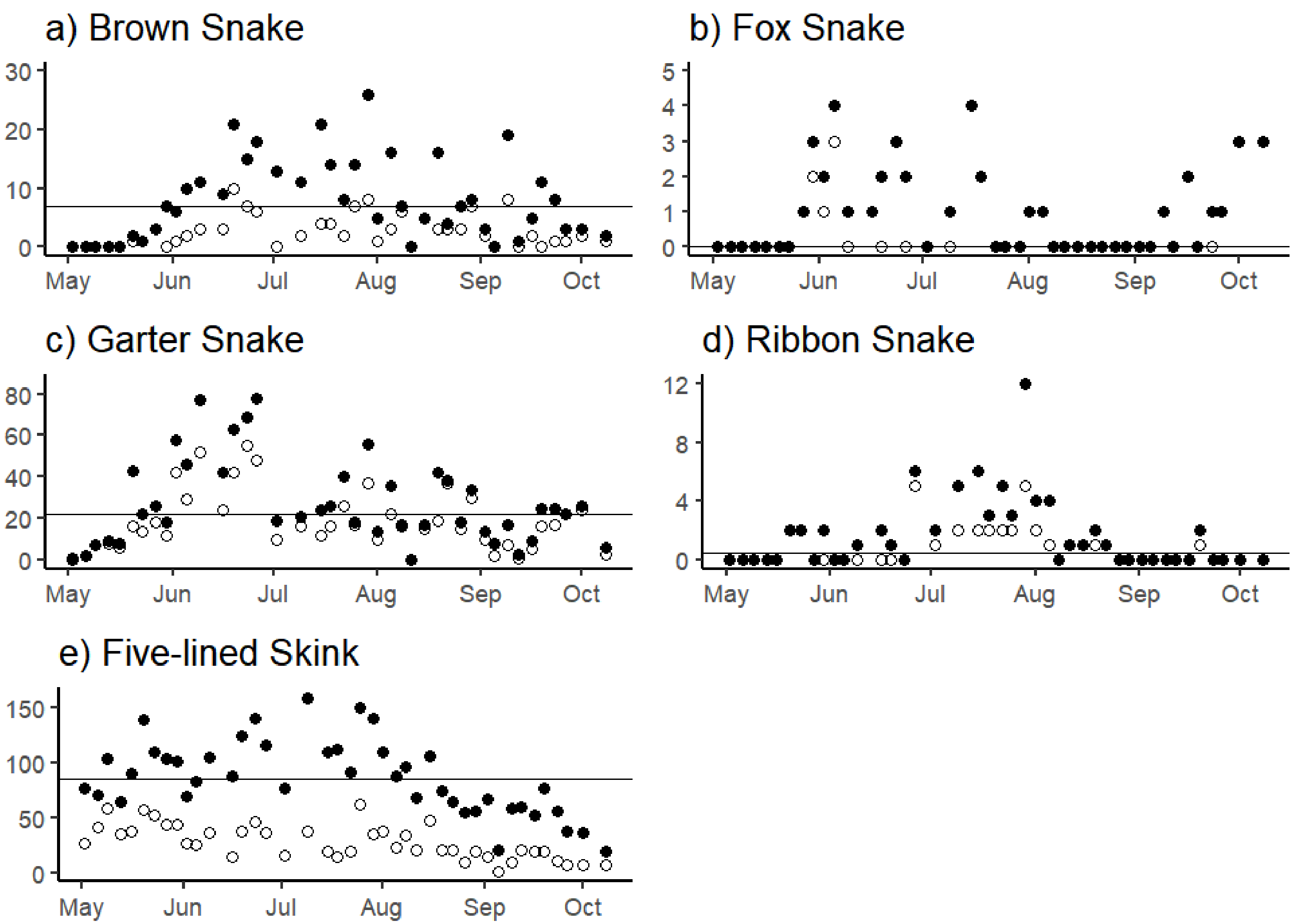

Figure 2.1. Total captures under all cover boards (solid dots) and plywood boards (open dots) of a) brown snake (*Storeria dekayi*), b) fox snake (*Pantherophis gloydii*), c) garter snake (*Thamnophis sirtalis*), d) ribbon snake (*T. sauritus*), and e) five-lined skink (*Plestiodon fasciatus*). The horizontal line on each graph represents the median daily total number of captures for all cover boards.

Among significant differences in capture success comparing cover boards, the larger plywood boards outperformed the spruce boards in the dune, built, and savannah habitats in captures of the five-lined skink ($\chi^2 = 380$, $p<0.001$). The plywood boards also outperformed in the forest and dune habitats for captures of the garter snake ($\chi^2 = 22.5$, $p<0.001$), but the spruce boards caught more than expected garter snakes in the savannah habitat. For captures of the brown snake ($\chi^2 = 10.5$, $p=0.001$), spruce boards outperformed plywood in the savannah and dune habitats, and plywood boards were more effective at captures in the built habitat.

SEASONAL HABITAT ASSOCIATIONS OF AMPHIBIANS IN RONDEAU PROVINCIAL PARK

Over 70 blue-spotted salamanders were captured on the first survey (Figure 2.2). At the start of June, captures of this species decreased by approximately half until mid-to-late August through October, and then they were restored to levels observed in the spring. Captures of the green frog did not occur until early July, with relatively few occurrences that peaked in mid-August, and there were no further captures after the first of October. Capture was not recorded until temperatures stabilized above 12 degrees Celsius at night and above 20 degrees Celsius during the day (Figure 2.3). The red-backed salamander was captured most frequently prior to July 1 and after September 1. The disappearance of the red-backed salamander during July-September aligned with higher daily temperatures, captures reoccurring as temperatures returned

Table 2.3. Species-specific counts at RPP of the 292 spruce boards, 111 plywood boards and 37 piles of natural debris.

Species	Spruce	Plywood	Natural debris	Highest daily capture for one cover board
Heterodon platirhinos Eastern hog-nosed snake	1	0	0	
Pantherophis gloydi Eastern fox snake	10	29	0	3 under plywood 1 under spruce
Plestiodon fasciatus Common five-lined skink	2452	1198	134	7 under plywood 10 under spruce
Storeria dekayi Dekay's brown snake	224	117	2	5 under plywood 5 under spruce
Thamnophis sauritus Eastern ribbon snake	34	33	0	2 under plywood 1 under spruce
Thamnophis sirtalis Common garter snake	370	824	9	8 under plywood 6 under spruce
Total reptiles:	3091	2201	145	
Anaxyrus americanus American toad	1	0	0	
Anaxyrus fowleri Fowler's toad	4	0	0	
Ambystoma laterale Blue-spotted salamander	2095	93	7	4 under plywood 9 under spruce
Lithobates clamitans Green frog	35	9	2	1 under plywood 2 under spruce
Lithobates pipiens Northern leopard frog	7	1	0	
Lithobates sylvaticus Wood frog	2	0	0	
Notophthalmus viridescens Eastern newt	3	0	0	
Plethodon cinereus Eastern red-backed salamander	134	1	0	1 under plywood 5 under spruce
Total amphibians:	2281	104	9	

Table 2.4. Expected and observed frequencies of capture of three common reptiles and two salamanders in RPP in five habitats under 292 spruce and 111 plywood cover boards. All Chi-square tests of goodness of fit were significant, $p<0.01$.

Species	Savannah		Built areas		Forest		Dune		Marsh		Chi-square
	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	
SPRUCE BOARD CAPTURES											
P. fasciatus Five-lined skink	310	175	1388	1690	370	38	383	546			492
S. dekayi Dekay's brown snake	29	90	122	76	35	23	36	32			149
T. sirtalis Common garter snake	34	133	179	102	122	45	31	84			472
A. laterale Blue-spotted salamander	199	475	1091	841	612	755	193	21			629
P. cinereus Red-backed salamander	15	0	81	0	19	132	19	0			828
PLYWOOD CAPTURES											
P. fasciatus Five-lined skink	258	246	206	416	198	5	387	463	120	37	425
S. dekayi Dekay's brown snake	25	20	20	39	19	12	37	6	11	35	96.3
T. sirtalis Common garter snake	214	144	134	163	182	54	160	203	91	216	304
A. laterale Blue-spotted salamander	18	13	18	22	22	41	22	16	11	1	31.6

to May-June levels (Figure 2.3). There were very few captures under natural debris relative to the artificial cover for any species, regardless of location (Table 2.3). The blue-spotted salamander was captured less often than expected in the dune and marsh and nearly double what was expected in the forest habitat given its area (Table 2.4). For the red-backed salamander, all captures occurred in the forest; for the green frog, most captures occurred in the forest. For the blue-spotted salamander (χ^2 = 150, p<0.001), plywood boards outperformed the spruce boards in the dune and forest habitats, whereas the spruce boards outperformed plywood boards in the savannah and built habitats.

DISCUSSION

The intent in reporting on the RPP herpetofauna surveys was that they might serve as baselines for future studies in the protected area or Ontario's Carolinian region. Even though natural debris occurred in most habitats in RPP, there was a strong preference for artificial cover among all species surveyed. Cover boards make an efficient artificial cover for captures as they are a new habitat rapidly colonized (Marsh and Goicochea 2003). The five-lined skink was the only species to use the natural debris piles in appreciable numbers. Captures in these piles still amounted to only 3% of totals for the season, suggesting that artificial cover (cover boards) may contain more preferable microclimates than natural debris. A study in South Carolina found that amphibians more readily colonized plywood, and reptiles preferred tin (Grant et al.

1992); the main difference between capturing reptiles and amphibians may be the material of cover board rather than placement within the known habitat.

Out of the four habitats surveyed with spruce and plywood boards, the preferred board appears dependent on habitat. The five-lined skink was more frequently found under spruce boards, whereas in the built areas and savannah, they favoured the plywood boards. One inference is that in areas of RPP subject to colder night temperatures, the more insulating spruce boards are the preferred artificial cover type. The tree and shrub cover in the built areas may mimic the savannah's dense understorey environment with little to no overhead cover providing protection from inclement weather, and for this reason the spruce board is favoured (Brazeau 2016). The preference for various cover types also varies across the extensive range of the five-lined skink – more northern populations prefer more open habitats than their southern counterparts (Watson and Gough 2012; Brazeau and Hecnar 2018). Seeking areas of higher temperature is consistent with finding some of the highest captures in the dune habitat not only for the five-lined skink, but also for the ribbon snake and garter snake.

Each reptile's peak captures occurred between the beginning of June and mid-late August when minimum daily temperatures were higher. A relative absence through most of May shows that the garter snake had a slow start to the active season, perhaps due to highly variable temperatures in RPP during April and into mid-May (Rowell 2012). The garter snake, as for initial predictions, was captured much more often under the plywood boards; their larger area may allow garter snakes to thermoregulate better or provide a warmer refuge during less active times (Hecnar and M'Closkey 1998).

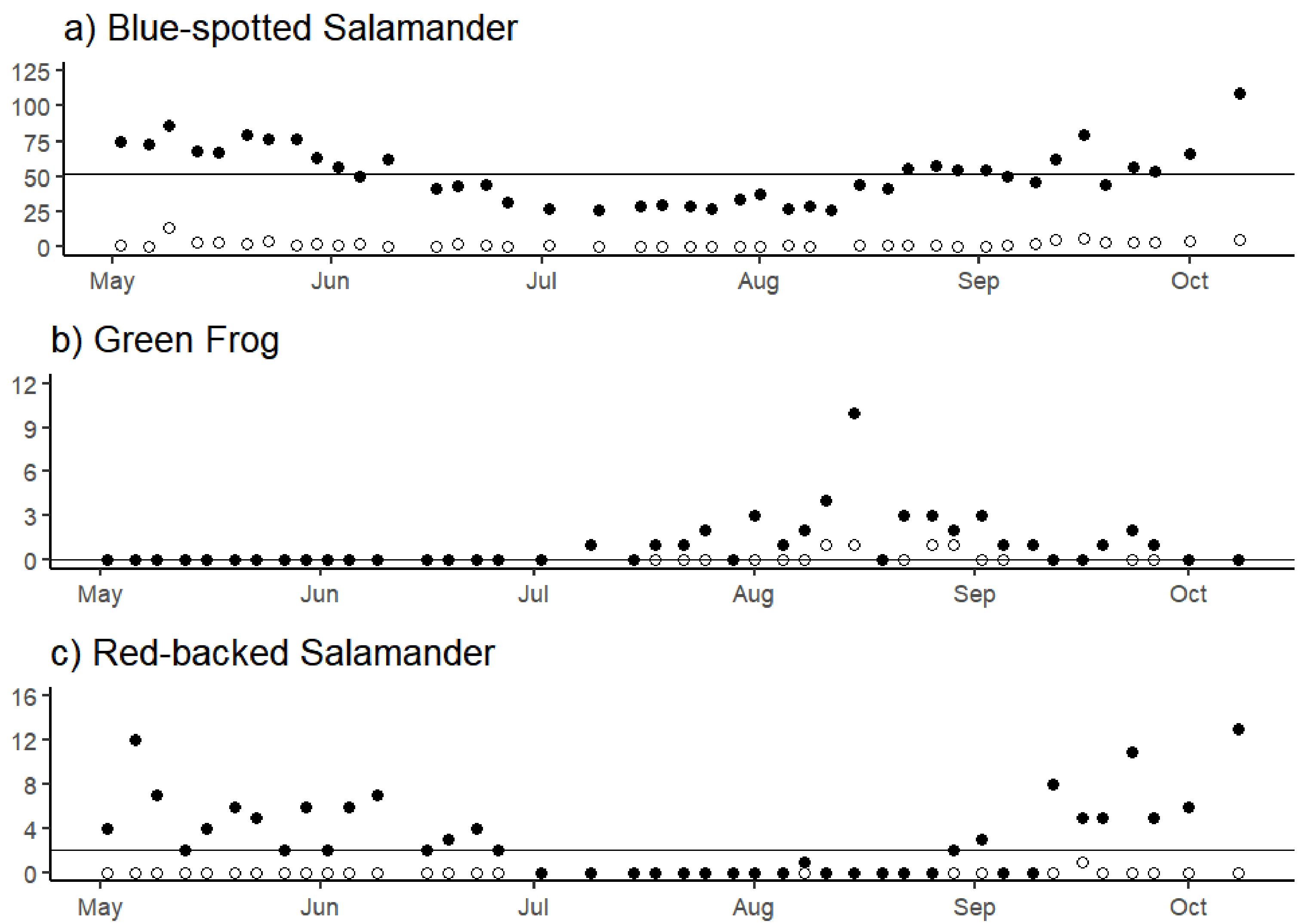

Figure 2.2. Total captures under all cover boards (solid) and plywood boards (open) of a) blue-spotted salamander (*Ambystoma laterale*), b) green frog (*Lithobates clamitans*), and c) red-backed salamander (*Plethodon cinereus*). The line on each graph represents the median daily number of total captures at RPP.

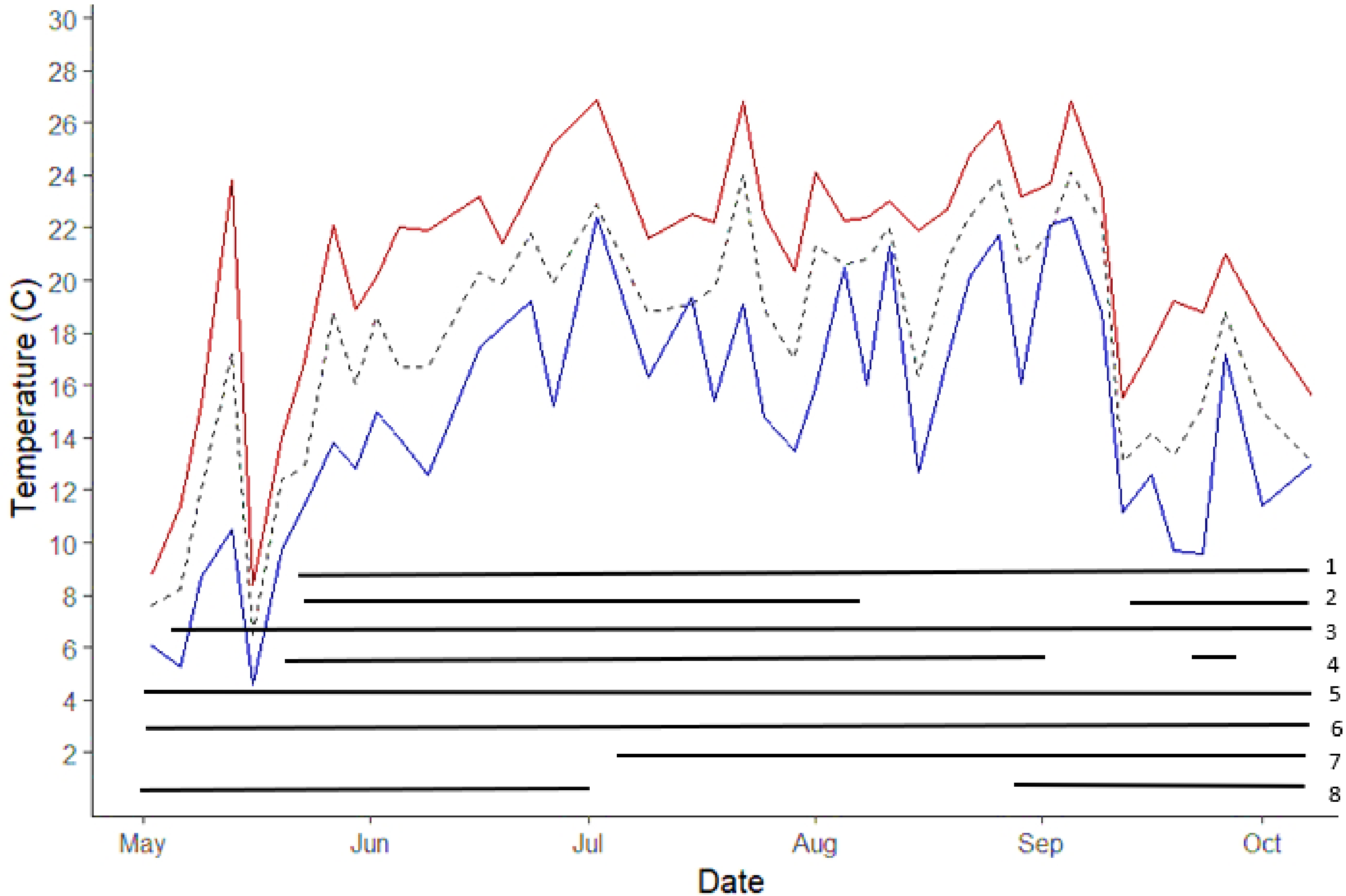

Figure 2.3. Temperature recorded at the Erieau weather station during the season of captures. Upper line is maximum temperature, dashed line is mean temperature, and lower line is minimum temperature. Horizontal lines illustrate a high activity season for RPP herpetofauna labelled at right. 1: brown snake, 2: fox snake, 3: garter snake, 4: ribbon snake, 5: five-lined skink, 6: blue-spotted salamander, 7: green frog, 8: red-backed salamander.

As another example, the brown snake emerges in March (King 1993), although captures in RPP did not occur until mid-May. For the brown snake, delay in captures may reflect this semi-nocturnal species becoming gradually more active during the day as individuals move between hibernation and summer ranges (Rowell 2012). The brown snake prefers savannah and marsh habitats, consistent with reports on a preference for moist microhabitats (Catling and Freedman 1980; Hecnar and Hecnar 2011). The preference for spruce boards in drier habitats among most reptiles, on the other hand, reflects that the more insulating board could emulate some of the conditions of a well-drained, damp microclimate.

For the fox snake, there were two distinct periods of high captures. The first, from late May to late July, is later than the cited breeding season for this species (Row et al. 2012). The second period of high captures in early autumn correlates with daily temperatures similar to those in June. The fox snake, like the garter snake, preferred plywood boards across all habitats, except in the savannah. They were nearly twice as likely to be found in the built area as the dune or savannah habitats. Their preference for less insulating plywood cover boards and built areas is typical of habitat specialists of open, dry habitats (Row et al. 2012; Rowell 2012). The ribbon snake was most active during warm months of July and August, with a single capture during September that correlated with a short-term increase in temperature. There were no captures under spruce boards in the forest with the highest captures being in the savannah. The highest captures in the dune and the forest under plywood boards indicates a preference for warm and dry microclimates. This conclusion appears remarkably different from the Eastern Canada ribbon snake population in Nova Scotia, which is described as preferring aquatic habitats (Bell et al. 2007). However, this description may correspond to a broader scale of preference, i.e., for shorter distances to a water body in a smaller land area, rather than a suggestion that ribbon snakes occupy wetlands themselves (Rowell 2012). This interpretation aligns with the RPP's ribbon snake broader-scale preference for forested habitat that borders a marsh.

The three amphibian species at RPP (the blue-spotted salamander, green frog, and red-backed salamander) were more active in spring and early fall than during summer, i.e., June through August. The forest and built areas yielded some of the highest captures of amphibians. The higher capture in these habitats aligns with what is commonly assumed about amphibians – they prefer cool, moist areas with insulating cover to prevent desiccation (Scheffers et al. 2014; Hoffmann et al. 2021). For example, the blue-spotted salamander was captured most often under the more insulating spruce boards in all habitats. The dual peaks in blue-spotted salamander captures may align with seasonal migration patterns (Brodman 2005). Minimal captures of amphibians were recorded in the dunes of RPP, where cover is lacking. The 'pure' diploid blue-spotted salamander is one of the rarest species of salamander in the northern United States and very little is known about its terrestrial habitat preferences (Ryan and Calhoun 2014). It is uncertain whether the individuals found in RPP are 'pure' diploids, or if they are a population of hybrids as noted nearby on Pelee Island and the mainland surrounding it (Bogart et al. 1985). Without genomic testing in Canada, the differences among hybrid and unisexual populations will remain unknown. In RPP, the savannah and the forest were the habitats with the most captures of this species. Most general accounts of the blue-spotted salamander's terrestrial habitats vary widely in descriptions of preference, from coniferous to deciduous woodlands, dry or moist, with or without sandy soils; often, adults are described as mainly fossorial (Brodman 2005). In Ontario the blue-spotted salamander has been recorded in most forest types under leaf litter and as almost always nocturnal (MacCulloch 2002). This species uses burrows created by other fossorial species, which is unusual for the Ambystomatidae family (Holman 2012).

Captures of the green frog occurred only during the warmest part of the active season. This period is later than emergence times recorded for the breeding season in other locations (Klaus and Lougheed 2013). Most captures were under spruce boards in the forest, with the second most frequent captures occurring under plywood in the forest. The green frog was half as likely to be captured in the built areas as they were in the forest, and no captures occurred in the savannah. As green frog adults are primarily aquatic, it is possible they do not inhabit cover boards as readily as most terrestrial species (Pauley and Lannoo 2005). There may be several reasons for the preference for forest habitat, beyond the moisture and temperature requirements of the green frog, such as crossing forest during dispersal or foraging adjacent to primary aquatic habitat. Populations are known to suffer declines as development of shoreline occurs for recreation or road mortality during migrations (Green et al. 2005; Pauley and Lannoo 2005). Also, green frogs call during periods of low ambient noise. As suggested by Vargas-Salinas et al. (2014), forests may provide this species with the sound barrier required for mating success, while built areas do not.

Similar to the fox snake, there were two distinct capture periods for the red-backed salamander. The life history of this salamander suggests the two periods correspond to egg-laying in spring and mating in autumn (Blanchard 1928). This was the only species out of the eight in this study that exclusively occurred in forest. The red-backed salamander is similar to the blue-spotted salamander in its ability to colonize a range of forest types, mainly inhabiting leaf litter on the forest floor. The difference is that the red-backed salamander has a limited ability to burrow and instead will seek out existing shelter (Highton 2005; Green et al. 2014). Avoidance of areas with low forest cover may be a reason for their relative rarity in RPP, but it is typical that captured individuals in a population could be as few as 1-3% of totals for amphibians (Highton 2005). It is possible that existing shelters are favoured over cover boards for this salamander for optimal temperature regulation consistent with the “Bogert effect” (Bogert 1949; Huey et al. 2003).

While the plywood boards were attractive to the snakes, the prediction was not met for amphibians that they would be more effective means of capture; in general, the smaller spruce boards performed better. Bias in the number of captures during this study may also vary by species and may be due to territorial behaviours (Houze and Chandler 2002). In such cases, the study design should account for differences in range size as I have done here using published home ranges. The recommended plywood boards of 122 cm^2 and 1.3 cm thick were always the better choice for captures of the garter snake, but for the other snakes and for the blue-spotted salamander, recommendations on cover board depend on habitat. Species preferring damp habitats were attracted to a thicker board that mimics damp microclimates; those preferring dry habitats were ready to use a thinner plywood board. Hotter temperatures can be achieved with a more insulating board in low canopy cover vs high canopy cover;

thicker boards will maintain higher night-time temperatures than thinner boards, as will a smaller surface area versus a larger one.

Management of Rondeau Provincial Park should continue to provide a high variation of cover types for their current species diversity. This research can assist in identifying high activity areas within the park and may also assist in isolating areas of importance. Furthermore, it will assist in developing preventative disturbance measures from park maintenance and guests. Considering the importance of timing in each species’ life events, park events and maintenance can be scheduled with the least disturbance possible to the wildlife.

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CHAPTER 3: RESOURCE SELECTION FOR EIGHT SPECIES OF HERPETOFAUNA IN RONDEAU PROVINCIAL PARK

Carolinian shoreline forest suffers multiple disturbances; primary factors are road construction, heavy browsing by white-tailed deer (*Odocoileus virginianus*), cottage developments, and tourism (Tanentzap et al. 2011; OMECP 2021). Other disturbances include logging (to remove hazard trees and some commercial logging) and beach erosion (OMECP 2021). Sometimes disturbance produces positive effects. Removing trees from densely populated stands has resulted in a landscape resembling the rare and historical oak-savannah habitat. The resulting sandy savannah supports ideal habitat for many reptiles, whereas closed-canopy forests are more suitable for most amphibians (Mierzwa 1993). Both configurations of this landscape are highly vulnerable, and they also contain the highest levels of diversity of species at risk within Ontario (OMECP 2021).

Road development is a significant disturbance. What is coined the "road effect zone" extends a significant distance into a habitat (1000 m or more), disrupting the life history of many species, similar to the edge effect in a forest fragment (Eigenbrod et al. 2009). With more research on roadway effects on habitat, it is becoming clear that the primary variables determining how animals adapt are the size of the roadway and the traffic density (Eigenbrod et al. 2009; Vargas-Salinas 2014). Roads have three primary influences on flora and fauna populations surrounding them: increasing mortality, decreasing habitat connectivity, and reducing habitat quality. Researchers will often choose one when discussing their results rather than comparing the relative consequences of each (Teixeira et al. 2020). The complication of describing multiple effects of fragmentation is that none is independent of another. For example, higher mortality is more likely to occur in areas of higher traffic density, where roads are wider and better maintained, therein creating a greater barrier to habitat connectivity (Teixeira et al. 2020).

Artificial structures associated with cottage development present multiple positive and negative effects across species of herpetofauna; examples of these structures in Rondeau Provincial Park (RPP), Ontario include housing (cottages), sheds, decks, and porches. Positive outcomes of such structures include that they may provide communal nesting or hibernacula (Ballenger et al. 2008). As another example, the negative impact of tourism on beaches and such intense disturbance as removing natural beach debris has been mitigated by adding artificial structures such as boardwalks and woodpiles (Hecnar and M'Closkey 1998). In the urban context, herpetofauna communities in cityscapes in the Mediterranean were recovered with green space fragments of increasing size and diversity so long as they included wooded and wetland areas (Vignoli et al. 2009). Thus, the extent of development, e.g., the degree to which green spaces are left intact, determines the direction of the effect of artificial structures on herpetofauna.

Studying roads and human disturbance are two ways to investigate how fragmentation influences passive captures of herpetofauna in RPP forms the aim of this chapter of the thesis. This chapter's objectives are: (1) to compare passive captures of herpetofauna under cover boards between disturbed and undisturbed forest in RPP, (2) to assess how forest canopy cover can influence differences in captures in disturbed and undisturbed forest, (3) to determine how distance to nearest road or distance to the nearest artificial structure might influence captures.

If the record of captures for a species does not illustrate the preference for the forest, it may indicate risk associated with roads and structures at different scales (Padié et al. 2015). For example, excursions nearer to roads and development (macroscale) are expected to pose a greater risk to individuals, resulting in avoidance of what otherwise would be suitable (microscale) cover. While in Chapter 2 the goal was to determine the most significant habitat associations and ideal cover board design, this chapter will compare occurrence of herpetofauna between adjacent disturbed and undisturbed forest and describe a road effect for those species with sufficient captures.

METHODS

The main road through RPP and most of the cottages are in the forest, no more than 150 m from the coastal dune habitat. Cover boards were placed in 2013 in locations representative of significant habitats in RPP and allowed to weather prior to the 2014 observations (Figure 1.1). Spruce boards were set in pairs, 2 m apart, and each placement site was located approximately 40 m apart. The spruce board (120 cm x 11.25 cm, 3.8 cm thick) layout contained nearly equal cover boards in each habitat, 30 in the built areas, and 40 in the forest. The layout of additional plywood boards (122 cm x 122 cm, 1.3 cm thick) was nearly equal across habitat types; these boards were placed in singles in transects surrounding the perimeter of RPP. There are 20 in the built areas and 19 in the forest. Surveys were conducted 42 times from May to October 2014. Cover boards were lifted, presence was recorded for each species, and the boards returned to original configuration. ArcGIS Pro (2.8.2) was used to map all board coordinates with Google satellite imagery for habitat characteristics.

ANALYSIS

Model selection based on Akaike’s Information Criterion for small samples (AICc) was used to find habitat associations for five species of sufficient captures in forest and built areas, distance to the nearest road, and distance to identified buildings in the cottage development. The surveys and mixed models followed sampling protocol A and study design 1 described by Manly et al. (2002): available and used resource units were sampled, measurements were made at the population level, and locations were classified into resource categories consisting of two habitats. The fox snake was excluded from modelling due to insufficient captures. The red-backed salamander was excluded from the model selection because it was only found in the forest, and the eastern ribbon snake was excluded because it was only found in the built areas.

Based on a necessary summary across the survey season of cover board captures, logistic regression was used in model selection for the other five species following a binary approach to presence and absence. For the brown snake, garter snake and green frog, a cover board that resulted in one or more captures recorded over the season determined ‘occurrence,’ and the ‘absence’ meant no captures. For the very abundant five-lined skink and blue-spotted salamander, ‘occurrence’ was determined for more than three captures recorded; three or fewer captures were considered less likely occurrence (recorded the same as an 'absence'). The six models compared were the univariate case for habitat preference (forest over built areas), the univariate case for road preference, and four mixed models that all included habitat preference: one with distance to the nearest road, a second with distance to the nearest building, a third with both distances included, and a fourth with distance to the nearest road and the interaction term between habitat and distance to the nearest road. The residuals were inspected for each mixed model. Individuals were not identified during this study. Equal probability of detection in both habitats and independent resource selection was assumed to be true. All modelling was completed using RStudio (version 2021.9.0.351) for R (version 4.1.2). Packages included were: lubridate, ggplot2, scales, gridExtra, and lme4 (Grolemund and Wickham 2011; Bates et al. 2015; Wickham 2016; Auguie 2017; Wickham and Seidel 2020).

RESULTS

Among the five modelled species, the univariate logistic regression based on habitat (forest *versus* built areas) was the top model in two cases and the second top model in one case (Tables 3.1 and 3.2): for the five-lined skink, captures were more likely in the built areas than in forest (Akaike weight, w = 0.37); for the brown snake (w = 0.38) and green frog (w = 0.19) captures were more likely in forest. The multivariate regression based on habitat (forest *versus* built areas), road distance, and their interaction was the top model for three species and second-best model for one species:

the garter snake (w = 0.36), the blue-spotted salamander (w = 0.99), the green frog (w = 0.37), and the brown snake (w = 0.23).

Interpreting the bivariate regression of habitat and distance from the nearest road varied by species and habitat, as roads were approximately twice as far on average from cover boards in forest compared to built areas (Figure 3.1). In comparison to the models built on habitat, support for the bivariate and univariate logistic regressions for road distance varied widely across species (Tables 3.1 and 3.2). The univariate model was not supported in explaining captures of the five-lined skink (w = 0.00), the brown snake (w = 0.02), the blue-spotted salamander (w = 0.00), or the green frog (w = 0.17). The bivariate regression was the second-best model for the five-lined skink (w = 0.19), a close third best model for the garter snake (w = 0.20), and a fourth best model for the brown snake (w = 0.14) and the green frog (w = 0.12), which were all more likely further from a road (Figure 3.1).

For the five-lined skink, built areas were the dominant habitat in all models, multiple captures in the forest were more likely further from a road; for the garter snake, at least one capture was more likely further from a road in both the forest (where captures were more likely) and the built areas (where captures were less likely); for the brown snake, at least one capture was more likely further from a road in the forest but more likely closer to a road in the built areas; for the blue-spotted salamander, multiple captures were more likely closer to a road in both forest (where captures were more likely) and built areas (where captures were less likely); and for the green frog, at least one capture was more likely further from a road in built areas (Figure 3.1).

Table 3.1. Results of model comparisons for habitat associations among common reptiles captured at Rondeau Provincial Park (RPP). Forest = probability of capture in the forest over the built areas; Road = distance captured (m) from the nearest road; Building = distance captured (m) from the nearest built structure. AICc is Akaike's Information Criterion for small samples and w is the Akaike weight. Parameter estimates show direction of effect.

Species captured	Model	Diagnostics			Parameter estimates (95% confidence limits)			
		AICc	Δ AICc	*w*	Forest	Road	Building	Forest*Road
Five-lined skink	Forest	297.970	0	0.37	-4.017, -1.909			
	Forest, Road	299.280	1.31	0.19	-4.355, -1.982	-0.004, +0.009		
	Forest, Road, Building	299.590	1.62	0.16	-4.005, -1.023	-0.003, +0.019	-0.021, +0.004	
	Forest, Building	299.950	1.98	0.13	-4.315, -1.492		-0.008, +0.007	
	Forest, Road, Forest*Road	300.050	2.08	0.13	-6.879, -1.720	-0.006, +0.007		-0.006, +0.021
	Road	346.360	48.39	0.00		-0.010, -0.002		
Garter snake	Forest, Road, Forest*Road	295.600	0	0.36	+0.125, +2.598	+0.003, +0.019		-0.019, +0.001
	Road	296.130	0.53	0.28		+0.002, +0.011		
	Forest, Road	296.750	1.15	0.20	-0.282, +1.156	-0.001, +0.001		
	Forest, Road, Building	298.610	3.01	0.08	-0.462, +1.625	-0.002, +0.015	-0.011, +0.008	
	Forest, Building	299.310	3.71	0.05	-0.699, +1.219		-0.001, +0.010	
	Forest	299.790	4.19	0.04	+0.228, +1.452			
Brown snake	Forest	235.310	0	0.38	+0.190, +1.572			
	Forest, Road, Forest*Road	236.280	0.97	0.23	-1.349, +1.358	-0.019, +0.002		-0.001, +0.023
	Forest, Building	237.180	1.87	0.15	-0.019, +2.077		-0.007, +0.005	
	Forest, Road	237.220	1.91	0.14	+0.150, +1.734	-0.006, +0.005		
	Forest, Road, Building	239.180	3.87	0.05	-0.099, +2.148	-0.009, +0.009	-0.011, +0.009	
	Road	240.400	5.09	0.02		-0.002, +0.007		

Table 3.2. Results of model comparisons for habitat associations among common amphibians captured at Rondeau Provincial Park (RPP). Forest = probability of capture in the forest over the built areas; Road = distance captured (m) from the nearest road; Building = distance captured (m) from the nearest built structure. AICc is Akaike's Information Criterion for small samples and w is the Akaike weight. Parameter estimates show direction of effect.

Species captured	Model	Diagnostics			Parameter estimates (95% confidence limits)			
		AICc	Δ AICc	*w*	Forest	Road	Building	Forest*Road
Blue-spotted salamander	Forest, Road, Forest*Road	307.800	0	0.99	-2.060, +0.309	-0.028, -0.010		+0.008, +0.030
	Forest, Road	318.390	10.59	0.00	+0.121, +1.531	-0.012, -0.002		
	Forest, Road, Building	320.390	12.59	0.00	-0.169, +1.826	-0.015, +0.001	-0.009, +0.008	
	Forest, Building	321.250	13.45	0.00	+0.179, +2.052		-0.011, -0.000	
	Road	321.680	13.88	0.00		-0.008, +0.000		
	Forest	323.630	15.83	0.00	-0.242, +0.968			
Green frog	Forest, Road, Forest*Road	174.830	0	0.37	-0.372, +3.772	+0.002, +0.025		-0.028, -0.001
	Forest	176.190	1.36	0.19	+0.053, +1.698			
	Road	176.400	1.57	0.17		+0.000, +0.011		
	Forest, Road	177.020	2.19	0.12	-0.379, +1.585	-0.301, +0.010	-0.009, +0.008	
	Forest, Building	177.880	3.05	0.08	-0.681, +1.890		-0.005, +0.009	
	Forest, Road, Building	178.670	3.84	0.05	-0.511, +2.347	-0.019, -0.006	-0.018, +0.010	

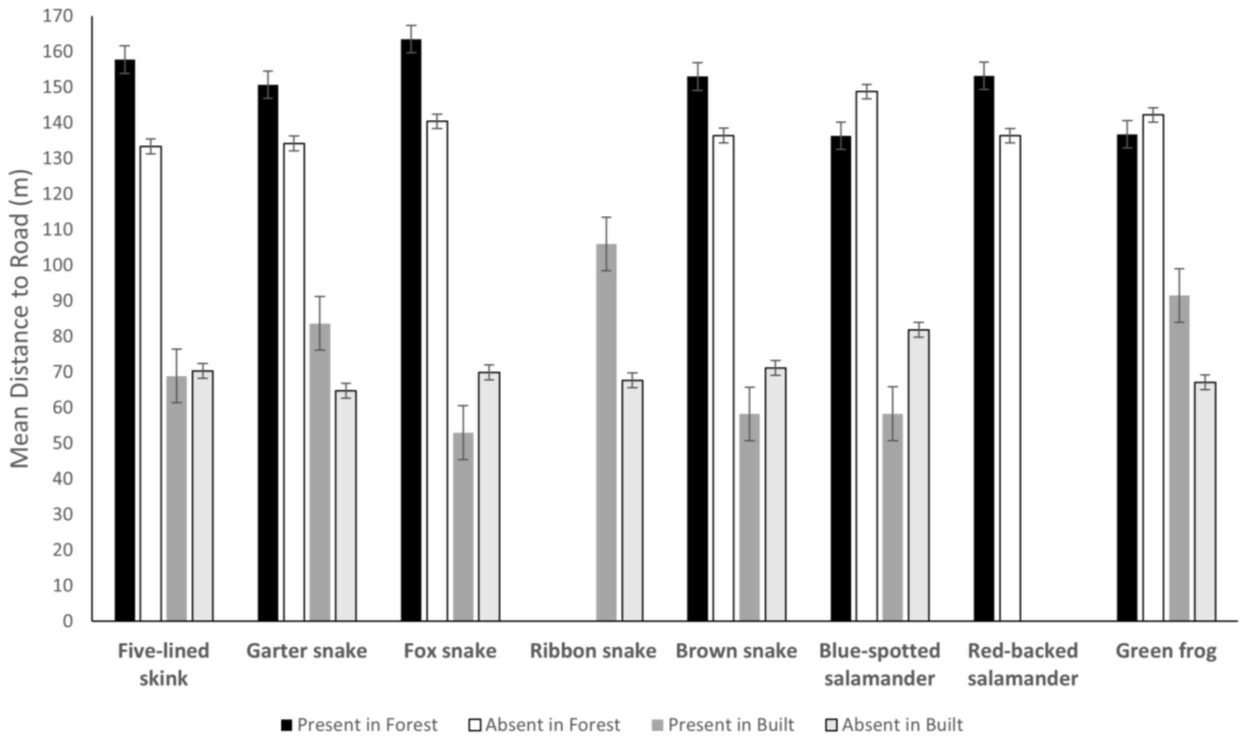

Figure 3.1. Average placement of cover boards from the nearest road with respect to captures of eight species in forested and built areas of Rondeau Provincial Park (RPP). Means and standard errors of distance (m) is shown by species, where one or more captures occurred (present, black bars) and where few or no captures occurred (absent, white bars) in forested areas, and where present (dark grey bars) and absent (light grey bars) in built areas. Five-lined skink and blue-spotted salamander presence is for captures of more than three individuals due to their abundance (i.e., absent indicates three or fewer captures over the season); for the other species, presence indicates at least one individual captured, and absent is no captures.

The road effect also varied for the three species without sufficient captures for logistic regression: for the fox snake, a capture was more likely further from a road in the forest, but closer to a road in the built areas; for the ribbon snake, a capture was more likely further from a road in the built areas; and for the red-backed salamander, a capture was more likely further from a road in the forest. Models for probability of capture that included distance to a building did not receive as much support (Tables 3.1 and 3.2).

DISCUSSION

The population of five-lined skinks in RPP is near the northernmost edge of its range (Brazeau and Hecnar 2018). These northern populations favour open habitats with sufficient wood or rock cover objects. The built area of RPP supports an open landscape with frequent spaces (woodpiles, porches, and sheds) for refuge. At the same time that built areas appear preferred, road avoidance by the five-lined skink might be inferred. This avoidance behaviour may be learned by some individuals, especially where heavier traffic or faster speed of traffic is experienced, or the road effect on captures may be due to roadkill creating a sink habitat (Farmer and Brooks 2012). The population of five-lined skinks in RPP appears considerably different regarding cover choices than that of the Canadian Shield population, which favours rock outcroppings more than organic debris (Howes and Lougheed 2004).

The common garter snake is a secretive species with little known about its life history. Captures in RPP occurred nearer to roads over all the dataset, yet further from roads when a preference for forest habitat is factored in, as might be expected from a study near the Raritan Canal in New Jersey, where the garter snake was located moderately close to a walking path (Burger et al. 2004). Both findings suggest this species locates itself where it can be covered by vegetation, even when basking. The garter snake is most likely associated with areas of higher tree canopy cover, regardless of whether this canopy is in a built area. Like the garter snake, the dampness of the forest is a generalized preference of the brown snake (Hecnar and Hecnar 2011). These arthropod specialists were captured somewhat more often near roads in the built area, where gastropods and earthworms may become available during rain events to avoid drowning. Within the built area of RPP, then, the brown snake may use low-traffic roads to hunt, but the most frequent captures of this species in the forest, like the other reptiles, was further from the road.

The blue-spotted salamander was captured closer to roads regardless of habitat. This species may use the roadside as an easy place to burrow because foundations of roadways in RPP, constructed of gravel, are associated with loose, non-compacted soil. It is also likely that migratory pathways to and from breeding wetlands lead the blue-spotted salamander to frequently cross the road or use vernal pools along roadsides as breeding grounds. The occurrence of the blue-spotted salamander has been positively correlated with depth of litter, coarse woody debris, and canopy cover (Ryan and Calhoun 2014). These three variables would be provided at the forest edge and in the dense vegetation associated with cottage areas. Green frogs prefer to breed in woodland marshes with permanent bodies of water (Klaus and Lougheed 2013). This species’ range of movement is limited due to its reliance on freshwater swamps for protection from predation and desiccation. Although they spend most of their time in or near freshwater, green frogs are terrestrial feeders, more likely to travel slightly further from their refuge on overcast days when light intensity is reduced and the relative humidity high (Martof 1953). Likely for these reasons, the majority of green frogs were captured in the forest habitat at RPP.

Being closer to roads is extremely dangerous for herpetofauna in high-traffic areas (Farmer and Brooks 2012). Slower-moving species, such as the fox snake, are likely more susceptible to road mortality as they cease movement when startled (Rowell

2012). Habitat fragmentation and loss are possible side effects of the road effect, as are increased mortality rates from vehicle collisions or exposure to predation (Jaegar et al. 2005). It is essential to consider that the road within RPP is for low-density traffic, and the effects would be considered minimal compared to a busier road within the greater township (Farmer and Brooks 2012). The captures in this study suggest that the road is either avoided by most species or is a sink habitat in some cases.

Preference to be in the built habitat, the cottage development at RPP, does not align with the most common narrative that built areas are inherently unsuitable for maintaining wildlife populations. Forested areas of RPP are the primary habitat for most herpetofauna within the protected area, but occurrence in forest habitat at RPP, which includes edge habitat, has been documented for the American toad, Fowler's toad, blue-spotted salamander, eastern newt, red-backed salamander, eastern hog-nosed snake, fox snake, five-lined skink, Dekay's brown snake, and the common garter snake (Chapter 1). Cottages can provide some thermal cover to reptiles and amphibians (Rowell 2012). Individuals can hide under sheds, decks, porches, and woodpiles from avian predators or the elements, while at the same time the cottage area provides openings for basking important for thermoregulation by amphibians and reptiles at high latitudes (Gregory 2007; Powell and Russell 2007). Many of the herpetofauna are also known to communally hibernate in and around artificial structures. Differences between the cottage development at RPP and development in a larger town or city may be that the structures in RPP were established many years ago and are not actively being renovated; there is also more green space in a cottage development. In some cases, buildings have been removed, and cottage lots actively returned to a natural state.

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CHAPTER 4: CONCLUSION

Habitat associations in herpetofauna are poorly understood, undermining understanding of functional diversity and, by extension, hampering conservation efforts (Guderyahn et al. 2016; Berriozabal-Islas et al. 2017; Roll et al. 2017). If it is unknown which changes to habitat components are responsible for a species' decline, then management for population maintenance or restoration cannot proceed (Webb and Shine 2000). In this thesis, patterns in capturing herpetofauna were described alongside recommendations on cover board material for survey. Then, habitat selection around roads and human structures in built areas were two ways to investigate how fragmentation influences passive captures of herpetofauna in the Rondeau Provincial Park (RPP).

Some species in this survey were captured much later than the literature suggests they would – in particular, the brown snake, garter snake, and green frog. Herpetofauna often take cues from the local climate to initiate some life history events, such as when to breed, emerge or go into hibernation (Beebee 1995; Shoo et al. 2011). As the climate changes, herpetofauna will be forced to change their activity seasons accordingly. There is a rapid trend for urbanization and land development worldwide, as humans struggle to keep up with the demand for food and resources for a growing population (Pike and Roznik 2009). The trend indicates that small, cryptic species of lizards could survive their habitat's anthropogenic disturbance. Their survival is conditional on whether a disturbance has been dormant for approximately one decade

(Pike and Roznik 2009; Krause Danielsen et al. 2014). The likelihood of many reptilian species surviving continued habitat degradation or living within the boundaries they currently hold becomes smaller with effects like climate change when coupled with anthropogenic disturbance. Herpetofauna may also see the opposite effect as ranges become more available to them with increasing temperature, resulting in range shift or expansion.

Forested habitat was the most likely predictor of habitat use by herpetofauna in RPP and roads are likely avoided by most species. Existence near a road can be pernicious to the health of a population. It is essential to consider that the road within RPP is for low-density traffic, and the effects would be considered minimal compared to a road within the greater township. Secondarily, built areas were favoured by many of the herpetofauna, an effect not unexpected (Krause Danielsen et al. 2014). Differences between the cottage development at RPP and development in a larger town or city may be that the structures in RPP were established many years ago and are not actively being renovated; there is also more green space in a cottage development. In some cases, buildings have been removed, and cottage lots actively returned to a natural state.

The following biases are present in this study: (1) most herpetofauna were not distinguished as juveniles or adults because they were not handled, (2) recaptures were not documented because there was no tagging of individuals, (3) higher captures in a location may not always indicate higher quality habitat and the potential for capturing dispersing individuals is real, especially if ecological traps are present, and (4) some species were caught less frequently because they are rare or they are nocturnal – this list calls for adaptive surveys. Targeted management efforts will enhance a higher understanding of habitat use and selection, preserving populations most at risk. By incorporating reptiles into the local conservation schemes, biodiversity will be better represented, understood, and therefore conserved (Roll et al. 2017). Studying habitat associations is essential to conservation efforts and environmental assessment programs regarding the often-neglected ectotherms, particularly when studying behaviour and ecology (Gibbon et al. 2000; Diele-Viegas et al. 2018). This sentiment can be especially true when devising management plans for regions of high disturbance and great importance to wildlife activity.

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