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Homing behaviour in *Speleomantes strinatii* (Amphibia Plethodontidae): a preliminary displacement experiment

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Abstract. The movements of 52 cave salamanders (*Speleomantes strinatii*) were studied from May to October 2012, in NW Italy. Cave salamanders, caught inside an artificial cave, were individually marked with fluorescent visible implant elastomers and displaced 20 m from the capture site. A total of 27 (52% of displaced individuals) were recaptured in the cave by the end of the experiment. Six (11.5%) of these were recaptured inside the cave within two nights and ten (19%) within five nights. There were no sex or body size differences between returning or non-returning salamanders. These preliminary results suggest the existence of homing behaviour in *S. strinatii*.

Key words: cave, cave salamanders, displacement, homing, movements, visible implant elastomers.

Understanding movement and dispersal in species that are geographically fragmented, ecologically specialized or genetically isolated may be relevant to interpret population connectivity and to plan and implement successful conservation measures among others. In amphibians, dispersal abilities are limited to a narrow range of environmental conditions and in particular by atmospheric and soil relative humidity (Russel et al. 2005). Because all members of the family Plethodontidae lack lungs and breath exclusively through their skin, dispersal abilities should be even more reduced and restricted to permanent humid microhabitats and climatic conditions. In the case of European plethodontid cave salamanders (genus *Speleomantes*), populations are found in humid subsurface habitats and in isolated calcareous systems in SE France, continental Italy and Sardinia (Lanza, 2007). The available data on individual movements in *Speleomantes* are limited, and the few studies are based on relatively small samples. For instance, Salvidio et al. (1994) studied for 16 months the displacements, inside an artificial cave, of eleven *S. strinatii* females that moved 4 m (range 1 – 13 m) on average. Furthermore, Forti et al. (2005) reported that, during a two-year mark-recapture study, some (the exact sample size was not given) *S. strinatii* moved up to 80 m, with an average displacement rate of 0.5 m per day. Indirect information on population dispersal may also be inferred from genetic data. Chiari et al. (2012), on the basis of the analysis of the cytochrome b gene, observed deep intra- and inter-specific genetic divergence in all the five Sardinian species, suggesting the existence of possibly very limited female dispersal. Up to now, however, no study has investigated the individual capacity of dispersal and homing of any *Speleomantes* species. In plethodontid salamanders displacement experiments are used to test if egg guarding females are able to return to their clutches or, mostly to measure the capacity of displaced individuals to return to their home site. In these experiments, the proportion of homing individuals varied by species and by travel distance (reviewed in Wells 2007, Table 6.6). For instance, in *Plethodon* the proportion of returning individuals was a linear function of the distance (*P. cinereus*: Kleeberger & Werner 1982; *P. jordani*: Madison 1969), while in *Desmognathus fuscus* this relationship was less clear (e.g. Barthalmus & Bellis 1969). In general, the ability of returning home after a displacement distance of $\geq$ 30 m, seems a common attribute of terrestrial plethodontids and suggests the existence of a complex navigation system in these salamanders (Wells 2007).

In this study, a preliminary displacement experiment was undertaken to test for the existence of homing behaviour in cave salamanders displaced from their home site, in favourable environmental and climatic conditions.

The experiment was conducted near the village of S. Bartolomeo (municipality of Savingnone, province of Genova NW Italy) at about 420 m a.s.l. Cave salamanders were captured inside an artificial cave, used as an air shelter during World War II. The site, is a "U"-shape tunnel with two entrances separated by a linear distance of about 12 m (Fig. 1). The cave is situated along a stream flowing in a

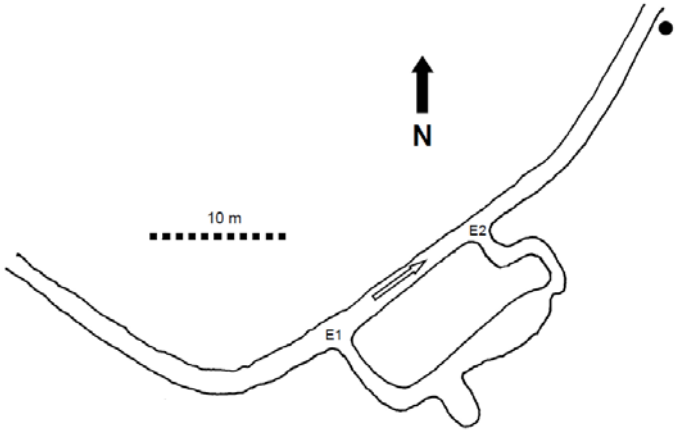

Figure 1. Schematic map of the study site showing the cave plan. E1 and E2 indicate the upstream and the downstream cave entrances, respectively; the white arrow indicates the direction of the stream flow; the black spot indicates the point of salamander release.

steep valley covered by a dense and humid mixed broadleaf forest. Salamanders were captured during four successive days in May, on the cave walls along the entire tunnel, sexed by the presence/absence of the male mental gland (Lanza 2007), measured (snout vent length = SVL) and assigned to an estimated age group, according to Lindström et al. (2010). Because all salamanders (with the exception of small juveniles) were removed from the cave, their abundance and capture probabilities could be estimated by the Capture software with M_{bh} removal estimator (White et al. 1982). All adults and sub-adults were marked individually by one subcutaneous injection of yellow or red fluorescent visible implant elastomer (VIE, Northwest Marine Technologies, Shaw Island, Washington, D.C.) in different body locations. Fluorescent VIE have no significant effects on survival and growth rates of salamanders and may constitute the best individual marking technique in the case of animals having no evident natural colour marks (Phillips & Fries 2009, Liebgold et al. 2011, Cecala et al. 2013), as in *S. strinatii*. Marked salamanders were released on the forest floor during a rainy evening, 20 m from the nearest cave entrance, at the same altitude of the entrance in downstream direction. This direction was chosen to increase survival, as the vegetation cover was denser and the rock substrate more fractured than upstream. The entire artificial cave was resurveyed in 17 occasions, from May to October 2012, during salamander activity season (Salvidio et al. 1994). Recaptured individuals were marked with a second VIE injection and released inside the cave. The SVL of salamanders recaptured inside the cave and of those not recaptured were compared by analysis of variance (ANOVA) followed by Tukey's post hoc comparisons. The distribution of recaptured salamanders among the three considered groups (i.e. females, males and sub-adults) was compared by means of logistic regression

The capture statistics of *S. strinatii* at the study site are given in Table 1. Overall, 52 individuals (15 females, 29 males and 8 sub-adults) were marked during the four removal occasions, and displaced outside the cave. Abundance and capture probabilities could be estimated for both females and males, but not for sub-adults, due to the low proportion of individuals removed during each capture session. At the end of the experiment in October 2012, 27 salamanders (52% of the total displaced sample) were recaptured inside the cave: 7 females (48% of displaced females), 18 males (58% of males) and 2 sub-adults (25% of sub-adults). There were no differences in return rates by sex or age group (linear logistic regression, Log-Likelihood = -35.472, test that all slopes are zero: $G = 1.143$, $df = 1$, $p = 0.285$). The temporal trend of return rates since removal is illustrated in Fig. 2. Six salamanders (three females and three males) were found in the cave within two nights from displacement and nine (three females and six males) within five nights. There were no differences in SVL of recaptured and non-recaptured individuals between and within sexes (sub-adults excluded from analysis due their small sample size, ANOVA; $F = 1.556$, $df = 43$ $p = 0.215$, all Tukey's post hoc pairwise comparisons $p > 0.10$, Table 2).

Terrestrial plethodontids are usually highly philopatric, displaying small home ranges and good homing capacities, in particular when displaced less than 60 m (Wells 2007). In the present study, only three directions were available for dispersion from the displacement site, because cave salamanders are fully terrestrial and are not supposed to swim voluntary across water streams. Therefore, casual dispersion could occur only upstream, downstream and uphill. If individual dispersion was only due to random movements through the landscape we would expect 33-50% of salamanders to return (the 50% value is due to the

Table 1. Capture statistics of removed salamanders estimated by model M_{bh} of Capture software. CI = confidence limits of the estimated abundance.

Sex or age group	Removal date				Total removed	N estimated (95%CI)	Capture probabilities
	I	II	III	IV			
Females	7	3	3	2	15	16 (15 – 30)	0.426
Males	13	8	7	1	29	31 (30 – 43)	0.467
Sub-adults	2	1	3	2	8	-	-
Total	22	12	13	5	52	54 (51 – 71)	0.425

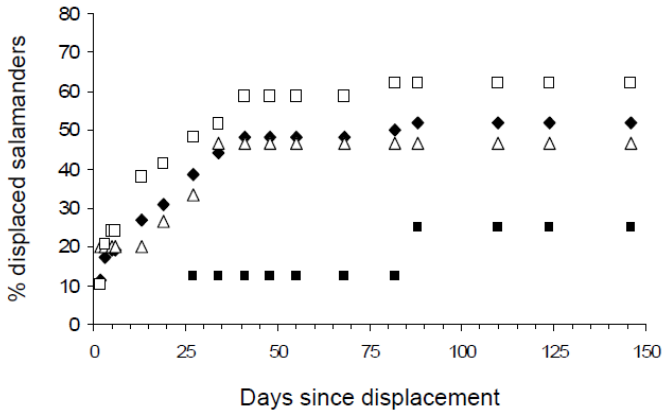

Figure 2. Percentage of marked cave salamanders that homed since the displacement. Full diamonds = total sample; open squares = males; open triangles = females; full squares = sub-adults.

Table 2. Mean SVL ± SD of cave salamanders that were recaptured or not inside the sampling site.

Displaced salamanders	N	SVL Mean ± SD (mm)
Returned Females	7	61.6 ± 4.2
Non-returned Females	8	62.8 ± 4.5
Returned Males	18	60.2 ± 2.9
Non-returned Males	11	59.3 ± 3.9
Returned Sub-adults	2	53.5 ± 2.1
Non-returned Sub-adults	6	49.3 ± 3.7

possible unfavourable uphill direction), but because the capture rates of resident *S. strinatii* in caves vary from 0.43 (this study) to 0.72 (Lindstrom et al. 2010), not all the returned individuals are expected to be recaptured, in particular if the recapture rates of displaced salamanders are similar to those of resident salamanders, as in the case of genus *Desmognathus* (Barthalmus & Bellis 1969; Huheey & Brandon 1973). The fact that 52% of displaced salamanders were recaptured inside their site of origin, strongly suggests the existence of a true homing behaviour in the species as this sample probably represents only a fraction of those individuals that were able to home. Six animals of both sexes (11.5% of the displaced salamanders) returned inside the cave within 48 hours with an average velocity of 10 m per day, a value 20 times higher than the only one reported for European cave salamanders (Forti et al. 2005). Males and females showed the same homing capacity and since they had similar capture probabilities inside the cave (see Table 1), these results seem robust and not due to differences in their detectability (i.e. one sex returning with higher rates, but less observable in the underground environment). Body size of salamanders recaptured at the sampling site was similar to that of salamanders that were not re-encountered, suggesting that homing was not influenced by size or age and/or experience. Moreover, homing also was observed in two out of eight sub-adults, which in *S. strinatii* corresponds to large non-reproductive individuals (Salvidio & Pastorino 2002), thus demonstrating that the observed behaviour was typical of both

large immature and adult individuals.

In conclusion, this study demonstrates that *S. strinatii* individuals are capable of moving on the forest floor at about 10 m per day, at least during favourable weather conditions, and that both females and males seem to display similar homing capacities. Future studies should estimate dispersal in other *Speleomantes* species, assessing in particular their homing capacities in less favourable environments, such as dry Mediterranean habitats.

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References

Barthalmus, G.T., Bellis, E.D. (1969): Homing in the northern dusky salamander, *Desmognathus fuscus fuscus* (Rafinesque). Copeia 1969: 148-153.

Cecala, K.K., Price, S.J., Dorcas, M.E. (2013): Modelling the effect of life-history traits on population parameters for cryptic stream species. Freshwater Science 32: 116-125.

Chiari, Y., van der Meijden, A., Mucedda, M., Lourenço, J.M., Hochkirch, A., Veith, M. (2012): Phylogeography of Sardinian cave salamanders (genus *Hydromantes*) is mainly determined by geomorphology. PloS One 7: e32332.

Forti, G., Cimmaruta, R., Nascetti, G. (2005): Behavioural response to seasonal variations of autoecological parameters in populations of *Speleomantes strianii* (Aellen, 1958) and *S. ambrosi i*(Lanza, 1955) (Amphibia, Plethodontidae). Annali Museo Civico di Storia Naturale "G. Doria", Genova 97: 179-192.

Huheey, J.E., Brandon, R.A. (1973): Rock-face populations of the mountain salamander, *Desmognathus ochrophaeus*, in North Carolina. Ecological Monographs 43: 59-77.

Kleeberger, S.R., Werner, J.K. (1982): Home range and homing behaviour of *Plethodon cinereus* in northern Michigan. Copeia 1982: 409-415.

Lanza, B. (2007): *Speleomantes strinatii* (Aellen, 1958). pp. 152–156. In: Lanza, B., Andreone, F., Bologna, M.A., Corti, C., Razzetti E. (eds.), Fauna d'Italia. 42, Amphibia, Edizioni Calderini, Bologna, Italy.

Liebgold, E.B., Brodie, E.D., Cabe, P.R. (2011): Female philopatry and male-biased dispersal in a direct-developing salamander, *Plethodon cinereus*. Molecular Ecology 20: 249-257.

Lindström, l, Reeve, R., Salvidio, S. (2010): Bayesian salamanders: analysing the demography of an underground population of the European plethodontid *Speleomantes strinatii* with state-space modelling. BMC Ecology 10: art.4.

Madison, D.M. (1969): Homing behavior of the red-cheeked salamander, *Plethodon jordani*. Animal Behaviour 17: 25-39.

Phillips, C.T., Fries, J.N. (2009): An evaluation of visible implant elastomer for marking the federally listed fountain darter and the San Marcos salamander. North American Journal of Fisheries Management 29: 529-532.

Russell, A.P., Bauer, A.M., Johnson, M.K. (2005): Migrations of amphibians and reptiles: an overview of patterns and orientation mechanisms in relation to life history strategies. pp. 151-203. In: Elewa, A.M. (ed.), Climatology, Geography, Ecology: Causes of Migration in Organisms. Springer-Verlag Publishers, Heidelberg.

Salvidio, S., Pastorino, M.V. (2002): Spatial segregation in the European plethodontid salamander *Speleomantes strinatii* in relation to age and sex. Amphibia-Reptilia 23: 505-510.

Salvidio, S., Tavano, M., Melodia, F., Pastorino, M.V. (1994): Ecology of a *Speleomantes ambrosii* population inhabiting an artificial tunnel. Amphibia-Reptilia 15: 35-45.

Wells, K.D. (2007): The ecology and behavior of amphibians. University of Chicago Press, Chicago.

White, G.C., Anderson, D.R., Burnham, K.P., Otis, D.L. (1982): Capture-recapture removal methods for sampling closed populations. Los Alamos, New Mexico, Los Alamos National Laboratory.