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STUDIES ON THE BIOLOGY AND ECOLOGY OF THE NORTHERN SCORPION, *PARUROCTONUS BOREUS* (GIRARD)[1]

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ABSTRACT.— An investigation to elucidate some facets of the biology and ecology of *Paruroctonus boreus* (Girard), in southeast Idaho, was conducted from 21 March to 13 October 1972. Three hundred and eighty-five observations were made on 202 scorpions captured in covered pitfalls and by ultraviolet light.

The greatest activity occurred at 2130 hours. Surface activity was not observed when ambient temperature was below 10 C, and, as ambient temperature increased, an increase in surface activity was noted. Male scorpions frequently moved as much as 30 m between observations, while females seldom moved more than five m.

Sex ratios varied considerably depending on time of year and method of sampling. Of 142 scorpions observed by blacklight, 92 were males, and 50 were females (1.84 males/female). Limited data suggest a mean litter size of 34 ± 11.

Paruroctonus boreus (Girard), the northern scorpion (Williams, 1972), is best known for its wide distribution and range northward into southern British Columbia and Alberta. In the United States, it has been reported from Arizona, California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, Utah, Washington, and Wyoming (Gertsch and Soleglad, 1966).

P. boreus has been found in numerous localities throughout southern Idaho (Fig. 1). Some individuals have also been reported from central Idaho, near Challis, and from an area in eastern Washington across the Snake River from Lewiston, Idaho (Anderson, 1972). Individuals have been collected in a variety of habitats throughout the state, but most commonly on arid hillsides where the soil is dry and cracked or very rocky. Cracks and rocks provide shelter for the scorpions during daylight.

Descriptions of the species have been provided by Ewing (1928), Gertsch and Allred (1965), and Gertsch and Soleglad (1966). It is a medium-sized scorpion of conventional pale color, with a V-shaped black marking centered on the median eyes, and dusky transverse bands on the segments of the preabdomen.

Several recent studies regarding the biology and ecology of various species of Vaejovidae have been published, but a paucity of

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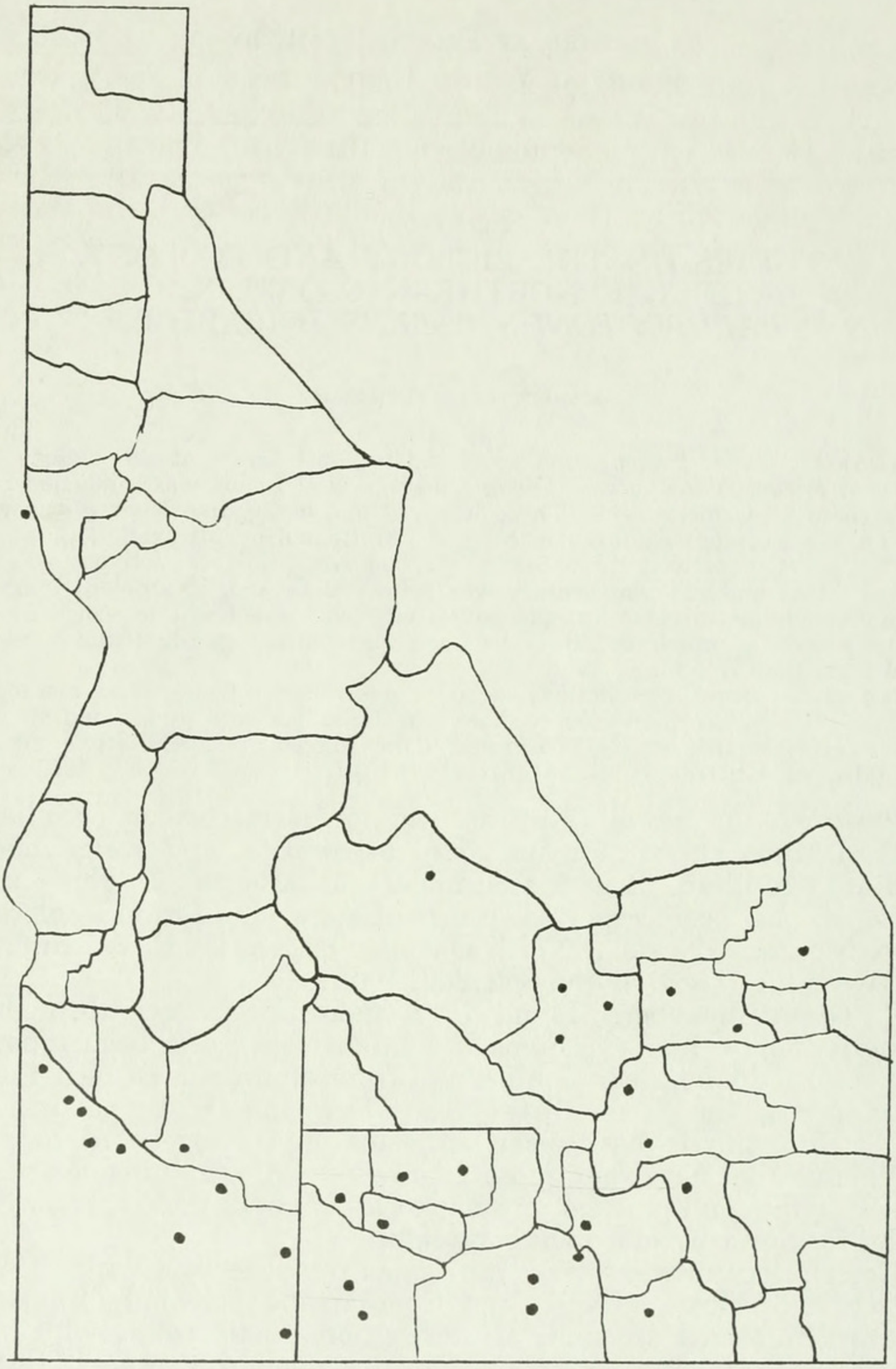

Fig. 1. Distribution of *P. boreus* in Idaho (after Anderson, 1972).

information regarding *P. boreus* still exists. Some aspects of the behavior of *Centruroides sculpturatus* Ewing, *Vaejovis spinigerus* (Wood), and *Hadrurus arizonensis* Ewing were described by Stahnke (1966). McDaniel (1968) studied the ecology of two species of scorpions in California; he compared an errant species, *Paru-*

roctonus sylvestrii Borelli, to a burrowing species, *Anuroctonus phaeodactylus* (Wood). Hadley and Williams (1968) described the nocturnal surface activities and feeding behavior of two species of Vaejovidae and one species of Buthidae. Williams (1966) described several aspects of scorpion biology, including the burrowing activities of *A. phaeodactylus*, birth activities of several species of scorpions, and (1970) the influence of various habitat types on the abundance, distribution, and community structure of *Vaejovis confusis* Stahnke, *V. spinigerus*, and *H. arizonensis*.

The present study was undertaken to elucidate some aspects of the biology and ecology of *P. boreus*, specifically: (1) daily and seasonal surface activity periods of a population of *P. boreus* in southeast Idaho, (2) frequency of surface activity for individual scorpions, (3) movement patterns, (4) sex-ratio characteristics, and (5) other facets relating to the biology and ecology of the species.

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Methods and Materials

The study site was one mile southeast of Pocatello, Idaho, near the base of Chinks Peak, at an elevation of approximately 5000 ft. The predominant plant species on the site was Utah juniper, *Juniperus osteosperma* (Torr.). Other plant species present included big sagebrush, *Artemisia tridentata* Nutt., cheat grass, *Bromus tectorum L.*, and Great Basin wildrye, *Elymus cynereus* Scribn & Merr. The site was characterized by dry cracked soil, with some rocky areas, and was selected following preliminary sampling of many areas the previous year because it contained numerous scorpions and was relatively free from human disturbance. Due to the large number of junipers on the site (Fig. 3), the sampling area (approximately 420 m^2) was kept minimal to insure that the entire area could be adequately and thoroughly examined on each sampling occasion.

Scorpions were captured for marking and releasing by two methods: (1) the blacklight technique of Honetschlager (1965) and (2) covered pitfalls. The blacklight detection method incorporates the phenomenon whereby a substance in the scorpion cuticle converts shortwave ultraviolet radiation into visible light. A Burgess Safari-Lite® was used as a source of UV. Twenty-three pitfall traps were arranged in two lines, crisscrossing the study area (Fig. 4). The traps were covered with 25 X 25 cm masonite squares, as described by Williams (1968). Pitfall traps were checked twice each day, at dawn and at dusk.

To maintain uniformity in sampling, the study area was divided into seven line transects. The transects were approximately five meters apart, and each transect was marked with reference points every 5 m (Fig 4). Uniformity between samples was maintained

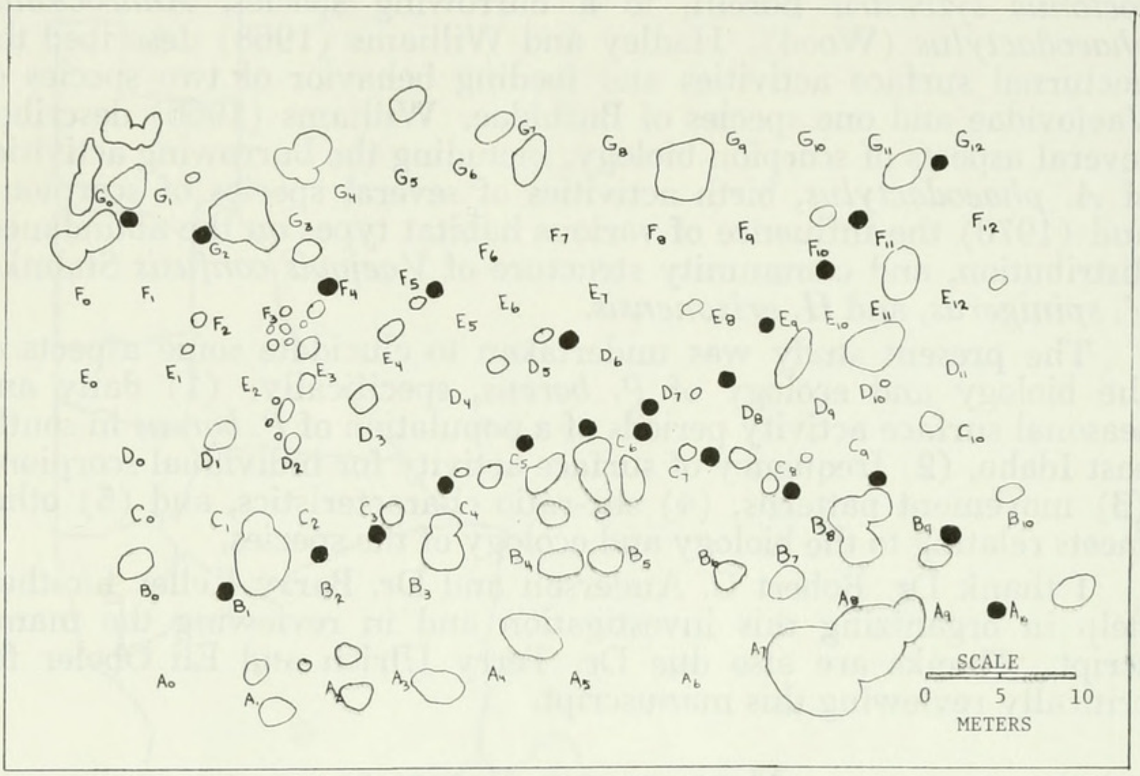

Fig. 2. Diagram of study area, indicating location of Utah juniper, *Juniperus osteosperma* (enclosures), pitfall traps (solid dots), and reference points (X_n).

by walking each transect at the same rate, while moving the light source from side to side. During periods of illumination from more than a quarter moon, the distance between transects was cut in half and the light source was held closer to the ground. By these pro-

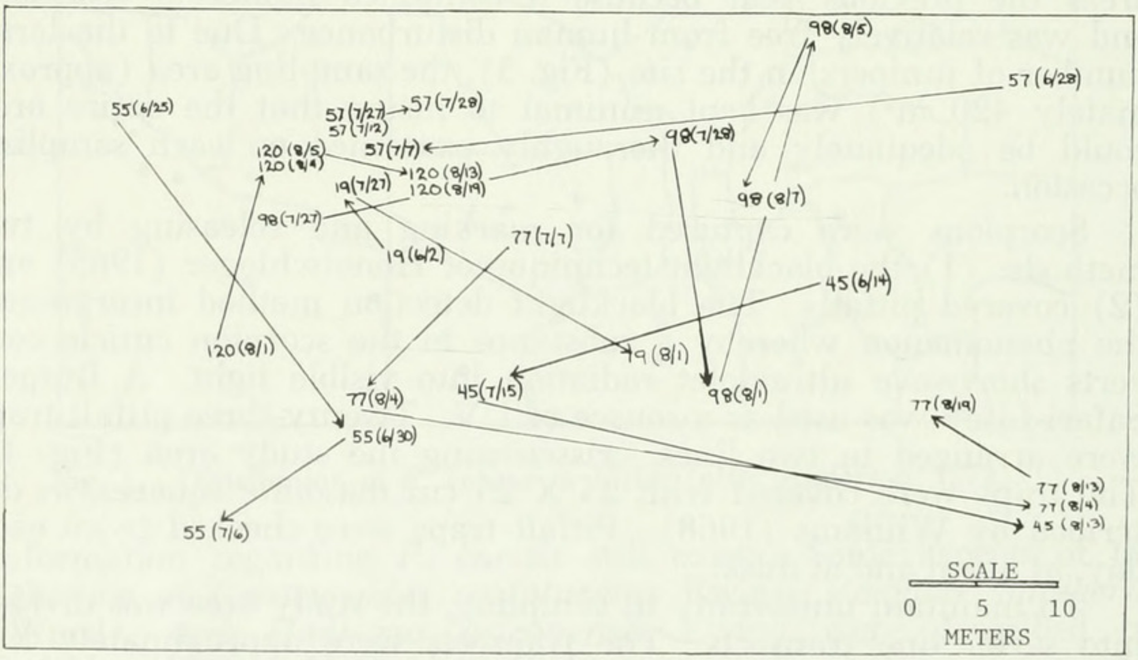

Fig. 3. Movement patterns of male *P. boreus* between 2 June and 17 August 1972 as determined by blacklight and pitfall.

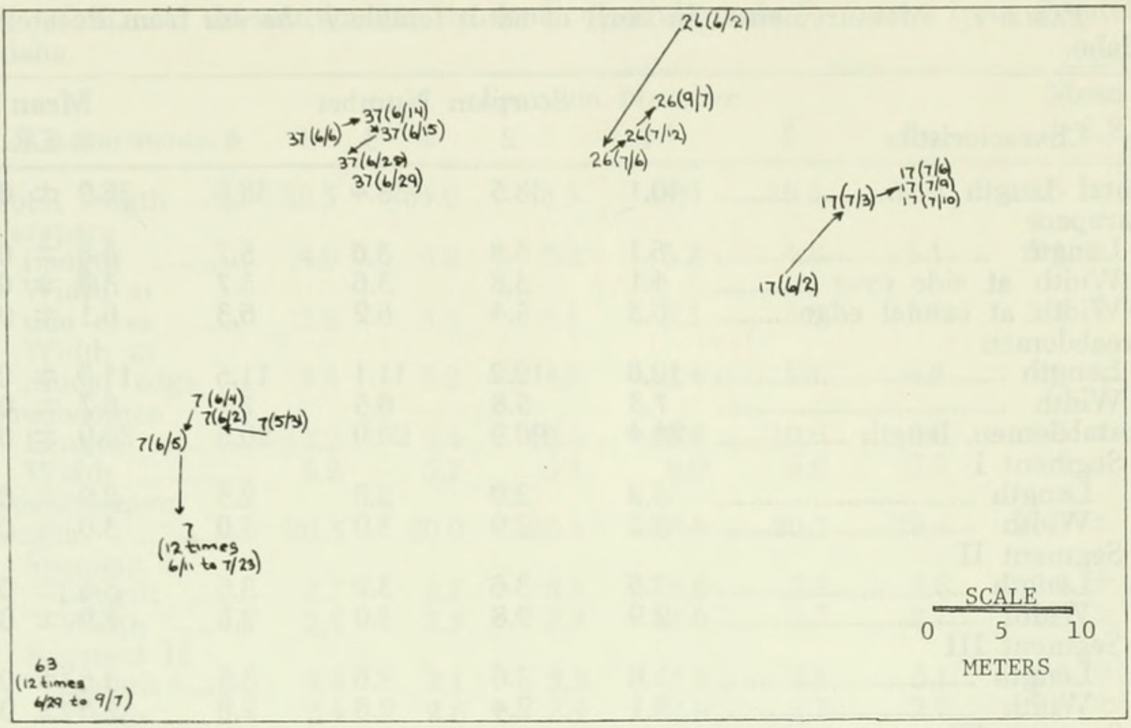

Fig. 4. Movement patterns of female *P. boreus* between 31 May and 7 September 1972 as determined by blacklight and pitfall.

cedures, active scorpions could be observed anywhere within the study site.

A map resembling that in Figure 3 was carried during each sampling occasion with blacklight. Reference points were used for recording the exact location of all scorpions observed. Scorpions larger than 30 mm total length were marked with a coded number system (Tourtlotte, 1973) by applying Testor's Pla Enamel®. Loss of marks due to molting was not evidenced, although some marks may have rubbed off as scorpions crawled into burrows and under debris. Sex, behavior, and location were recorded for all scorpions observed. Several gravid females were examined in the laboratory to obtain information on fertility.

By early fall several burrow locations were found and marked. During the first two weeks of March 1973, six burrows were excavated in an attempt to disclose the nature of the overwintering characteristics for the species.

Weather information recorded at the site included precipitation, air temperature at ground level, and soil temperature. Precipitation was measured with a Victor Rain-Gage®. A Taylor maximum-minimum thermometer was used to determine air temperature at ground level. Soil temperature was measured with a standard mercury bulb glass thermometer enclosed in a metal sleeve and placed at a depth of 15 cm.

Results

Mensuration of biotype.— Taxonomic characteristics of four female and six male *P. boreus* from Pocatello were measured (Tables 1, 2) following the criteria of Gertsch and Soleglad (1966). Length

Table 1. Measurements (in mm) of adult female *P. boreus* from Pocatello, Idaho.

Characteristics	Scorpion Number 1	2	3	4	Mean ± S.E.
Total length	40.1	38.5	38.4	38.6	38.9 ± 0.4
Carapace					
Length	6.1	5.8	3.6	5.7	5.8 ± 0.1
Width at side eyes	4.1	3.8	3.6	3.7	3.8 ± 0.1
Width at caudal edge	6.3	5.4	6.2	6.3	6.1 ± 0.2
Preabdomen					
Length	12.8	12.2	11.1	11.5	11.9 ± 0.4
Width	7.3	5.8	6.5	7.1	6.7 ± 0.4
Postabdomen, length	21.4	20.9	20.9	20.5	20.9 ± 0.2
Segment I					
Length	3.2	2.9	2.8	2.5	2.9 ± 0.2
Width	3.2	2.9	3.0	3.0	3.0 ± 0.1
Segment II					
Length	3.6	3.6	3.2	3.5	3.6 ± 0
Width	2.9	2.8	3.0	2.8	2.9 ± 0.1
Segment III					
Length	3.6	3.6	3.6	3.5	3.6 ± 0
Width	3.1	2.4	2.8	2.8	2.8 ± 0.2
Segment IV					
Length	4.4	4.2	4.4	4.4	4.4 ± 0
Width	2.8	2.6	2.7	2.6	2.7 ± 0
Segment V					
Length	6.6	6.6	6.9	6.6	6.7 ± 0.1
Width	2.8	2.5	2.5	2.6	2.6 ± 0.1
Telson, length	6.2	5.9	6.6	6.6	6.3 ± 0.2
Pedipalp	18.6	17.3	19.5	18.5	18.5 ± 0.4
Femur					
Length	4.8	4.2	5.1	4.4	4.6 ± 0.2
Depth	1.3	1.0	1.4	1.2	1.2 ± 0
Tibia					
Length	5.3	4.8	5.2	4.8	4.5 ± 0.1
Depth	2.0	1.6	1.9	1.8	1.8 ± 0
Hand					
Length	8.5	8.3	9.2	9.3	8.8 ± 0.2
Width	3.8	3.5	3.7	3.8	3.7 ± 0.1
Depth	2.7	2.7	2.6	2.8	2.7 ± 0
Palm length	5.1	4.7	4.5	5.0	4.8 ± 0.2
Moveable finger length	6.1	5.7	5.9	5.9	5.9 ± 0.2
Pectines					
Number of teeth					
Right	21	22	20	20	21 ± 0.5
Left	21	22	20	21	21 ± 0.5

and width of the carapace and preabdomen were consistently larger in females than in males, but the number of pectine teeth in females was considerably less than in males. Females possessed 20-22 pectine teeth, while males possessed 27-32. Although the number of teeth on the two pectines of one female and each of three males was not consistent, these differences appeared to be due to physical damage rather than of congenital origin. Two individuals observed in the field each had one pectine missing entirely.

Surface activity.— Surface activity was not indicated during the daylight period, as no scorpions were captured in pitfalls between

TABLE 2. Measurements (in mm) of adult male *P. boreus* from Pocatello, Idaho.

Characteristics	Scorpion Number 1	2	3	4	5	6	Mean ± S.E.
Total length	38.5	34.0	35.5	36.0	36.3	32.9	35.5 ± 1.7
Carapace							
Length	4.9	5.2	5.2	5.2	4.8	5.1	5.1 ± 0.1
Width at side eyes	3.2	3.5	3.1	3.1	3.6	3.6	3.4 ± 0.1
Width at caudal edge	4.8	5.2	4.9	5.4	5.1	4.8	5.0 ± 0.1
Preabdomen							
Length	13.2	9.4	10.2	10.6	10.9	9.0	9.8 ± 0.4
Width	5.2	5.7	5.1	6.0	5.6	5.5	5.5 ± 0.2
Postabdomen, length	20.3	20.0	20.1	20.8	20.3	19.4	20.2 ± 0.2
Segment I							
Length	2.7	2.7	3.1	2.8	2.8	2.6	2.8 ± 0.1
Width	2.5	2.5	2.4	2.6	2.7	2.7	2.6 ± 0.1
Segment II							
Length	3.4	3.1	3.3	3.4	3.1	3.1	3.2 ± 0.1
Width	2.4	2.6	2.4	2.6	2.7	2.7	2.6 ± 0.1
Segment III							
Length	3.6	3.7	3.6	3.8	3.8	3.4	3.7 ± 0.1
Width	2.5	2.4	2.4	2.2	2.6	2.5	2.4 ± 0.1
Segment IV							
Length	4.6	4.4	4.1	4.5	4.2	4.0	4.3 ± 0.1
Width	2.5	2.4	2.4	2.2	2.6	2.3	2.4 ± 0.1
Segment V							
Length	6.0	6.1	6.0	6.3	6.4	6.3	6.2 ± 0.1
Width	2.0	2.0	2.1	2.0	2.4	2.2	2.1 ± 0.1
Telson, length	5.8	5.7	6.1	6.5	6.0	5.5	5.9 ± 0.2
Pedipalp	16.1	17.1	18.8	17.4	17.0	16.3	17.1 ± 1.0
Femur							
Length	4.4	4.4	4.5	4.6	4.2	4.0	4.4 ± 0.2
Depth	1.1	1.4	1.1	1.2	1.1	1.1	1.2 ± 0.1
Tibia							
Length	4.2	4.5	4.4	4.4	4.7	4.5	4.5 ± 0.1
Depth	1.6	1.7	1.5	1.6	1.4	1.4	1.5 ± 0.1
Hand							
Length	7.5	8.2	7.9	8.2	8.1	7.8	7.8 ± 0.1
Width	3.7	3.6	3.4	3.6	3.6	3.3	3.5 ± 0.1
Depth	2.7	2.5	2.5	2.5	2.5	2.3	2.5 ± 0.1
Palm Length	4.8	4.8	5.0	4.6	4.8	4.6	4.8 ± 0.1
Moveable finger length	4.8	5.2	4.8	5.2	5.5	4.8	5.1 ± 0.2
Pectines							
Number of teeth							
Right	29	33	31	30	28	29	30 ± 0.8
Left	31	33	33	30	29	29	31 ± 0.8

dawn and dusk. Several scorpions were observed leaving their burrows shortly after sunset, apparently to spend the nocturnal hours on the ground surface. Surface activity was most intense during the first two hours of darkness, diminishing until dawn.

Observations were made at intervals between 2130 and 0330 hours to determine if scorpion activity was equally distributed throughout the nocturnal hours. Samples of surface activity were made at 2130, 0030, and 0330 hours on 7 and 12 July, and on 7 and 9 August 1972. Activity was highest at 2130 hours and lowest at 0330 hours on all sampling periods (Table 3). The number of scorpions observed at different times was compared by a chi-square test of homogeneity and goodness of fit. Heterogeneity was not detected, but analysis of the pooled data gave a significant ($P < 0.05$) chi-square value of 14.71, indicating that surface activity was not equally distributed throughout the night.

Surface activity was first observed on the study area 22 March 1972, and last observed on 13 October 1972. Surface activity may have occurred before and after these dates but was not evidenced. On 15 sampling periods in June, 89 scorpions were observed (5.93 scorpions/night); 98 scorpions were observed for 16 sampling periods in July (6.13 scorpions/night); 97 scorpions were observed for eight sampling periods in August (12.13 scorpions/night); and 18 scorpions were observed for six sampling periods in September (3 scorpions/night). Surface activity was greatest between 27 July and 9 August when 109 scorpions were observed on seven nights sampled (15.57 scorpions/night).

Frequency of surface activity for individual scorpions.— The frequency of surface activity varied greatly among individual scorpions. Many were observed only once throughout the study, while others were seen repeatedly. One female (#7) was observed 16 times, including 10 of the 15 nights sampled in June. Another female (#63) was observed on 11 of 17 sampling periods between 29 June and 1 August, and again on 7 September. No individual male scorpion was observed more than five times. Four males (#'s 57, 77, 98, and 120) were observed five times, and two males (#'s 82 and 125) were observed four times during the course of this study.

A total of 224 observations were made on 142 different scorpions by the blacklight technique. Fifty females were observed on 101 occasions (2.02 observations/female), and 92 males were observed on 123 occasions (1.33 observations/male). The observed frequency of surface activity was considerably higher for females than for males.

Movement patterns.— Movements of individuals within the study area were assessed by noting the location of each scorpion

Table 3. Number of *P. boreus* observed by blacklight at three different times of night.

Date	Number of scorpions observed at different times 2130	0030	0330
July 7	5	3	2
July 12	7	4	1
August 7	21	13	9
August 9	14	9	5
Total	47	29	17
Mean ± S.E.	11.7 ± 3.6	7.2 ± 2.3	4.2 ± 1.8

observed. These data are summarized in Figures 3 and 4. It was not uncommon for males to move 30 meters or more between observations, while females seldom moved more than 5 meters. Two females (#'s 7 and 63) were each observed 12 times within the same square decimeter. Data from the pitfall traps further substantiated that males were more mobile than females. Of 161 scorpions captured in pitfall traps only 10 were females. Williams (1966) reported a similar differentiation in movement patterns with regard to sex in *Anuroctonus phaeodactylus*. In a pitfall study conducted for one year, he captured 33 scorpions, all mature males.

Several scorpions were marked and released on and around the study site during the previous summer (July 1971). During this study 11 of these individuals were recaptured, indicating that *P. boreus* will remain in the same general area for at least two seasons.

Sex ratio.— The sex ratio of *P. boreus* was extremely variable throughout the study (Fig. 5). Since pitfall data tended to drastically underestimate the number of females in the population, only blacklight data was used for sex ratio determinations. Of the 224 blacklight observations, 123 were of males and 101 were of females (1.22 males/female), and of the 142 individuals observed, 92 were males and 50 were females (1.84 males/female). The ratio of males to females was 24:67 (0.36 males/female) in June, 39:22 (1.77 males/female) in July, 91:6 (15.7 males/female) in August, and 11:6 (1.83 males/female) for the month of September.

During the period 29 June to 27 July, 12 of 17 females observed possessed a swollen mesosoma, indicating a gravid condition. Very few females were observed following this period. Williams (1969) reports that species of *Vaejovis*, *Anuroctonus*, and *Hadrurus* give

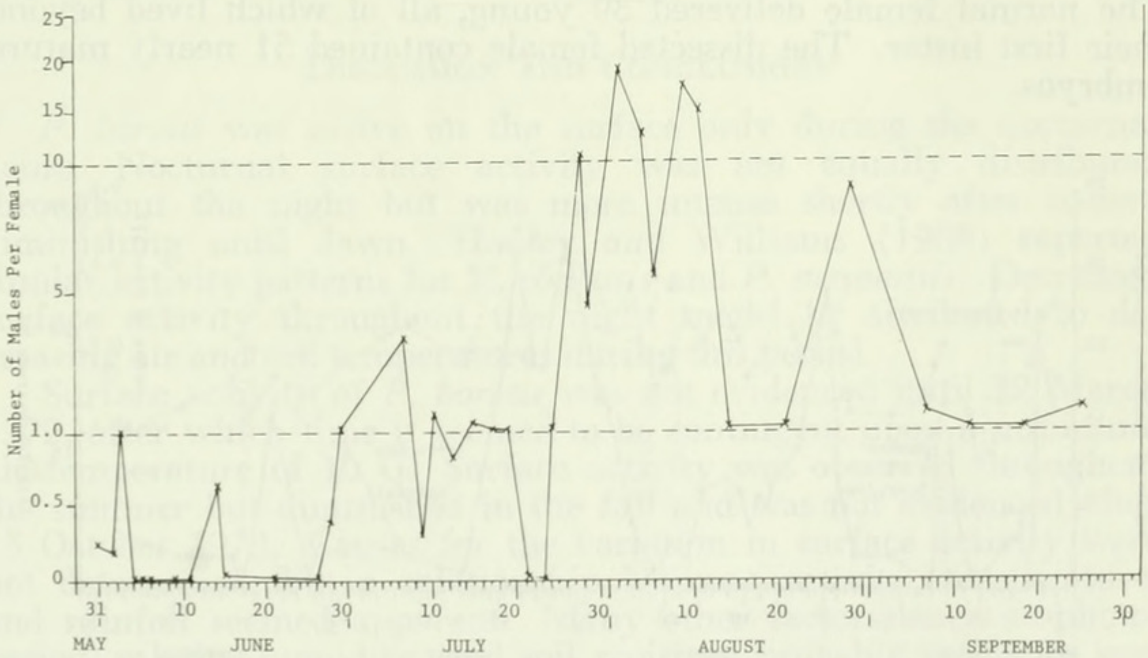

Fig. 5. Number of male *P. boreus* observed per female, between 31 May and 25 September 1972.

birth during the late summer and early fall, and that females usually remain in their burrows or other shelters while carrying young on their dorsum. The tendency of vaejovids to remain in seclusion following parturition would probably account for the paucity of females observed beyond 27 July.

Environmental influence.— Despite the fact that a multitude of factors probably interact to regulate the surface activity of terrestrial organisms, some interesting relationships between surface activity of *P. boreus* and temperature and rainfall were identified. Surface activity was not observed when the air temperature was below 10 C. As temperature increased, an increase in surface activity was noted (Fig. 6), except for the period between 29 June and 21 July, when there was no measurable precipitation (Fig. 6). The dry conditions during this period may have been responsible for the decrease in scorpion surface activity. Following the rainfall of 19 and 21 July, the original relationship of activity versus temperature was resumed.

Any measurable precipitation was immediately followed by a decrease in surface activity (Fig. 6). This decreased activity was followed within three to five days by a period of increased activity. Surface activity was not observed during periods of rainfall.

Reproduction.— No courtship activity was observed during this study. However, several gravid individuals were observed from 29 June to 27 July. During this period five gravid females were transported to the laboratory to determine fertility. Only two of the scorpions gave birth. A third died prior to parturition and was dissected. A female with only one pedipalp and a normal female each gave birth on 17 August 1972. The female with one pedipalp delivered 13 young, 10 of which she consumed before their first molt. The normal female delivered 39 young, all of which lived beyond their first instar. The dissected female contained 51 nearly mature embryos.

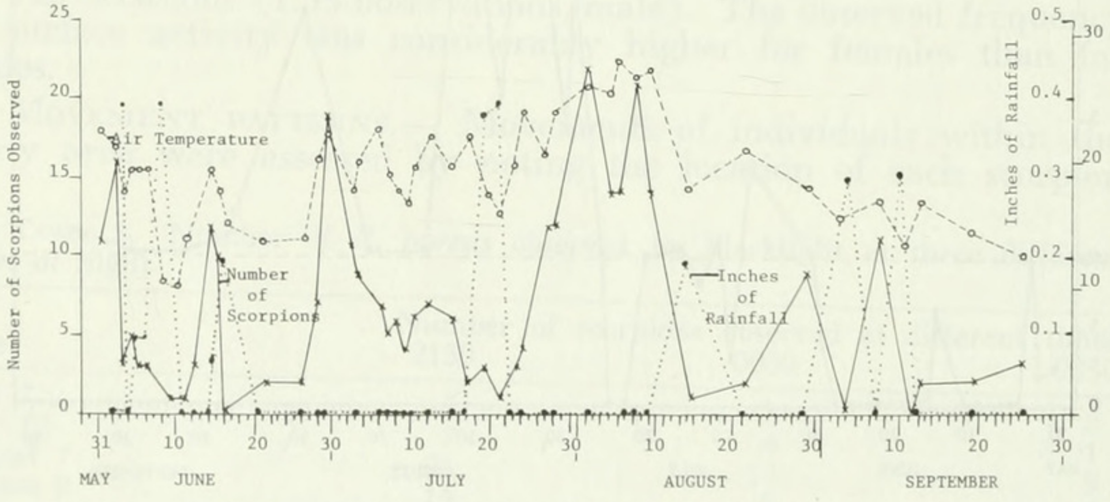

Fig. 6. Relationship between scorpion activity, air temperature, and rainfall, between 31 May and 25 September 1972.

Both females observed assumed a stilting position during parturition. The young, completely encased in a transparent birth membrane, passed through the genital aperture one by one. Within 10 to 20 minutes the young had freed themselves from the birth membrane and had climbed up the mother's walking legs to occupy a nonrandom position on her dorsum. The young scorpions first molted 12 days following birth, and within the next week they began to move from the mother's dorsum to assume an independent existence. The birth process and subsequent development of the young were similar to those described by Williams (1969). The mean litter size for the three observations was 34 ± 11.

MISCELLANEOUS OBSERVATIONS.— With few exceptions, all scorpions observed by blacklight were stationary. Similar behavior was reported by Hadley and Williams (1968) for other vaejovids. Most scorpions were observed sitting directly on the ground surface; however, several were seen on vegetation, as high as 50 cm above the ground.

Although scorpions were not observed in the act of capturing prey, feeding behavior was observed seven times during the study. Prey organisms included one grasshopper, two spiders, one scorpion (in a pitfall trap), two pentatomids, and one unidentified arthropod.

One adult female was uncovered by excavation on 10 March 1973. She was in a cavity approximately 30 mm long, 15 mm wide, and 10 mm high, at a depth of 25 cm. The air temperature at the time of capture was -1 C, and the ground temperature was approximately 8 C.

No organisms were observed to prey upon *P. boreus*, although several scorpions were killed in pitfall traps by Jerusalem crickets, *Stenopelmatus* sp. Cannibalism was observed only once in the field, but again in a pitfall.

DISCUSSION AND CONCLUSIONS

P. boreus was active on the surface only during the nocturnal hours. Nocturnal surface activity was not equally distributed throughout the night but was more intense shortly after sunset, diminishing until dawn. Hadley and Williams (1968) reported similar activity patterns for *V. confusis* and *P. mesaensis*. Decreased surface activity throughout the night might be attributed to decreasing air and soil temperatures during this period.

Surface activity of *P. boreus* was not evidenced until 22 March 1972, after which time it seemed to be contingent upon a minimum air temperature of 10 C. Surface activity was observed throughout the summer but diminished in the fall and was not evidenced after 13 October 1972. Causes for the variation in surface activity were not determined, but a relationship between activity, temperature, and rainfall seemed apparent. Many other factors, such as photoperiod, relative humidity, and soil moisture probably influence surface activity as well as temperature and rainfall, but these were not considered in this investigation.

Frequency of surface activity varied considerably among individuals. This variability might be explained by examination of such biologically necessary activities as feeding, mating, and population-dispersal. Nocturnal surface activity could provide a means of satisfying these necessities, after which the scorpion could remain in its burrow. Hadley and Williams (1968) suspected that nocturnal surface activity might be a means of maintaining water balance in a dry environment.

The high frequency of surface activity for females would permit a higher probability of mating encounters with the more mobile males. Once she has located a suitable shelter, the female appears to limit her surface activity to this vicinity. Williams (1966) suggested that the differentiation of movement patterns in male and female *A. phaeodactylus* might relate to the mate-seeking activity of males.

Sex ratios for *P. boreus* varied greatly, depending on time of year and sampling method. Allred (1973) assumed that males wander more extensively than females and are therefore more apt to fall into the pitfall traps. Because of the differentiation in mobility between males and females, data from pitfall studies were misleading in sex-ratio determinations. And because female vaejovids become less active on the surface in late summer and early fall, even blacklight data from this period tended to underestimate the number of females in the population. Probably the best method to determine sex ratio would involve comparison of the total number of males observed to the total number of females observed over the entire study period.

On the basis of the three litters examined, the variation in litter size for *P. boreus* is considerable. The smallest litter recorded (13) may have been a result of the female's handicapped condition, while the largest litter (51) may represent only the potential fecundity, since parturition had not yet occurred. The observed range in litter size is well within the range described by Baerg (1954) for several species of Scorpionida.

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