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How many salamanders are in the forest? Testing capture-recapture

Featured scientist: SPARCnet: Salamander Population Adaptation Research Collaboration Network

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***Research Background**:* SPARCnet is a regional research effort founded in 2013 by the Northeast Amphibian Research and Monitoring Initiative of the U.S. Geological Survey and Pennsylvania State University. The overall objective of the network is to develop a large-scale, replicated field experiment to understand salamander climate adaptation and population dynamics across multiple scales using Eastern Red-Backed Salamanders (*Plethodon cinereus*) as a model species. Researchers across the Northeastern U.S. are participating in a large study examining how the effects of climate change may impact the survival of this woodland salamander and, perhaps more importantly, whether these salamanders can adapt to these changes.

The Eastern Red-Backed Salamander is a small lungless terrestrial salamander that is distributed broadly across the eastern United States (Fig 1). A study carried out at Hubbard Brook Forest in New Hampshire in 1975 indicated that Red-Backed Salamanders accounted for 93.5% of the total biomass of salamanders. [This total biomass is estimated by multiplying the total number of salamanders in the sampled area by the average mass of a single salamander.] At Hubbard Brook Forest researchers estimated that the biomass of salamanders was greater than the biomass of birds during the peak breeding season (Holmes and Sturges 1973), and approximately equal to the biomass of mice and shrews (Burton and Likens 1975). Field studies also indicate that given this high biomass, Eastern Red-Backed Salamanders are important in regulating populations of forest floor invertebrates (Wyman 1998; Rooney et al. 2003) and impact nutrient cycling in the forest.

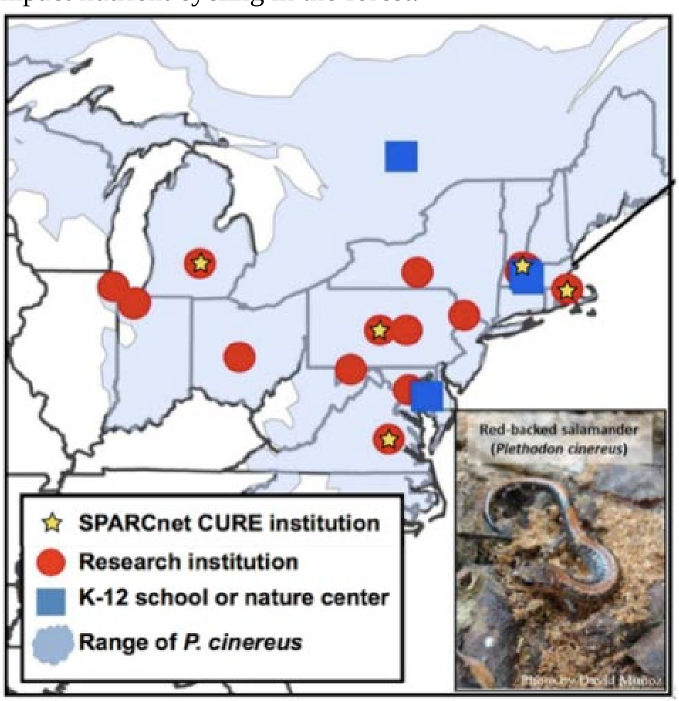

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Figure 1. Map of the range of *Plethodon cinereus* with research sites indicated and photo inset.
Despite being so widespread and reaching high abundances in some places, salamanders are difficult to study because of their cryptic nature, small size, patchy distribution, and behavioral sensitivity to environmental conditions (Connette and Semlitsch 2015; Durso and Siegel 2015). Because they are also lungless they rely on their wet skin for cutaneous gas exchange, and may be particularly sensitive to physiological stress as environmental conditions change. These salamanders tend to spend the majority of their time in underground burrows, only coming to the surface under wet and cool conditions to forage for insect prey. If we want to be able to investigate how populations respond to environmental change, we need to have some way of estimating the size of a population (N), and be able to evaluate the assumptions that are incorporated into these models.

Analysis Method: To estimate salamander abundances we will use a capture-recapture method to estimate population size. A proportion of the population is captured, marked, and released. During another sampling period, another proportion is captured and the number of marked individuals within the sample is counted. Since the number of marked individuals within the second sample should be proportional to the number of marked individuals in the whole population, an estimate of the total population size (N) can be obtained by dividing the number of marked individuals by the proportion of marked individuals in the second sample.

Example (M = marked, and C = captured, and R = recaptured):

Let's run through a hypothetical example	Sample period 1	Sample period 2	Marked individuals captured during Sample Period 2.
	Captured 1st (M)	Captured 2nd (C)	Recaptured 2nd (R)
Example *Population A*	**283**	**327**	**206**
Example Population B	114	120	23

In the hypothetical example, in *Population A*, **283** individuals were captured on the first sampling period, and all of these individuals were marked and released. During the second sampling period, **327** individuals were captured, of these **206** were marked individuals that had been captured during the first sampling period (recaptures).

1. **Based on these data alone, what do these numbers tell you about the population size?**

2. **Which population do you think is larger? Why?**

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We can use these data to estimate the population size, assuming the chance for each individual in the population to be caught is equal and constant for both the initial sampling and marking period and the recapture period. Since the number of marked individuals in the second sample should be proportion to the number of marked individuals in the population, the size of the population can be estimated by dividing the number of individuals by the proportion of marked individuals in the second sample.

	Sample Period 1	Sample Period 2	Marked individuals recaptured during Sample Period 2.		Population size
	Captured 1st (M)	Captured 2nd (C)	Recaptured 2nd (R)		Estimate of N
Example Population A	283	327	206		449.23
Example Population B	114	120	23		594.78

General equation: N = population estimate = (M x C) ÷R

M = number initially caught, marked, and released (M)
C = total number of individuals caught in the second sample (C)
R = number of marked individuals encountered in the second sample (R)

SPARCnet Study

Researchers in **New York**, **Pennsylvania**, and **Virginia** set up *replicated study sites* (referred to as NY, PA, and VA). Each site has at least six replicated plots spaced a minimum of 20 m apart. Each plot is 5 m x 10 m with wooden cover boards spaced 1 m apart, so each plot contains 50 boards (Fig. 2).

Figure 2. Example setup of a typical cover board plot for sampling.

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During the primary seasons (**spring** and **fall**), each plot must be surveyed a minimum of three times, up to eight times. At least a week must pass between survey occasions, otherwise survey effectiveness drops because salamanders don't like having their cover objects moved (Marsh & Goicochea, 2003). To sample a plot, the researchers carefully turn over each wooden cover board one at a time and record the presence or absence of Red-Backed Salamanders under the cover board. If a salamander is found, it is collected, placed in a small plastic bag with the corresponding number of the wooden cover board recorded on the bag. The salamander is then set aside so that data on snout-vent length (body length) and sex can be collected. The researchers use a visual elastomer implant to uniquely mark salamanders (Fig. 3), allows for identification of a marked individual upon recapture at a different sampling time.

Figure 3. Visual elastomer implant markings just under the skin of a captured salamander.

3. Given the sampling periods and locations, generate a scientific question(s) related to estimates of population sizes.

Scientific Data: Using the capture-recapture equation above, estimate the population sizes for each locality for each sampling period:

	Captured 1st (M)	Captured 2nd (C)	Recaptured 2nd (R)	Estimate of N	Pop size per plot	Density (per m^2)
Ithaca Fall - 2014	90	77	33			
Ithaca Spring-2015	127	135	67			
PA Fall - 2014	52	54	14			
PA Spring-2015	39	37	14			
PA Fall - 2016	28	56	8			
PA Spring - 2017	74	50	20			
Richmond Fall - 2016	150	254	38			
Richmond Spring	196	225	79			

- 2017						

Interpret the data:

4. In additional estimating population size, it can also be useful to estimate the density. To obtain such an estimate, calculate the population size per plot (N/3). Each plot is 50m^2, divide population size per plot by 50. Do you observe any differences in population sizes among plots?

5. Thinking back to your scientific question(s), can you make a claim based on the evidence provided. If so, refer to specific parts of the table or graph.

6. What are the assumptions of the model, and how might your answer change if these assumptions were relaxed?

7. *Your next steps as a scientist:* Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?