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A Habitat Model for the Detection of Two-lined Salamanders at C. F. Phelps Wildlife Management Area, Fauquier and Culpeper Counties, Virginia

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ABSTRACT

Aquatic salamanders represent an important component of Virginia river watersheds, but despite potential declines, few specifics are known about their habitat preferences. We surveyed the habitats of the northern two-lined salamander and collected data on an array of habitat variables associated with the species. We used a logistic regression analysis to develop a model predicting its presence or absence for a given 50m-transect. Our final model incorporated the variation in stream depth and direction of stream flow and accounted for 25% of the variation in our data. We conclude that stream depth variation is an important feature of salamander habitat ecology, and surmise that direction of flow is of site-specific importance possibly related to stream order. Both features may be behavioral adaptations to avoid fish predation.

INTRODUCTION

Stream-dwelling salamanders are an important component of aquatic ecosystems. They account for a significant proportion of the biomass of a stream ecosystem, and act as a key trophic link, important as both predators and prey (Spight 1967, Burton and Likens 1975, Rocco and Brooks 2000). Consequently, these salamanders have potential to act as an indicator of stream health (Rocco and Brooks 2000, Barr and Babbitt 2002). This is particularly true for headwater streams were salamanders may act as the dominant vertebrate predator (Davic and Welsh 2004). Accordingly, it would be beneficial to better understand how these species make use of their available habitat. This is especially important in the face of on-going amphibian declines (Alford and Richards 1999). Knowledge of this type may provide better insights into the conservation of these species and their associated ecosystems (Cushman 2005).

Previous surveys of stream and terrestrial amphibian diversity have been carried out in the Rappahannock River watershed of northern Virginia; however, more needs to be done to quantify the habitat preferences of important stream species (Mitchell 1998, McGhee and Killian 2010). To begin addressing this need, we conducted a preliminary study of salamander habitat at C.F. Phelps Wildlife Management Area (WMA) located in the Rappahannock River watershed and developed a simple habitat model for the

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northern two-lined salamander (*Eurycea bislineata*), a common stream species for the area (McGhee and Killian 2010).

Northern two-lined salamanders are common to northern Virginia forest streams within the Rappahannock River watershed (Mitchell and Reay 1999). While they are considered potentially important components of the local ecosystems in which they occur, few studies have developed predictive models of habitat use (Davic and Welsh 2004). They occupy stream margins and seeps, using submerged rocks and woody debris for cover; but may periodically be found in upland terrestrial sites (Petranka 1998). Females attach eggs beneath submerged rocks of varying surface area in headwater streams (Jakubanis et al. 2008). Larvae of this species are benthic predators associated with stream pools with low silt (Smith and Grossman 2003, Petranka 1998). Two-lined salamanders are able to access low-order streams typically inaccessible to predatory fishes, and have become adapted to these headwater stream environments (Vannote et al. 1980, Davic and Welsh 2004). We hypothesized that two-lined salamanders would be detected in or near cool narrow, shallow streams. From this hypothesis, we predicted that important habitat variables in a logistic regression model would be stream temperature, stream depth, and stream width.

METHODS

We chose sampling sites by randomly selecting a GPS starting location constrained to occur within C. F. Phelps WMA, and moving from that point to the nearest stream. We then moved upstream or downstream a randomly selected distance of up to 50m, and laid a 50m transect running downstream. We sampled stream transects by searching five 1-m^2 quadrats placed within each of the five 10-m sections of the transect. The particular location of the quadrat within these 10-m sections was randomly selected (Jaeger 1994, Jaeger and Inger 1994). We searched quadrats by looking under larger cover objects such as rocks or decaying logs, leaf pack, leaf litter, and using a standard-mesh aquarium dip net (1/16 inch mesh size) to sample stream bottoms (Mitchell 2000). We identified captured salamanders to species (Petranka 1998). Data were collected at both transect and quadrat levels (Table 1).

We used logistic regression to select models with those predictive variables most associated with salamander captures at the transect level. Variables measured at the quadrat level were averaged and averages and standard deviations were used as separate predictor variables. As synergistic effects may occur between the variables we measured, we created *a priori* multiplicative variables for testing as well (Table 1). We used forward stepwise selection ($P = 0.05$ to enter and 0.10 to remove) in SPSS (SPSS Inc., Chicago IL). We assessed variable coefficients using the change in -2 loglikelihood and evaluated the explanatory value of models using Nagelkerke's r^2 (Ryan 1997, Hosmer and Lemeshow 1989, Nagelkerke 1991). For all statistical analyses $\alpha = 0.05$.

RESULTS

From 13 April 2007 – 21 April 2009, we sampled 78 stream transects with 390 stream quadrats. We located 256 two-lined salamanders, 203 of which were larval. Two-lined salamanders were detected in 45 of the 78 stream transects, for a 58% encounter rate. Logistic regression selected two predictor variables: the standard deviation of maximum stream depth (SDMD: -0.12 ± 0.06 SE, change in -2 log

Table 1. Habitat variables for stream and terrestrial transect sites at C. F. Phelps Wildlife Management Area, Virginia. For variables that had a standard deviation (SD) associated with them, the SD was included in the analysis as a separate predictor.

Transect-Level	Quadrat-Level
Season[a]	Mean Maximum Depth
Relative Humidity	Maximum Depth SD
Vapor Pressure Deficit	Mean Stream Width
Air Temperature (C)	Stream Width SD
Air Pressure	Mean Depth*Width
Weather[b]	Depth*Width SD
Bank Habitat[c]	Mean Water Temperature
Direction of Stream Flow	Water Temperature SD
Slope of Stream Flow	

[a] Spring: Mar 20/21, summer: June 20/21, fall: Sep 22/23, winter: Dec 21/22
[b] Clear, partly cloudy, overcast, light rain, medium rain
[c] Deciduous, coniferous, mixed deciduous/coniferous, open field/shrub

likelihood = 5.331, df = 1, $P = 0.021$), and direction of stream flow (Direction: 0.10 ± 0.01 SE, change in -2 log likelihood = 4.301, df = 1, $P = 0.038$, Figure 1). The model explained 25% of the variation in data ($r^2 = 0.25$). Probability of predicting the detection of a two-lined salamander within a stream transect was equal to

$$\frac{1}{1+e^{-(0.10Angle-0.12SD\,\max depth-0.753)}}.$$

This model would correctly predict the presence of two-lined salamanders in 84% of cases in our study site, and correctly predict the absence in 48% of cases. The standard deviation and the average of the maximum stream depth were positively correlated r = 0.75, $P << 0.0001$), and so the majority of transects with low variability in depth also tended to be shallow. Two-lined salamanders tended to be found in streams flowing both south and west (logistic regression $\beta = 0.10$, $P = 0.05$). No other variables or combinations thereof produced models of significant predictive value.

DISCUSSION

Our model indicated that two-lined salamanders are sensitive to variation in stream depth. As those streams with high depth variation tended to be generally deeper, we interpret this as a preference for shallower sites in avoidance of fish predators (Sih et al. 1992). The majority of our captures were larval, and Barr and Babbitt (2002) found that larval two-lined salamanders occurred in negative association with brook trout (*Salvelinus fontinalis*), a fish predator. Average maximum depth also tended to be chosen by models if depth SD and direction of stream flow were removed, reinforcing the likely importance of depth. Variation in depth may provide refuges for predators to feed on larvae, or larvae and adults may simply tend to avoid deeper sites. No salamanders were found in our study site at depths greater than 20 cm.

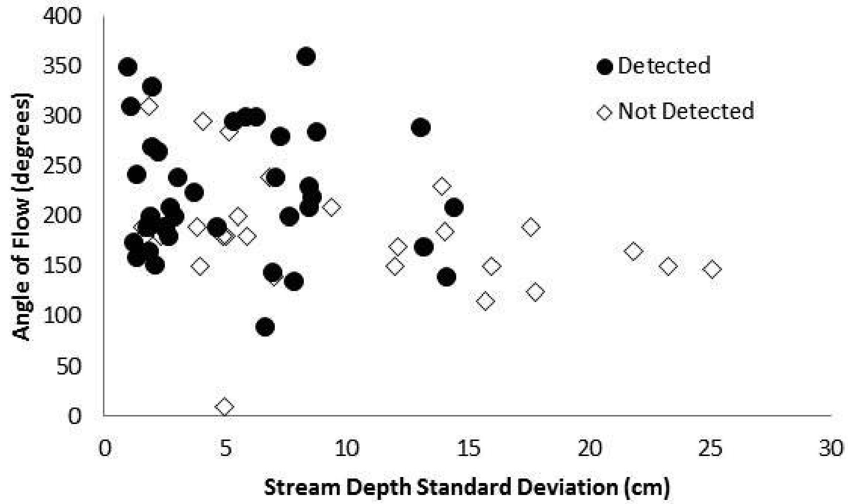

FIGURE 1. The relationship between angle of stream flow and stream depth variation for transects at C. F. Phelps Wildlife Management Area, Virginia. Salamanders were typically detected (circles) in streams with relatively low variability, flowing southwest.

The model's selection of stream flow direction as a predictor of the presence of two-lined salamanders is difficult to interpret. Individuals were most easily detected in streams flowing towards the south and west, towards the general direction of the bordering Rappahannock River. South and west flowing streams tended to flow either close to the Rappahannock or to be a 2nd or 3rd order stream, and larvae, which often drift downstream, may be attempting to find slow moving, shallow, or low depth-variance pools with sufficient cover (Petranka 1998, Barr and Babbitt 2002). Bruce (1986) found that first-year two-lined larvae tended to dominate downstream samples compared to upstream samples. Unfortunately, direction of stream flow is unlikely to translate this effect to other sites very well.

Interestingly, the model failed to include stream temperature. Grant et al. (2005) also failed to detect a water temperature effect for two-lined salamanders in the Shenandoah National Park, Virginia. Barr and Babbitt (2002) and Rocco and Brooks (2000), however, detected a positive relationship between two-lined salamander presence and temperature, but they may have found a greater range of temperatures concurrent with the greater elevation variability at their sites (300 – 1200 m and 358 – 752 m compared to our 200 – 400 m).

Our model was able to provide significant information on the habitat used by two-lined salamanders using only two relatively easily acquired variables, and recommends itself for use as a preliminary predictor for presence/absence surveys when relatively few man-hours are available. It does tend to discount sites where the species does occur (false absences) about half the time, however, so more complete models are required to better understand the habitat ecology of the species.

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