Patterns of Snake (Colubridae: *Storeria*) Movement and Mortality During Seasonal Migrations Between Habitats

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Abstract

Roads are among several anthropogenic structures that can have negative impacts on a landscape. In addition to road surfaces altering and fragmenting habitat, organisms crossing them experience direct mortality from vehicles in transit. Mortality rates are typically greater when a roadway passes between distinct habitat types used differentially by individuals within a single year. Our study quantifies spatial and temporal patterns of Midland Brownsnakes (*Storeria dekayi wrightorum*) that biannually cross a 2.4-km stretch of park road separating over-wintering sites from summer activity areas. We collected both live and dead-on-road individuals using a combination of visual encounter surveys and nine 100-m drift fence-pitfall trap arrays outfitted with adjacent cover objects and funnel traps. We recorded morphometric, behavioral, life-history, and GPS location data for all individuals, and uniquely marked each snake prior to its release. Male snakes incurred higher mortality than females within and between years. When returning to over-wintering sites each Autumn, peaks in migratory activity tended to coincide with periods of highest traffic volume along the park road. Further analyses using GIS also indicated that snake movements across the road follow specific corridors associated with temporary streambeds and other areas of low slope topography. Limiting vehicular access to the park road during the second half of October, or adding culvert structures, would improve survivorship for this population, and other snake species in this ecosystem.

Introduction

- Individuals within a population often move on a seasonal basis between 2 habitats within a home range *(e.g.*, seeking nest sites or hibernacula; [2]).
- Roadways in the United States span over 6.4 million km, often acting as barriers between habitats within an ecosystem [3], and generating high mortality rates for animals that attempt to cross them [8].
- We examined the influence of extrinsic and intrinsic factors on the migratory behavior and road mortality of Midland Brownsnakes (*Storeria dekayi*) at a state park.

Methods

- Fox Ridge State Park (FRSP; Coles County, Illinois; Fig. 1a) is 835.3 ha, composed mostly of upland oak-hickory forests and patchy lowland habitat (old field or bottomland forest habitat), with 8 km of paved road running through the park's interior.
- We sampled snakes along a 2.7-km stretch of road that follows the contour of an ecotone between upland and lowland areas.
- We installed nine 100-m drift fence and pit-fall trap arrays at regular intervals along the uphill side of the road, and surveyed the road every 24-48 h during the activity season.
- We recorded snake orientation at each capture location, as well as standard morphometrics for all live individuals [4], each of which we marked with a cautery unit [9]. For road-killed individuals, we recorded only gender (if possible) and location.
- We used Kruskal-Wallis tests to assess patterns of mortality or movement as a function of season and sex.
- We employed a kernel density function within ArcMap 10.1 (ESRI; Jenk's method) to identify migratory "hot spots" for snakes crossing the road.

Results

- Snake orientation on the road varied by season (K-W stat = 14.28, p = 0.001), with more snakes heading towards upland habitat in the Autumn (Fig. 2). Orientation was similar as a function of subject gender (p = 0.19).
- Kernel density analyses revealed a shift from snake encounters associated with the fence array in Spring (Fig. 1b), to clusters of snake occurrence that included other parts of the road in Autumn (Fig. 1c).
- Snake mortality was highest in Autumn (K-W stat = 7.95, p = 0.02), with male snakes tending to incur higher mortality than females (p = 0.37; Fig. 3).
- More snakes were encountered at the end of the activity season, with a peak in snake encounters occurring when the daily high temperature fell below 20°C (blue arrow, Fig. 4).

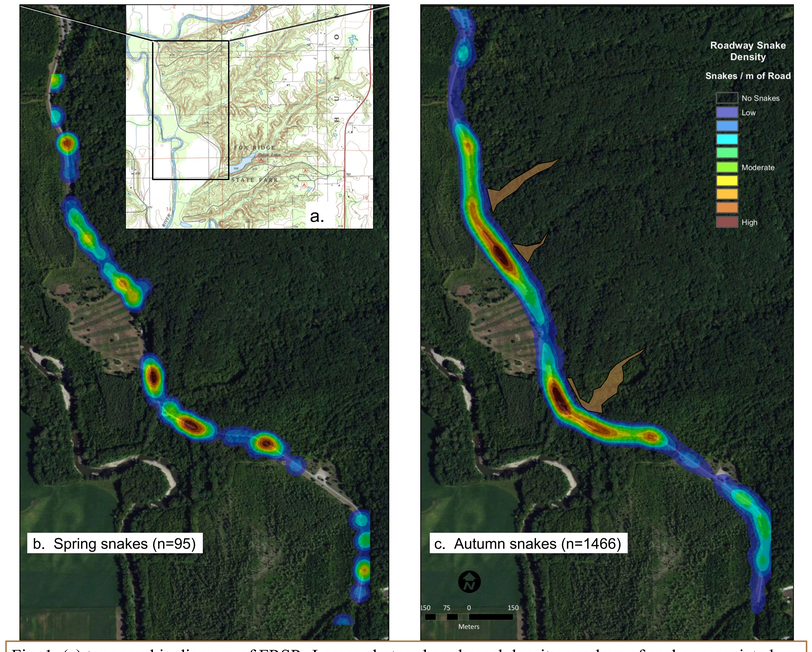

Fig. 1. (a) topographic diagram of FRSP. Larger photos show kernel density overlays of snakes associated with the park road during (b) Spring and (c) Autumn, from October 2010 to November 2012. Brown-shaded polygons in panel (c) indicate areas of low-slope topography.

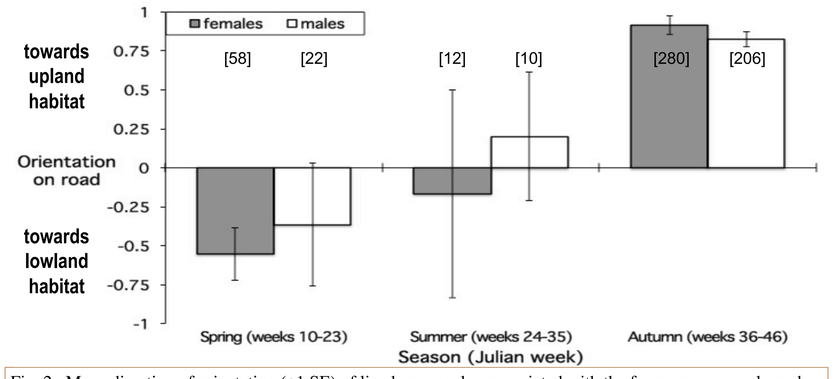

Fig. 2. Mean direction of orientation (±1 SE) of live brownsnakes associated with the fence array or park road, observed between October 2010 and November 2012. Values in brackets indicate sample size for each bar.

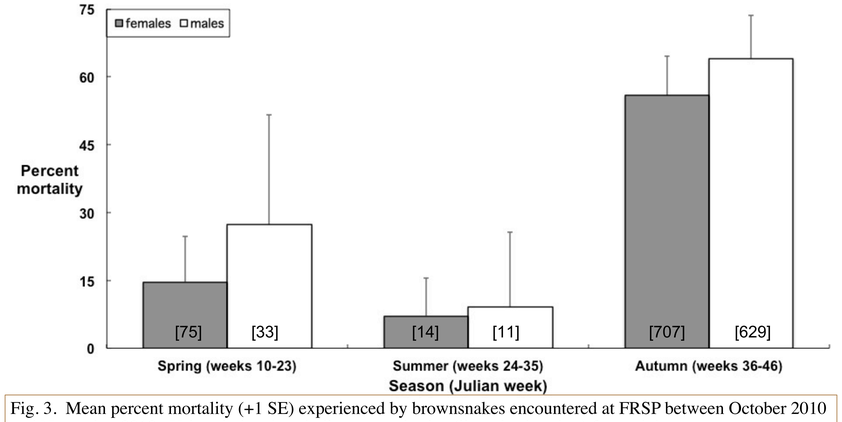

Fig. 3. Mean percent mortality (+1 SE) experienced by brownsnakes encountered at FRSP between October 2010 and November 2012. Values in brackets indicate sample size (live+dead snakes) for each bar.

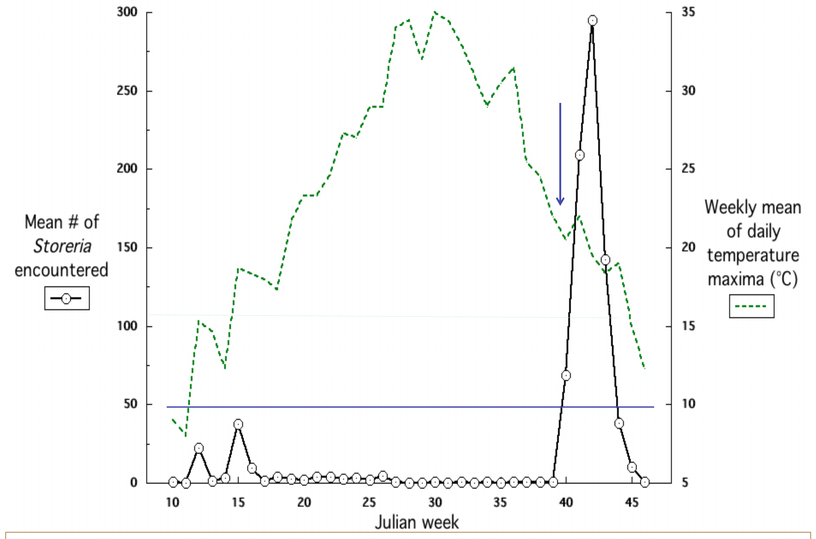

Fig. 4. Weekly means of the number of brownsnakes observed (left y-axis) and daily high temperatures (right y-axis), during the activity periods from October 2010 through May 2013. The blue horizontal line represents the 10°C temperature minimum below which snakes were not encountered.

Discussion

- Seasonal differences in brownsnake orientation on the road are consistent with snake movement between 2 habitats that provide different ecological functions.
- Brownsnakes adopt a freezing defensive behavior when threatened [1]; this posture on the road increases their probability of mortality, regardless of snake size or orientation on the road.
- Greater mortality in Autumn is likely associated with a synchronized migratory pulse that follows a decline in daily high temperatures. The trend of higher male mortality might be an artifact of increased mate-searching behavior [2].
- The FRSP road does not appear to fragment the brownsnake population because: (a) individuals cross the road prior to, and following, their over-wintering period [7]; and, (b) the pattern of crossing in the summer weeks is both inconsistent and infrequent (Fig. 2).
- Below-grade culverts or other mitigation efforts are warranted strategies to reduce snake-road mortality during temporally-restricted migrations along predictable corridors [5,6].

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