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Ecology and Distribution of the Jemez Mountains Salamander, *Plethodon neomexicanus**

DOUGLAS P. REAGAN

Field studies involving *Plethodon neomexicanus* were made from September, 1965 to March, 1967. This species is limited to north facing slopes and steep canyons within the upper montane forest (2420–2800 m) of the Jemez Mountains, Sandoval County, New Mexico. *P. neomexicanus* maintains burrows among the rocks of talus slopes and moves easily through them. Salamanders are active at the surface at temperatures from 10.5 to 13.0 C with the surface dripping wet. Gut analysis revealed that they eat a variety of invertebrates including large numbers of ants. Intestinal nematodes, *Thelandros salamandrae*, were found in 41% of the specimens examined. Salamanders reach sexual maturity at a total length of 98 mm in males and 104 mm in females. Total and S–V length are significantly greater in females than in males. Mean clutch size was estimated at 7.7, range 5–12. *P. neomexicanus* appears to deposit eggs during late July and early August. Testes weights increase from June to September while salamanders are active at the surface. Salamanders were not accessible at other times. Collections from five new localities extended the known geographic range 19 km.

INTRODUCTION

THE first specimen of the Jemez Mountains salamander (U. S. National Museum No. 42921) was collected by Junius Henderson (Van Denburgh, 1924). It was originally identified as *Eurycea multiplicata* and the Jemez Mountains recorded as an extension of its range (Dunn, 1926). During the summer of 1949, Stebbins and Riemer (1950) collected 18 salamanders from the Jemez Mountains which they described as *Plethodon neomexicanus*. They also identified USNM 42921 as belonging to this species.

Highton (1962) grouped *P. neomexicanus* with the eastern small plethodons on the basis of similarities in body proportions and structure of the trunk vertebrae. He stated that the amount of variation between *P. neomexicanus* and other species suggests that it may have been isolated from the other members of this group previous to the late Pleistocene.

Blair (1958) postulated that the withdrawal of the Wisconsin glacier which caused the retreat of the Arcto-Tertiary forest was the factor which brought about isolation of *P. neomexicanus* from plethodontid populations

in the southeastern United States. The species is presently limited to relict stands of Arcto-Tertiary forest in the Jemez Mountains of New Mexico. This study was undertaken to provide information on the ecology, distribution and life history of *P. neomexicanus*.

METHODS AND MATERIALS

The primary area investigated was limited to the north-northwest facing slope of the south rim of Jemez caldera (Fig. 1). This area was chosen because it included the type-locality and salamanders were abundant.

During the summer of 1966, 143 salamanders were collected at two-week intervals and subsequently examined in the laboratory. Each specimen was measured (to nearest 0.1 mm with vernier calipers) for total length, snout–vent (S–V) length, and tail length. Snout–vent length was measured from snout tip to the anterior end of the vent (Riemer, 1958). The sex and condition of the cloacal aperture were noted for each salamander. Specimens were examined, by dissection, to determine extent of sexual development. The contents of digestive tracts from 39 salamanders collected at regular intervals during the summer were examined and identified. The number and location in which they were found were recorded (Martin and Korschgen,

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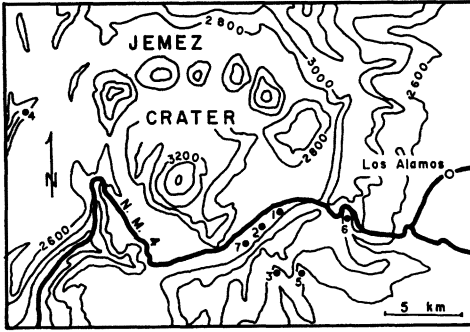


Fig. 1. Map showing known localities of *Plethodon neomexicanus* in Jemez Mountains of New Mexico. Contour interval 200 meters.

1963). The incidence and number of parasites were noted for each specimen. All salamanders were preserved and placed in the Museum of Southwestern Biology at the University of New Mexico.

A terrarium with nine adult salamanders was maintained in the study area throughout the summer to supplement field activity observations. The techniques used to gather ecological data are given under the appropriate headings.

DISTRIBUTION

Geographic Distribution

Plethodon neomexicanus is limited in range to isolated slopes in the Jemez Mountains of New Mexico. During the summer of 1966, the species was found in 7 of 41 separate sites visited. Five of these were previously unrecorded and are included in the following list. All localities are in Sandoval County, New Mexico. The locality numbers are shown on the map (Fig. 1); initial collector(s) are given when other than the author:

- 1) 19.3 km W and 6.4 km S Los Alamos, 2680 m, type-locality (Stebbins and Riemer, 1950);
- 2) 2.4 km W junction of Paso del Norte Canyon road, W of road, 2700–2785 m;
- 3) 2.4 km SE of junction of N. M. Rt. 4, and Paso del Norte Canyon road, W of road, 2700–2780 m;
- 4) Northwest slope S of Seven Springs State Fish Hatchery, 2415–2525 m;
- 5) North, east, and west facing slopes at head of Pines Canyon, 2540–2600 m;
- 6) East fork of Rito de los Frijoles near N. M. Rt. 4, 2740 m, G. A. Schad;
- 7) North slopes of Los Griegos, 2600–2815 m.

Ecological Distribution

The habitat of *Plethodon neomexicanus* lies entirely within the Rocky Mountain upper montane forest association. This occurs in New Mexico at 2140 to 2900 m elevation (Castetter, 1956). Within this area, this salamander is limited to isolated north facing slopes and sheltered canyons.

Associated Flora.—During late spring and early fall, *P. neomexicanus* is found in forested edges and along the edge of montane meadows. Two of the specimens which I collected on 30 June, 1966 were at the edge of meadows, the rest were from well forested areas. Three of the salamanders collected during September, 1966 were also collected from meadows. At no other times during the study were salamanders collected from areas which were not forested. Collections of vegetation associated with salamanders (within a one meter radius of a salamander location) were made throughout the summer. Because no striking relationships were noted, only plants characterizing the salamander habitat are listed.

The principal trees present are *Abies concolor*, *Acer glabrum*, *Picea engelmannii*, *Picea pungens*, *Pinus ponderosa*, *Populus tremuloides* and *Pseudotsuga taxifolia*. Prominent shrubs and forbs of the forested areas are *Aquilegia caerulea*, *Draba standleyi*, *Galium* sp., *Geranium richardsoni*, *Juniperus communis*, *Monotropa latisquama*, *Parthenocissus inserta*, *Robinia neomexicana*, *Rubus parviflorus* and *Viola canadensis*.

Parasites.—Intestinal nematodes *Thelandros salamandrae* have been found in *P. neomexicanus* (Panitz, 1967). Two large subadults and 14 adults (8 females and 6 males), 41% of the specimens examined in this study contained these nematodes. The number of nematodes ranged from one to nine per salamander with a mode of three. No deleterious effects were visible in the infected individuals.

Temperature and Moisture.—Observations during this study and information from other collectors indicate that emergence in the spring, presence near the surface during the summer, and retreat below the surface in the fall are related to moisture and temperature relationships. The following observations are presented as evidence.

On 26 June 1966 I spent two hours searching for salamanders beneath rocks and logs

TABLE 1. RESULTS OF SALAMANDER COLLECTING DURING 1966.

Collection Interval	No. Males	No. Females
1. June 30–July 9	10	21
2. July 10–23	21	15
3. July 24–August 6	11	12
4. August 7–20	12	15
5. August 21–September 3	3	12
6. September 4–25	1	7
	—	—
Total	58	82

at the type-locality. The soil and logs were no longer frozen and the substrate temperature ranged from 9 to 14 C. No precipitation had occurred since the surface had thawed, and no salamanders were found. I returned to the area on 30 June 1966 and spent one hour searching for salamanders. It had rained heavily on 28 and 29 June, and the ground was soaked. Nine salamanders were collected from beneath rocks at substrate temperatures from 11 to 13 C.

Over 100 additional substrate temperatures were recorded throughout the summer. Salamanders were found only under conditions approaching 100% relative humidity and between substrate temperatures of 10.5 to 13.0 C.

Slope and Exposure.—All salamanders were found on slopes ranging 5 to 36 degrees from horizontal. Evaporation and sublimation occur at greater rates on south facing slopes and exposed areas than on north facing slopes which are protected from direct solar radiation. The difference in available moisture may vary as much as 21% (West, 1959).

On south facing slopes increased incident solar radiation causes more rapid snow melt and runoff. In contrast, north facing slopes retain their snow cover longer. The gradual melting allows water to soak into the ground instead of being lost by sublimation or as runoff (Anderson, 1963). Such conditions sustain substrate moisture for extended periods and provide a suitable environment for *P. neomexicanus* on the north-facing slopes where it occurs.

Substrate and Litter.—Needles of *Abies concolor*, *Pinus ponderosa*, and *Pseudotsuga taxifolia* interspersed with leaves of *Acer glabrum* and *Populus tremuloides* form litter to an average depth of 6 cm. The presence of conifer logs and volcanic rock fragments are

prominent features of the habitat. These rocks from the exposed underlying talus slopes are composed of rhyolitic extrusion material with a characteristic fragmentation pattern which produces rocks 15 to 30 cm in diameter and 3 to 5 cm in average thickness. Salamanders were observed passing through the litter during nocturnal activity. All inactive salamanders were seen within or beneath conifer logs or under small rocks.

The soil of montane forested areas in the Jemez Mountains is an acidic podzol (Pearson, 1931). The range is volcanic in origin and is dominated by the world's largest collapse caldera (Ross, Smith, and Baily, 1961). The rim of the caldera forms a circular ridge on which all of the localities occur (Fig. 1). At all salamander localities remnants of talus slopes were visible at the surface. Several salamanders were found active among these rocks.

ACTIVITY

During summer when the soil is moist and cool, salamanders are active near the surface. During September, salamanders were observed in tunnels among the talus several centimeters below the litter while conditions were becoming cool and dry at the surface. On the basis of these observations it is probable that salamanders spend the months from early fall to late spring among the talus beneath the surface. Because of their inaccessibility during this interval, nothing is known of their underground activity.

Seasonal Activity.—Emergence of salamanders following the first soaking rains of late spring (mid to late June) has been noted on three occasions. These rains usually occur at a time when suitable temperatures for activity exist at the surface. Although other factors undoubtedly influence the activity of *P. neomexicanus*, conditions of temperature and moisture show a direct relationship to salamander activity at or near surface.

To determine if surface activity of both sexes differed, Chi-square tests were made for each two week collecting period on the basis of an expected 1:1 sex ratio (Table 1). Significant differences ($p < 0.05$) from the expected were detected in the first collecting period in the spring (25 June–9 July) and the last two collecting periods of the summer (21 August–3 September, 4–25 September). The last two regular collecting periods were pooled to obtain an adequate sample size.

As more females than males were present in these samples, the data indicate that females may consistently be more active at the surface than males.

Diel Activity.—Observations were made in the primary study area at dawn, dusk, and randomly throughout several 24 hour periods. Salamanders were seen active at the surface only when litter and foliage were dripping wet as the result of afternoon thundershowers or infrequent night storms.

Individuals were never observed at the surface before total darkness. In response to the flashlight beam they sought cover. Salamanders were observed to be most abundant at the surface between 2100 hrs and midnight, although a few could be located at anytime between dusk and dawn. All salamanders observed during the day were inactive and usually in a coiled position when discovered. Similar activity periods were observed among salamanders in a terrarium set up in the primary study area. Water was sprinkled on the surface to simulate conditions following thunderstorms at which times salamanders were seen active on the surface.

At the beginning of the summer nine salamanders were placed in the terrarium with several pieces of rock and a 6 cm layer of soil from the study area. Burrowing activity was noted within one week which continued throughout the season. By the end of August an extensive network of tunnels and chambers existed among the rocks in the soil of the terrarium. Although actual construction by the salamanders was never observed, the absence of other macroscopic organisms in the enclosure indicated the tunnels were the result of salamander activities. Similar tunnels and chambers existed among the rocks of the talus slopes in the study area and were inhabited by salamanders. This network of tunnels was traced to a depth of one meter beneath the surface and were attributed to salamanders. Such tunnels systems are extensive in the habitat of *P. neomexicanus* and could facilitate rapid retreat in response to unfavorable surface conditions and provide environmentally stable nest locations, although no nests have been reported and none were found during this study. The presence of exposed talus slopes is a unique feature of the habitat and may explain the survival of *P. neomexicanus* in the Jemez Mountains.

Feeding Habits.—The stomachs and intes-

TABLE 2. DISTRIBUTION OF FOOD ITEMS AMONG 39 ADULT *Plethodon neomexicanus*.

Food Item	% Occurrence
ANNELIDA	3
ARTHROPODA	
Arachnoidea	
Araneae	3
Pseudoscorpionida	5
Insecta	
Coleoptera (larvae)	13
Coleoptera (adults)	
Carabidae	3
Staphylinidae	8
Tenebrionidae	5
Diptera	
Mycetophilidae	10
Tipulidae	5
Hymenoptera	
Formicidae	77
Isoptera	5
Lepidoptera (larvae)	18
MOLLUSCA	
Gastropoda	3

tines of 39 specimens contained a variety of invertebrates (Table 2). The type of food taken (tipulid and mycetophilid flies) suggests some nocturnal foraging. Conversely, the secretive habits of pseudoscorpions, annelid worms, and staphylinid beetles indicate subsurface foraging. Contents of digestive tracts from animals collected in late summer revealed a greater variety of prey than earlier in the season probably reflected an increase in types of available food items rather than a shift in dietary preference.

Ants are the most frequently consumed prey being found in 30 of the 39 stomachs examined. The number taken varied from 1 or 2 in stomachs containing other invertebrates to 25 in one digestive tract containing no other food items. All prey items were organisms commonly observed in the habitat of *P. neomexicanus*.

REPRODUCTION

Collections made throughout the summer of 1966 consisted of 143 animals of which 84 were adults and 59 were juveniles. Johnston and Schad (1959) obtained a similar ratio in collections of *Aneides hardii* from the Sacramento Mountains of New Mexico. They explained the results by suggesting more juve-

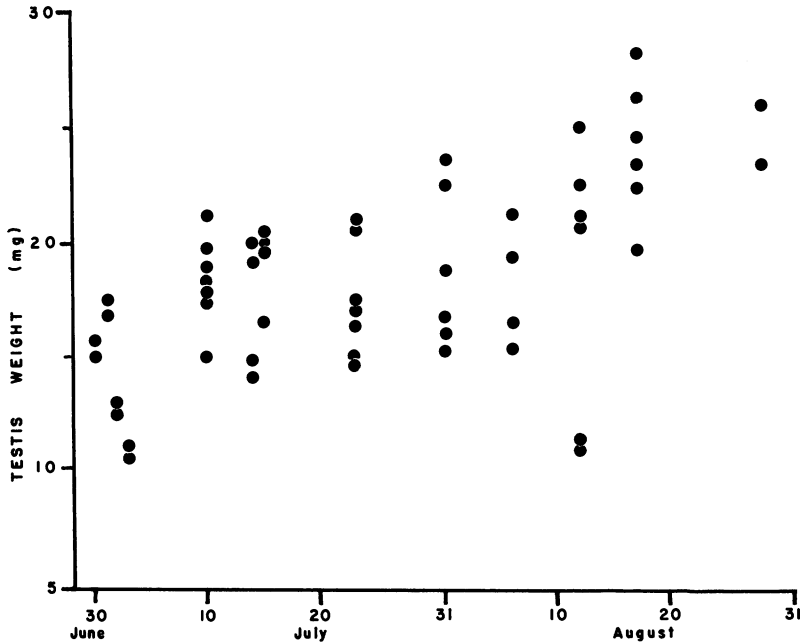


Fig. 2. Testis weights of adult male *Plethodon neomexicanus* collected during summer of 1966.

niles than adults might be present underground. This may also be true for *P. neomexicanus*, but I have no evidence to support such a conclusion.

Of the adult salamanders, 39 were males and 45 were females. Males with dark, enlarged testes and females with large, yolked follicles were considered sexually mature.

Snout-vent length varied from 56.5–70.0 mm ($\bar{x} = 60.5$) for mature females and from 51.4–68.0 mm ($\bar{x} = 57.9$) for mature males. Using Student's *t*-test, the probability is less than 0.01 that the mean S-V length of both sexes are the same. Total length varied from 103.7–136.0 mm ($\bar{x} = 117.9$) for mature females and from 97.5–127.7 mm ($\bar{x} = 112.4$) for mature males. The differences, however, are not sufficiently great to render this character useful for separating sexes in the field. The smallest mature salamanders of each sex are similar in size to the smallest adults collected by Stebbins and Riemer (1950) and indicate the approximate size at which sexual maturity is attained.

No egg clutches were found during the study despite repeated searching. *P. neomexicanus* probably deposits its eggs in rock cavities deep in the talus slopes. This would render the eggs less subject to environmental fluctuations than would deposition near the

surface and also explain why none have been found.

Clutch size and breeding period were estimated by analyzing counts and measurements of enlarged follicles in adult females. The number of enlarged follicles varied from 5–12 ($\bar{x} = 7.7$).

Individual testis weights for adult males indicate a gradual gain throughout the summer and early fall (Fig. 2). Microscopic examination verified that the gain was caused by increased sperm production and storage in the testis. Examination of reproductive tracts showed sperm present in the vas deferens of some males throughout July and August. All adult females contained enlarged follicles in late June and throughout July (Fig. 3). No females with enlarged follicles over 2.8 mm in diameter were found after the first week in August. During this same period, spent females with no follicles larger than 0.5 mm appeared in collections. One female collected 3 July, and one 6 August, 1966 each had sperm present in their cloacas. Both females also contained enlarged follicles. The 6 August female contained the largest follicles (3.4–3.8 mm) found during the study. Both would probably deposit eggs shortly after the capture date. Sayler (1966), working with *P. cinereus* in Maryland, found

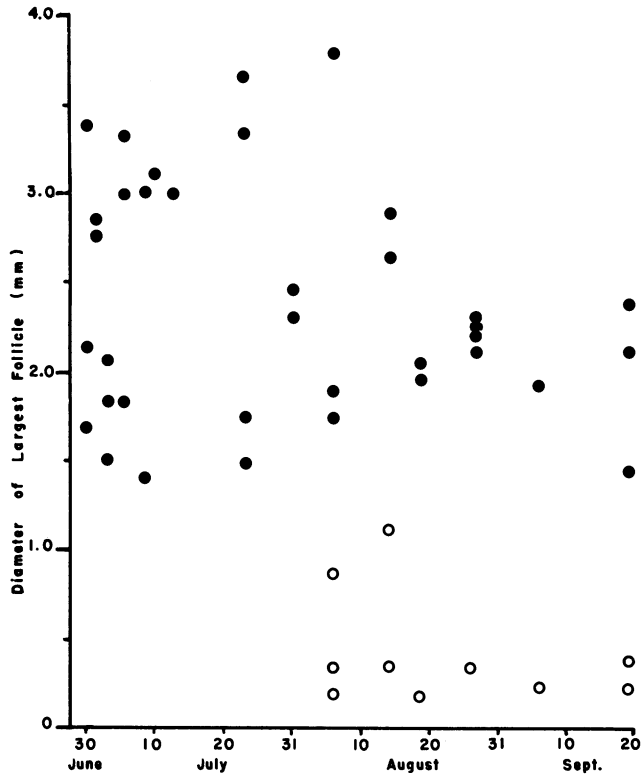


Fig. 3. Distribution of follicle size (greatest diameter of largest follicle) of adult female *Plethodon neomexicanus* collected during summer of 1966. Circles indicate females in which follicles were less than 0.5 mm in diameter.

greatly enlarged follicles in adult females until late June and spent females thereafter. By combining these data with reports of eggs newly deposited immediately after June, she concluded that eggs are laid during June. By interpreting my data on *P. neomexicanus* similarly, this salamander probably lays its eggs during the month of July and early August.

Adult females with greatly enlarged follicles and some with smaller follicles are both present during the period when egg deposition occurs. This indicates that females require a two year period to develop fully yolked follicles as has been found in *P. cinereus* in Maryland (Sayler, 1966). Presumably about half of the female population deposit eggs each year.

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