Spatial distribution of Red-backed Salamanders *Plethodon cinereus* (GREEN, 1818) in relation to microhabitat structure

Territoriality of the red-backed salamander, *Plethodon cinereus* (GREEN, 1818), has been intensively studied in both field and laboratory investigations (reviewed by MATHIS et al. 1995; PETRANKA 1998). Adults of this small North American species (about 90 mm total length) defend territorial foci under logs and rocks on the forest floor; these sites provide moisture and prey during dry periods. A recapture study of salamanders active on the surface at night showed that intersexual overlap of home ranges was greater than intrasexual overlap (MATHIS 1991). In transect sampling, members of the same sex were only once encountered together, whereas 28% of adults were found as female-male pairs under the same cover objects; juveniles entered some adult territories during rainless periods (JAEGER et al. 1995). These observations led to the hypothesis that *P. cinereus* is socially monogamous (GILLETTE et al. 2000), with pairs defending their territories together (LANG & JAEGER 2000), even outside the breeding season, and tolerating intrusion of their offspring (JAEGER et al. 1995, 2001).

To test – by means of repeated observations in the field – the hypothesis that some *P. cinereus* live in female-male pairs during the non-courtship summer season, we established an array of 100 boards of pine wood (each 20 cm x 24 cm x 2 cm) at Mountain Lake Biological Station in southwestern Virginia. These boards were arranged in a square 10 x 10 array with rows spaced by 5 m, in a flat forested area which was free of rocks and had been cleared of fallen wood (JAEGER et al. 2001). Salamanders were censused in this 100-board-array for ten consecutive days in July 1996, a year after the boards had been placed. To examine how the findings from this experimental array would relate to distribution patterns in unmanipulated terrain, we simultaneously censused salamanders in two nearby study plots. These plots were gently sloping and rich in natural cover objects, mostly stones. Here, we report observations of salamanders on these "stony plots" and compare them to those from the 100-board-array (for a detailed analysis of the latter data, see JAEGER et al. 2001).

We marked two study plots (A and B, about 30 m apart) of 10 m x 10 m each in deciduous forest at Mountain Lake Biological Station, Giles County, Virginia, and mapped all moveable cover objects on these plots. We characterized 151 cover objects (83 on plot A and 68 on plot B) by type (stone or log), approximate area (longest x shortest axis), position (flat or tilted) and predominant ground beneath the object (soil, stones, or leaf litter). On ten consecutive mornings (5 to 14 July 1996) we carefully searched for salamanders, lifting or turning all cover objects on the plots. To minimize disturbance, we did not move stones again under which we had found females attending their eggs. For all encountered specimens of *P. cinereus*, we measured snout-vent length (SVL) to the nearest 1 mm with callipers, determined the sex of adults, and took notes on color patterns of back and tail, missing or damaged toes, and tail length and shape (intact, broken, or regenerating tip), to aid with identification of individuals. We classified juveniles between 20 and 30 mm SVL as 1-yr-olds, and between 31 and 37 mm SVL as 2-yr-olds (SAYLER 1966). At the end of this investigation, we measured the distances between those cover objects under which we had found *P. cinereus*.

We captured a total of 63 *P. cinereus*, and recaptured 13 of them (table 1). Nine salamanders were recaptured once, three were recaptured twice, and one female was

Table 1: Numbers of observed and recaptured individuals of *Plethodon cinereus* (GREEN, 1818) on two 100 m² study plots.

Individuals	Observed (plot A + plot B)	Recaptured (plot A + plot B)
1-yr juveniles	12 (5 + 7)	4 (2 + 2)
2-yr juveniles	17 (6 + 11)	2 (1 + 1)
Females *)	3 (10 + 13)	4 (0 + 4)
Males	11 (4 + 7)	3 (1 + 2)
Total	63 (25 + 38)	13 (4 + 9)

*) Four (2+2) females attending their eggs are included in the count of individuals, but no attempts were made to recapture them (see text).

Table 2: Records of *Plethodon cinereus* under cover objects which were refuge to more than one salamander during the 10-day study period (f - female, j - juvenile, m - male).

Cover object	Date (July 1996) 5	6	7	8	9	10	11	12	13	14
A34					j33		j51			j51
A36	f3					j43				
A39	f4					j44				
A80			j23							f61
B6	j9							j9	j57	j9
B24	f13	f14, m21	m25		f14	f14				
B29								m55	j58	
B41	f16		f27	m30, j31						

recaptured four times. Three salamanders were found under other cover objects than at first capture: a 2-yr juvenile moved 60 cm, a female moved 110 cm, and the female encountered most often was three times recaptured under a neighbouring stone, but then returned to the place of first capture.

Under eight cover objects, we recorded more than one salamander (table 2). In only two of these cases, more than one adult was involved: under stone B24, two males and two females were found (a male and a female together on 6 July); under stone B41, two females, a male and a juvenile were recorded (the latter two on the same occasion).

Fourty-seven out of 55 cover objects inhabited were stones and eight were logs. Their size ranged from 130 to 2500 cm^2, with a median of 530 cm^2. Under 52% of cover objects with leaf litter underneath (n = 33) a salamander was found at least once during the study, compared to 41% of objects with soil (n = 81) and 6% with stones only underneath (n = 34) ($\chi^2 = 17.78$, $df = 2$, $P < 0.001$). The means of the nearest-neighbour distances among inhabited cover objects were 104 cm (± 54.7 standard deviation, n = 22) for plot A and 93 cm (± 60.7, n = 33) for plot B.

While results from the 100-board-array corroborated the hypothesis of nonrandom intersexual associations – 13 female-male pairs shared a territory, but no pair of the same sex was found (JAEGER et al. 2001) – the number of recaptures on the stony plots was too small to allow inferences on the social system of these salamanders. The two cases where several adults were found under the same stone are not in accord with the idea of a pair sharing a territory. Subsequent laboratory experiments, however, demonstrated social monogamy and shared territorial defense in *P. cinereus* (GILLETTE et al. 2000; LANG & JAEGER 2000). How can we explain these contrasting results?

In many parameters observations on our stony study plots match those on the 100-board-array very well: the same time was used to census the study areas, the number of inhabited cover objects was 55 (stony plots) and 56 (100-board-array), respectively, sizes of cover objects were similar (a median of 530 cm^2 on the stony plots compared to 480 cm^2 boards), the total number of observed *P. cinereus* was 63 (stony plots) versus 67 (100-board-array), in both situations four females guarding their eggs were found. Noteworthy differences between the study areas were total area (200 m^2 versus 2025 m^2) and the distances between cover objects. Thus, apparent population density was about an order of magnitude higher on the stony plots. The proportion of juveniles was much higher there (46%) than in the 100-board-array (10%).

We offer two tentative explanations for the discrepancies between the results from the two study areas: Territorial behaviour may break down in areas with many available cover objects, when costs of defending a particular site exceed the profit of doing so (JAEGER et al. 2000). Thus, on the stony plots we encountered a high proportion of non-territorial floaters. Alternatively, territorial foci may have been situated deeper underground on the stony plots, in crevices or under rocks too large to move. While on the 100-board-array we could enter the

living rooms of salamander homes, we perhaps had only access to their attics on the stony plots.

QUINN & GRAVES (1999) reported that in northern Michigan groups of *P. cinereus* were found in high quality habitat (without giving details on group size or sex composition) and that under identical laboratory conditions salamanders from Michigan displayed an aggregated spatial distribution, in contrast to conspecifics from Virginia, who formed a uniform distribution. They speculated that differences in availability of cover objects and food, and perhaps also predation pressure, might cause this geographical variation in territoriality. While our results highlight the difficulties of studying the social behaviour of animals that spend much of their lives underground, they suggest that variation in spatial organization of salamander populations – in response to habitat structure – does occur at a much smaller geographical scale than discussed by QUINN & GRAVES (1999).

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Bungarus sindanus BOULENGER, 1897, an addition to the venomous snake fauna of Afghanistan

The Sind Krait, *Bungarus sindanus*, was described by BOULENGER (1897) based on three specimens from Umarkot and Sukkur (Sind, Pakistan). Because of its great superficial similarity to the Common Krait, *Bungarus caeruleus* SCHNEIDER, 1801, its occurrence within the wide range of the latter, and despite having 17 rather than 15 dorsal scale rows, this taxon was long regarded as a subspecies, or the name as a junior synonym, and its representatives as rare individual mutations of *B. caeruleus* (e.g., WALL 1913, 1919; SMITH 1943; MINTON 1962, 1966; MERTENS 1969).

KHAN (1984) rediscovered and revalidated *B. sindanus* and recognized three populations of kraits with 17 dorsal scale rows on the Indian subcontinent: a Cholistan-Rajasthan Desert population (*sindanus* s. str.), a Gangetic population (*Bungarus walli* WALL, 1907, referred by KHAN [1984] to the synonymy of *sindanus*), and a population in the northwestern highlands of Pakistan. Later, KHAN (1985) resurrected *walli* as a subspecies of *B. sindanus* and described the northwestern highland population as a new subspecies, *B. sindanus razai*. The holotype and the two paratypes of this form were collected near Makerwal, Mianwali District, Punjab, Pakistan. An additional specimen was recorded from the type locality (KHAN