**Assessing Use of a Corridor by a Fragmented Metapopulation of an Endangered Salamander Species**

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Habitat fragmentation is one of the most severe threats facing amphibian populations today (Cushman 2006). Animal movement may be restricted by roads, open land, and habitat edges, contrary to within habitat interiors (Gibbs 1998). This might affect factors key to population viability, such as juvenile dispersal, genetic structure, and colonization of patches (Rothermel and Semlitsch 2002; Marsh et al. 2005). Amphibians are particularly vulnerable, as caused by a combination of factors such as low vagility and permeable skin (Cushman 2006). Specifically, previous studies show that migratory success of juveniles is restricted with further distances to travel, which may increase risk of predation and desiccation (Rothermel 2004; Cushman 2006). However, there is a lack of literature on the effects of habitat fragmentation at the landscape level. According to a literature review by Cushman (2006), such experiments are difficult to conduct because of their financial costs, extended timelines, and need for large sample sizes. Some studies instead used semi-natural enclosures (Rothermel and Semlitsch 2002; Messerman et al. 2020). Moreover, although many assessments have been conducted on dispersal ability of juvenile and adult salamanders, survival rates resulting therefrom are rarely tied into population viability analyses (Trenham and Shaffer 2005). This presents a conservation issue, as the question is raised of whether strategic efforts to reduce mortality might show different levels of success in adult and juvenile animals. Mark-recapture studies are commonly used in research involving amphibians, and this technique presents an opportunity to conduct an analysis of what effects conservation actions have ecologically (Rothermel and Semlitsch 2002; Whiteman et al. 2016; Messerman et al. 2020).

Of the amphibian species, salamanders are perhaps among the most well-studied with regard to effects of habitat fragmentation (Gibbs 1998; Marsh et al. 2004, 2005; Cushman 2006). Their need for pools to breed, a quick metamorphosis period, and a variety of efficient capture mechanisms provide ample opportunity for tagging a large number of individuals (Pilliod and Fronzuto 2020). In California, where habitat fragmentation is a growing concern, salamander metapopulations are commonly separated via urbanization and agricultural fields (Pilliod and Fronzuto 2020). One such species, which is endangered, is the Santa Cruz long-toed salamander (*Ambystoma macrodactylum*) (Pilliod and Fronzuto 2020). On a rainy night, individuals may be seen crossing roads to reach the nearest pool (Gibbs 1998). Their robust bodies and ease of capture additionally make them ideal candidates for PIT-tagging, a technique that shows merit in tracking animals for extended periods of time (McDonough and Paton 2007; Whiteman et al. 2016; Messerman et al. 2020).

The goal of this study is to determine whether adult or juvenile salamanders are most likely to use a corridor connecting subpopulations within a fragmented metapopulation. Maintaining connectivity within a metapopulation has ramifications for sustaining genetic diversity, as well as preventing extinction of small populations of endangered species (Cosentino et al. 2012). Risk of desiccation, predation, and their potential interaction may prevent dispersal and underlie barriers to connectivity (Cosentino et al. 2011). Though previous studies have assessed the efficacy of structures to help breeding adults reach pools, few examined this technique at a larger scale to determine whether it may be useful in connecting isolated subpopulations (Cushman 2006). This question is addressed here via a mark-recapture study. Animals in their first year of life are categorized as stage 1, those in their second year are stage 2, and any older individuals are classified as stage 2+. Sex and weight are considered as potential explanatory variables for use of the corridor as well. I hypothesize that the corridor will be most used by younger salamanders because of their tendencies to disperse, followed by older individuals (Rothermel 2004).

Materials and Methods

Study Site

The Santa Cruz long-toed salamander currently exists in several different fragmented metapopulations (Pilliod and Fronzuto 2020). One such metapopulation is located in Santa Cruz County, which consists of approximately three different subpopulations and contains a diversity of landscapes and agricultural land (USFWS 2010). The northern population is bordered to the south by the Pajaro River, the central population is situated between the Pajaro River and Elkhorn Slough, and the southern population is bordered to the north by Elkhorn Slough (USFWS 2010). The northern, central, and southern subpopulations were assigned identification numbers of 1, 2, and 3, respectively.

Field Trapping

Trapping was conducted for ten pools in the southern part of the northern subpopulation, and for ten in the northern part of the central subpopulation. Two pitfall traps set along a 10 m drift fence were set from 1 January to 30 February of year A (Trenham and Shaffer 2005). A total of ten drift fences were set evenly spaced around each pool’s circumference. They were opened one day prior to predicted rain and checked three days thereafter, coinciding with when adult salamanders enter pools to breed (Trenham and Shaffer 2005). No more than five drift fences per pool had open traps on any given trapping night, for the purpose of ensuring all set traps could be checked within a day. Any caught individuals were implanted with a PIT tag in a lab, allowed to recover for two weeks, and released again (Messerman et al. 2020). Sex, weight, location (subpopulation ID), and any recaptures were recorded. Pitfall traps were set again from 1 May to 15 August, coinciding with when juvenile salamanders exit pools (Pilliod and Fronzuto 2020). These traps were likewise opened one day prior to predicted rain and checked three days thereafter, and any caught juveniles were implanted with a PIT tag (Trenham and Shaffer 2005; Messerman et al. 2020). These were considered stage 1 individuals, including ones recaptured in the spring of year B. Those recaptured in the spring of year C were considered stage 2, and those captured in the spring of year A were assumed to be stage 2+. This process was repeated for ten pools in the southern part of the central subpopulation, and for ten in the northernmost part of the southern subpopulation. The purpose of this was to compare the connected northern and central subpopulations with the unconnected central and southern subpopulations. During the summer of year A, a small tunnel made of PVC pipes was built along the highway running from Watsonville Slough to Elkhorn Slough (Woltz et al. 2008). It was roughly 4.8 km in length, 0.5 m in diameter, lined with soil, and had openings spaced every 30 m to allow animals to exit when they wanted (Woltz et al. 2008). It crossed the Pajaro River, enabling salamanders to move over this barrier in addition to the surrounding agricultural fields (Pilliod and Fronzuto 2020). The tunnel was manually wetted through its evenly spaced openings once per week from 1 May to 30 October, coinciding with the dry season when rainfall is lowest (USFWS 2010).

Statistical Analysis

Statistical analyses were conducted via a generalized linear model with a binomial distribution. A value of 1 indicated an animal moved from one subpopulation to another (e.g., northern to central), whereas 0 indicated the contrary. This was determined from animal recaptures. Likelihood of movement was modeled as a function of sex, weight, stage number, and subpopulation ID, and a top model was selected based on Akaike’s Information Criterion (Nelder and Wedderburn 1972). Parameter coefficients were calculated using the top ranked model to establish relationships between the explanatory variables and probability of movement between connected and unconnected subpopulations (Nelder and Wedderburn 1972).

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Budget

I. Year A

A. 4.8 km PVC pipe tunnel

1. 1575 pieces of 3 m long PVC pipe (0.5 m in diameter)

2. 48 pieces cost $728, need 33 sets of these to equal 1575 pieces

3. Total = 33 \* $728 = $24,024

B. Drift fences and traps

1. Trapping at 40 pools total with 10 drift fences per pool = 400 drift fences

2. Each 10 m silt drift fence costs $8.00 x 400 = $3200

3. Two pitfall buckets per fence = 400 \* 2 = 800, one costs $15.00

4. Total = 800 \* $15.00 = $12,000

C. PIT tags: ~250 PIT tags, $10.00 per PIT tag = $2500

D. Gas: $500

II. Year B

A. PIT tags: ~250 PIT tags, $10.00 per PIT tag = $2500

B. Gas: $500

III. Year C

A. PIT tags: ~250 PIT tags, $10.00 per PIT tag = $2500

B. Gas: $500

IV. Total: **$48,224**