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Influence of Forest Age on Densities of Cope's and Pacific Giant Salamanders

Abstract

We surveyed first-order streams in forest stands 0–94 yr old on industrial timberlands in the Cascade Mountains of southern Washington during the summer of 1998 and 1999 to determine how short-term changes in forest age can affect the abundance of the stream-breeding Cope's and Pacific giant salamanders. Based on results from cross-validated regression trees, densities of both species were unrelated to changes in forest age or any other habitat variable measured. There was also no difference in any of the measured habitat variables between streams in which a species was present and streams in which it was not detected. However, densities of the Pacific giant salamander were negatively correlated to percent of riparian canopy cover in one of the years.

Introduction

The stream-breeding giant salamanders (*Dicamptodon* spp.) have received much attention with respect to their habitat associations (Hawkins et al. 1983, Corn and Bury 1989, Parker 1991, Wilkins and Peterson 2000). Several studies correlated the presence of giant salamanders with stream habitat characteristics such as high gradient riffles (Hawkins et al. 1983, Corn and Bury 1989) and coarse substrates (Parker 1991, Wilkins and Peterson 2000) or have shown increases of giant salamanders in streams running through recently clearcut timber stands (Murphy et al. 1981, Murphy and Hall 1981, Hawkins et al. 1983). Other studies have concluded that giant salamanders are most often found in or near streams surrounded by older forest stands (Corn and Bury 1989) or in stands that have old growth characteristics such as large conifers (Gomez and Anthony 1996). This knowledge of old growth association is valuable, however, little old growth exists today in National Forests or on private timberlands. Because the current ranges of these amphibians occur partly on industrial timberlands it is also important to study habitat associations and population distribution of these animals in forests that rarely reach old growth status and are subject to regular, intensive harvest management.

Many previous studies did not differentiate between Cope's giant salamander (*D. copei*) and Pacific giant salamander (*D. tenebrosus*) when examining how this genus responds to changes in forest age or other habitat variables. It is often difficult to differentiate between Cope's giant salamander and larval Pacific giant salamanders in the field, and there is generally an unstated assumption that, despite differences in morphology and life history, the two species respond similarly to changes in environmental parameters. Cope's giant salamander was not distinguished from larval Pacific giant salamanders until its description in 1970 (Nussbaum 1970). Cope's giant salamander is an obligate neonate, remaining in an aquatic larval stage throughout its life. Metamorphosed individuals are found rarely, whereas neotony is only occasionally exhibited in some populations of the Pacific giant salamander. The difficulty of distinguishing between neotenic Cope's giant salamanders and sympatric larval Pacific giant salamanders in the field is likely preventing comparative field studies on these two species. Morphological differences between the species are slight, making field identification difficult. It has been assumed that the two species respond similarly to changes in stream substrate (Wilkins and Peterson 2000), but it has not been determined how Cope's giant salamander responds to changes in forest age and whether their responses are similar to those of Pacific giant salamanders.

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This study, performed in areas of regenerating second-growth forests, intended to examine how the abundance of Cope's giant salamander and sympatric larval Pacific giant salamanders are associated with changes in forest age. This study also intended to examine stream habitat associations of each species.

Methods

The study took place on corporate timberlands in southern Skamania County, Washington, between 45°46' to 45°38'N latitude and 122°14' to 121°53'W longitude (Figure 1). Annual precipitation occurs mostly as rains from October through March and ranges from 229 to 305 cm (Daly et al. 1994). Geology of the area is mostly basalt and andesite flows with their associated breccias and tuffs (Franklin and Dyrness 1988). Elevations range from 240 to 800 m. The region experienced nine localized stand-replacing fires between 1902 and 1952 (Felt 1977). The area is managed primarily for the production of wood pulp and small saw-logs with even-aged silviculture and 50-70 yr rotations. Dominant vegetation varies with harvest management, but Douglas-fir (*Pseudotsuga menziesii*) is usually the dominant conifer as it is commonly planted after timber harvest. Noble fir (*Abies procera*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and red alder (*Alnus rubra*) also contribute to the overstory at most sites. The understory comprises huckleberries (*Vaccinium* spp.), devil's club (*Oplopanax horridum*), blackberries (*Rubus* spp.), salal (*Gaultheria shallon*), and western sword fern (*Polystichum munitum*).

We located all first-order streams, using maps of the study area, across the range of forest ages available. Ages of surrounding timber stands were calculated from the time of replanting. Stands < 70 yr had been clearcut up to the stream banks and replanted with Douglas-fir seedlings. Stands > 70 yr were rare and likely regenerated naturally after one of the regional fires. While timber harvest was not the primary disturbance for streams in these oldest stands, two streams were sampled to provide additional data from older aged forests that are uncommon on industrial timberlands.

Streams with continuous permanent flow were located in the field to confirm their presence and to determine if they met the selection criteria for sampling. Streams selected for sampling measured ≤2 m wide, had a maximum depth of ≤15 cm, and

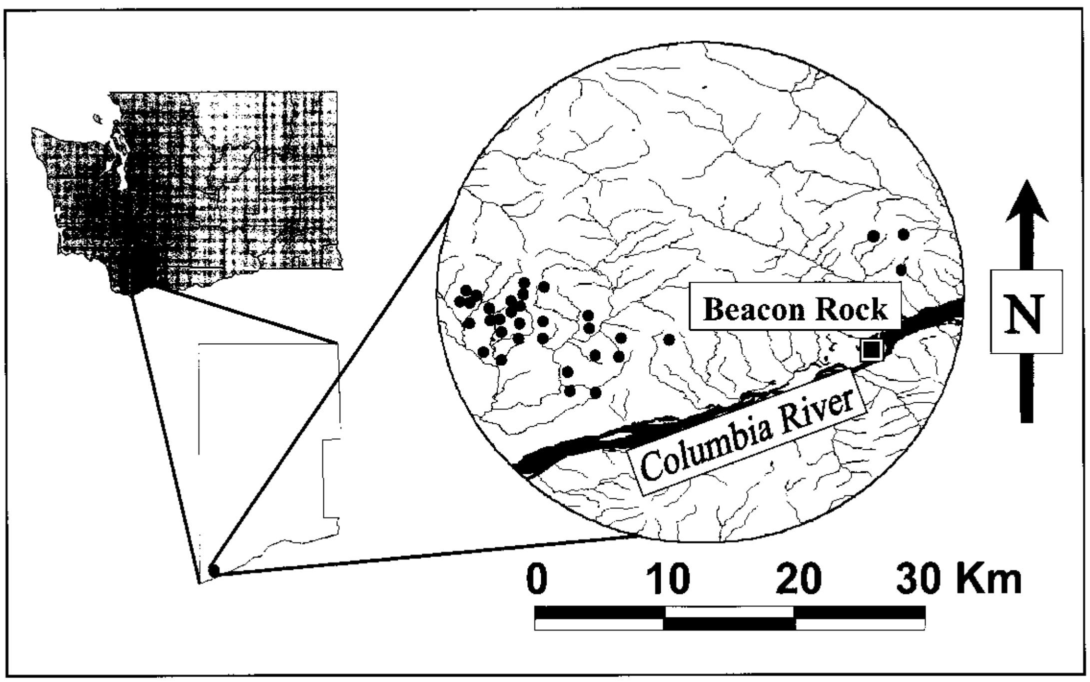

Figure 1. Location of streams sampled in Skamania County, Washington.

had an unembedded substrate that was visually estimated to comprise more than half cobble and gravel. These criteria ensured that appropriate stream habitat for giant salamanders (i.e., unsilted rocky substrates) was sampled in streams of a manageable size while minimizing variation of physical stream characteristics. Because of the high gradient and small size of these headwater streams, sampling was precluded in slow-water habitats such as pools, runs, or glides. All streams meeting these criteria in the study area were sampled. Twenty-nine streams that met the selection criteria were surveyed in 1998. In 1999 these same streams were resampled along with an additional four streams. All streams were within 29 km of each other.

Three plots in each stream were sampled between June and August during 1998 and 1999. Selection of plots within a stream began 10 m below the immediate headwaters (i.e., where the headwaters first formed a recognizable channel). Plots were 2 m long, as wide as the wetted width, and separated from each other by at least 10 m. All plots were located upstream from roads. We measured these stream and riparian habitat characteristics at each plot before sampling for salamanders began: water temperature, stream depth, width, gradient, aspect, elevation, and percent cover of trees and tall shrubs. A single measurement of stream depth for each plot was obtained by averaging nine depth measurements to the nearest centimeter: depth of the thalweg (deepest channel of the stream) at the middle, upstream, and downstream edges of the plot, and depths at midpoints between each thalweg measurement and either bank. Stream width was averaged to the nearest 10 cm from measurements at the middle, upstream, and downstream edges of the plot. Upstream gradient of the stream was measured with a clinometer. Elevation and aspect were taken from topographic maps. Percent canopy closure was measured with a spherical densiometer at the middle of each plot. The timber stands surrounding the streams were relatively homogenous, even-aged stands. Measurements of habitat variables were averaged from the three plots to give an overall measurement of the stand and stream characteristics for individual streams.

Sampling for salamanders began at the upstream portion of each plot and moved downstream to a net placed across the stream at the lower end of the plot. Salamanders were collected by systematically placing a square framed dip net in the plot, removing all cover items, raking the substrate for approximately 0.5 m in front of the dip net, and repeating the process with the intention that all salamanders would either be caught by hand or swept into the dip net. Periodically during the sample, the large net spanning the stream was searched for salamanders. Because large larvae will leave a stream during intensive sampling, a 1-m wide plot on the stream bank on either side of the stream was also intensively searched for amphibians that had either left the stream during sampling or were associated with stream edges. This 1-m wide terrestrial plot was subjected to a systematical search in which all cover items were turned over and the substrate was raked. Cover items were replaced in all plots at the end of the search.

Because larvae are often difficult to identify to species in the field, it was necessary to preserve all captured larvae in formalin for later identification in the laboratory. Using criteria established by Nussbaum (1970, 1976), preserved larvae were identified as either Cope's or Pacific giant salamander. The Pacific giant salamander usually has 6-7 gill rakers on the first and second gill arches while Cope's giant salamander has 4-5. Also, the Pacific giant salamander usually has 5-6 rakers on the fifth and sixth gill arches while Cope's giant has 3-4 (Nussbaum 1976). Gill rakers were counted for each specimen to determine the species.

Salamander abundance and habitat data of each stream were averaged from the three plots to give an overall measurement of stream habitat characteristics and salamander abundance for an individual stream in each year. Data from each year were analyzed separately using regression tree analysis with the computer program S-Plus 2000 for Windows (S-Plus 1999). Regression trees are used to uncover structure or patterns in data when either a set or a single predictor variable is used to estimate a single response variable (Clark and Pregibon 1992) and are appropriate when classification of data based on threshold values is needed rather than a linear association (Verbyla 1987). Regression trees are advantageous because data may be assumed to be non-normally distributed, both continuous and categorical data may be used, and data also do not need to be linearly related to predictor variables. We performed regression tree analysis to examine the mean number of salamanders caught per stream relative to forest age. Optimally sized regression trees were selected based on the results of a cross-validation process (Breiman et al. 1984) repeated 500 times. The presence or absence of either species in a stream was determined from both years of sampling. Comparative, two-tailed Student's t-tests, or Welch's t-test in the case of unequal variance between groups, were used to test for differences in habitat variables between streams in which the species was present and streams in which it was not detected. The 5% significance level of the *P*-values for these tests were adjusted using the Bonferroni correction method described by Rice (1989).

Results

In 1998 a total of 166 larval Cope's and 98 larval Pacific giant salamanders were captured from the 29 streams sampled. When present, the range of densities of Cope's and Pacific giant salamanders were 0.05–1.16/m^2, and 0.05–0.79/m^2. Of the 29 streams sampled, Cope's giant salamanders were in 23 (79%) and Pacific giant salamanders were in 16 (55%). Twelve streams contained both species; the ratio of Cope's to Pacific giant salamanders in these streams was 1.0:1.2. In 1999, 105 larval Cope's and 114 larval Pacific giant salamanders were captured from the 33 streams sampled. When present, ranges of densities for Cope's and Pacific giant salamanders were 0.06–1.43/m^2 and 0.06–2.5/m^2. Of these streams sampled, Cope's giant salamanders were detected in 19 (58%) and Pacific giant salamanders in 16 (48%). Both species of giant salamanders were detected in 10 of the streams; the ratio of Cope's giant salamanders to Pacific giant salamanders in these streams was 1.0:1.1.

Densities between years were significantly correlated for both Cope's ($r = 0.65$, $P < 0.01$) and Pacific giant salamanders ($r = 0.44$, $P = 0.02$). Regression trees based on the capture data for either year (Figure 2) were not supported through cross-validation and are not presented. Of the 33 streams sampled over the 2-yr period, none of the measured habitat variables was significantly different between streams in which either species was present and streams in which they were not detected (Table 1).

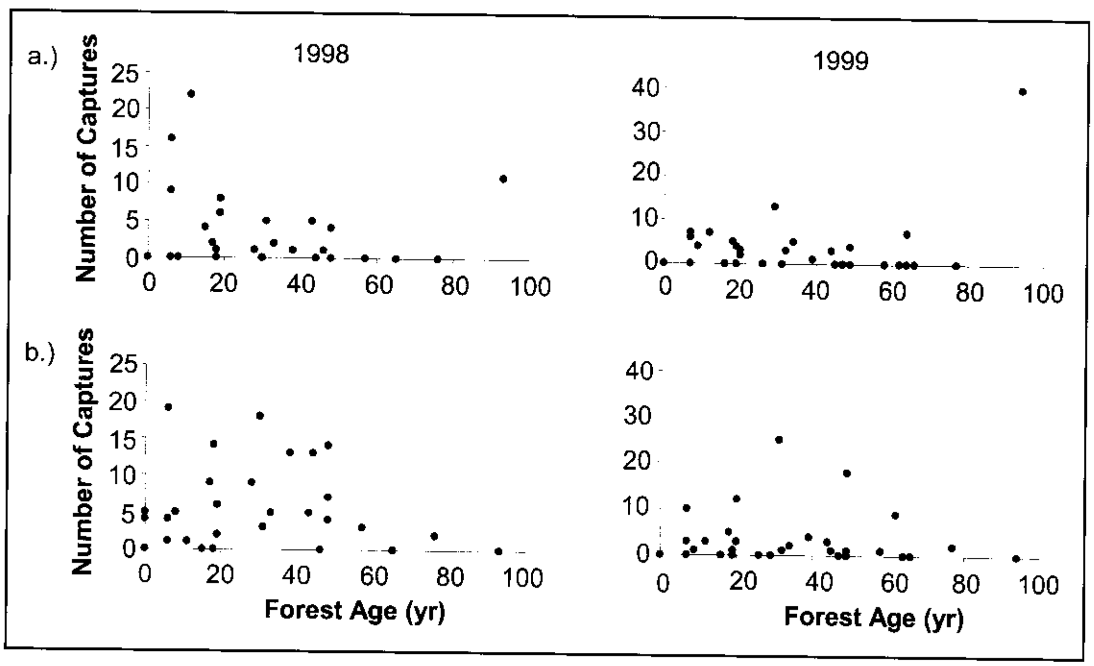

Figure 2. Scatterplots showing change in density of Pacific giant salamanders (a.) and Cope's giant salamanders (b.) in 1998 and 1999. Some data are obscured by overlapping points.

TABLE 1. Comparison of mean (SE) measured variables between streams in which a species was detected and streams in which it was undetected. [w] indicates that Welch's t-test of unequal variances was performed.

Variable	Detected	Undetected	P
Cope's giant salamander			
Number of streams	24	9	
Canopy cover (%)	79.4 (5.3)	85.1 (4.6)	0.43[w]
Gradient (degrees)	16.5 (1.2)	17.3 (2.2)	0.77
Average width (cm)	82.8 (3.5)	75.0 (4.5)	0.23
Average depth (cm)	4.3 (0.4)	3.9 (0.5)	0.61
Forest age (yr)	29.4 (4.3)	43.7 (10.2)	0.14
Water temperature (C)	9.4 (0.3)	9.8 (1.1)	0.72[w]
Elevation (m)	552.2 (32.4)	504.0 (59.1)	0.46
Pacific giant salamander			
Number of streams	18	15	
Canopy cover (%)	76.4 (6.9)	86.5 (2.6)	0.19[w]
Gradient (degrees)	15.3 (1.4)	18.5 (1.5)	0.14
Average width (cm)	85.9 (4.2)	74.5 (3.3)	0.05
Average depth (cm)	4.6 (0.5)	3.7 (0.2)	0.11[w]
Forest age (yr)	30.6 (5.3)	36.6 (6.9)	0.5
Water temperature (C)	10.3 (0.5)	8.5 (0.4)	0.01[w]
Elevation (m)	550.0 (34.6)	525.5 (47.5)	0.67

Discussion

The inability to cross-validate any of the regression trees suggests that either none of the habitat variables we measured was an effective predictor of salamander density or that the high levels of variance in the data prevented a consistent response pattern from being determined. However, an examination of the data shows that high densities of Pacific giant salamanders during 1998 were seen in streams located in recently clearcut forests (Figure 2). Elevated densities of Pacific giant salamanders are often observed in streams running through recently harvested timber (Murphy et al. 1981, Murphy and Hall 1981, Hawkins et al. 1983) and are considered to reflect the removal of riparian canopy cover, which temporarily increases aquatic production and produces an abundance of invertebrate prey. As in these previous studies, densities of Pacific giant salamanders in 1998 are negatively correlated with canopy cover ($r = 0.65$, $P < 0.001$). Patterns of density of Cope's giant salamanders differed from those of Pacific giant salamanders and were not correlated with canopy cover. Because of the high degree of variation in the number of captures between years for both species, it remains unclear if densities of Cope's giant salamander respond to changes in habitat parameters in the same way that has been documented for Pacific giant salamanders by other authors. A concerted effort by researchers to become familiar with differentiating Cope's and Pacific giant salamanders will be necessary to further our understanding of the ecological differences between these species.

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