Home range geometry of the desert scorpion *Paruroctonus mesaensis*

Gary A. Polis1*, C. Neal McReynolds1, and R. Glenn Ford2

1 Department of Biology, Vanderbilt University, Box 93, Station B, Nashville, TN 37235, USA
2 Department of Biology, University of California, La Jolla, CA 92093, USA

Summary. The home range of the desert scorpion *Paruroctonus mesaensis* is analyzed using techniques of Ford & Krumme (1979). Possible factors influencing home range geometry of *P. mesaensis* include prey distribution, prey abundance and renewal, energy requirements, risk of predation and body size. There are differences in home range size among the three year classes with the youngest year class maintaining a significantly smaller home range. Home ranges of each year class are approximately circular indicating that these scorpions are remarkably symmetric in the directional use of space around their burrow. The majority of surface activity occurs within 1.0 m from the burrow for all ages. These patterns along with equal probabilities of prey capture at all distances from the burrow suggest that scorpions do not deplete prey within their home ranges.

A home range is the area used by an animal during normal activity; it does not include areas visited during migration or erratic wanderings (Burt 1943; Brown and Orians 1979). Home ranges are usually characterized by focal points of activity (Ford and Krumme 1979; Dixon and Chapman 1980; Getty 1981a; Don and Renolls 1983).

Several factors determine the shape, size and areas of concentrated activity within a home range. Focal points may be refuges from predation or other environmental hazards (Covich 1976). Alternately, such areas may be burrows or nests where offspring are reared or food is cached (Orians and Pearson 1979). There are constraints on home range size. An animal may restrict its foraging area due to increased risks away from the central place (Covich 1976; Anderson 1978; Getty 1981a) or because of the increasing costs of transporting resources back to its nest or burrow (Orians and Pearson 1979). Such risks include predation, loss of central place to competitors, or danger to offspring from predators (Covich 1976; Martindale 1982; Ford 1983). In general, these types of risk increase with distance from the central place.

An increase in energy requirements is correlated with an increase in foraging area (McNab 1963; Schoener 1968; Turner et al. 1969; Ford 1983). For example, since larger animals require more energy, increased body size is usually associated with increased foraging distances and thus larger home ranges (Harestad and Bunnell 1979; Mace and Harvey 1983). Similarly, a decrease in prey abundance may increase home range because a particular rate of prey capture can be maintained only by increasing foraging distances (Andersson 1978; Orians and Pearson 1979; Schoener 1979; Getty 1981a; Ford 1983). Rates of prey renewal also may affect home range size because central place foragers must travel a greater distance to find prey as prey are gradually depleted near the central place. If prey are renewed at a sufficiently high rate then foraging distance and home range should decrease (Andersson 1978; Ford 1983).

Distribution of prey will also affect the shape of the home range ( Getty 1981a; Ford 1983). A central place forager in a homogeneous (fine grained) habitat should have a circular home range (Andersson 1978; see Ford 1983). However, a central place forager in a patchy (course grained) habitat would have an irregular shaped home range with more activity in better patches (Getty 1981a; Don and Renolls 1983; Ford 1983). The overall activity in any patch is determined by the relative resource level in that patch and the distance to the central place ( Getty 1981a).

The purpose of this paper is to use analytic and graphical techniques developed by Ford and Krumme (1979) to describe the use of space during foraging by a scorpion, *Paruroctonus mesaensis* Stahnke. This method uses composite population data to represent the home range of an average individual. Although considerable information exists on the home ranges of vertebrates (see Schoener 1968; Turner et al. 1968; Schoener and Schoener 1982; Mace and Harvey 1983; and refs. in each), this paper presents one of the few and one of the most complete analyses of the home range of an invertebrate (also see Riechert 1978; Baker 1983). *Paruroctonus mesaensis* utilizes a central place by constructing a burrow in the desert sand dunes in which it lives. Most burrows are constructed on 20–25° slopes on the face of the dune to an average depth of 29 cm (mature females) (Polis et al. in press). This burrow is a physical refuge from fires, predators and the extreme desert temperatures and low humidities that occur during the day (Polis and Farley 1980; Polis in press). Predators include scorpions of the same and different species, some large spiders and solpugids, and a number of birds and mammals (Polis 1980a; Polis et al. 1981).
Materials and methods

The study site was a desert sand dune 9 km northwest of Palm Springs, California (Riverside County). Information on climate and vegetation are given elsewhere (Polis and Farley 1979). Data were collected during a 53 month period from April 1973 through September 1977. Overall, these data were obtained from > 1000 h in the field on more than 225 nights distributed evenly over the study period.

Although scorpions are nocturnal, they are easily observed in the field at night because they fluoresce brightly under ultraviolet light (Stahnke 1972). Portable lights (Coleman Charger 3000® and Burgess Safari-light®) with ultraviolet bulbs (Sylvania® F8TS) (wavelength = 320-400 nm) were used to locate and observe scorpions.

A permanent quadrat (28 x 50 m) was established in April 1973. This 1,400 m² area was gridded by placing stakes 2 m apart in 26 rows. These stakes were also separated by 2 m in 15 columns. Each of the 390 stakes was assigned a letter and a number designating its row and column position.

Over 850 scorpions observed in the grid were individually color coded. Unique markings were achieved by using fluorescent paints of different colors in various dot combinations. The paint was tested on scorpions and found to be non-toxic; further, it did not affect the behavior of marked individuals in any detectable way. Individual burrows were marked with coded stakes. Individual activity, forage range from burrow, and the distance scorpions moved between successive sightings were tabulated from repetitive surveys of the grid area. Grid surveys were conducted on the average of once per week for the entire research period. Data from the first sighting of scorpions are presented elsewhere (Ford and Krumme 1979; Ford 1983). This shape is due to the tendency of scorpions to move down the face of the sand dune when they leave their burrows rather than up or to the sides of their burrows; thus one axis of the home range is longer than the other. The largest isopleths (with the lowest probability of location = 0.005) are irregularly shaped for all three age classes. Such asymmetry at the furthest distances from the burrows was determined by only one or two observations in each case. In general, however, isopleths around the central burrow tend to be symmetric (Fig. 1). Such symmetry is unusual; most other species are characterized by marked asymmetries in spatial use of the home range reflecting patchy or course grained resources (Ford and Krumme 1979; Ford 1983; Don and Rennolls 1983). Symmetry suggests the hypothesis that the distribution of resources around the burrow is homogeneous (fine grained), i.e., the probability of prey location and capture is similar for all points within the area (Andersson 1978; Getty 1981a; Ford 1983).

If scorpions deplete prey from the area immediately around their burrows then foraging distance and home range size should increase (Andersson 1978; Ford 1983). However, depletion may not occur for several reasons. Scorpions spend little time on the surface during the relatively few nights that they emerge from their burrows to forage (Polis 1980b, in press; Polis and Farley 1980). Ecdysis, birth and maternal brooding of newborn all occur within the burrow. On the average, an individual remains in its burrows for 92-97% of its existence; it emerges <20% of the nights in a year and remains on the surface for only 2-5 h before returning to its burrow. This emergence is only to capture prey and to mate. Most prey are eaten where captured.