Short notes

Offspring condition determines dispersal patterns in western whip snakes, *Hierophis viridiflavus*

Lorenzo Rugiero[1], Massimo Capula[2], Leonardo Vignoli[1] & Luca Luiselli[1]

[1]*Centre of Environmental Studies Demetra s.r.l., via Olona 7, 00198 Roma, Italy*

[2]*Museo Civico di Zoologia, Via Aldrovandi 18, I-00197 Roma, Italy*

Dispersal patterns from a communal nesting/birth site of hatchlings of the oviparous colubrid snake *Hierophis viridiflavus* were investigated using capture-mark-recapture data from a 17-year study. We found that hatchlings lighter at birth dispersed more than heavier ones, whereas after one year there was no difference in body mass between the individuals which rested close to their birth site and those which dispersed further. We interpret this result as an adaptive dispersal behaviour in which heavier newborn snakes are less inclined to disperse from the hatching site, whereas lighter snakes move further away to increase their foraging efficiency.

Key words: body mass, Central Italy, Colubridae, Communal nesting, dispersal behaviour, *Hierophis viridiflavus*

Our knowledge on movement patterns of wild snakes has significantly advanced since the technique of radiotracking was applied to a large number of species in different habitats and environmental conditions (e.g., see Madsen, 1987; Angelici et al., 2000; Shine et al., 2001; Carfagno & Weatherhead, 2006). For instance, it has been demonstrated that snake dispersal is male-biased (e.g., Keogh et al., 2007), with females that may move extensively in search of a suitable place for laying eggs (e.g., Madsen, 1984, 1987). However, very scant data are available on the movement patterns of juveniles (but see Saint Girons, 1981; Webb &Whiting, 2005), especially of those species which may possess communal nesting sites (Gordon & Cook, 1980; Gomille, 2002; Filippi et al., 2007). It is important to obtain field data on these poorly understood aspects of snake behaviour if we want to fully understand their ecological strategies.

In this paper, we investigated the dispersal (=distances moved) from hatchling Western whip snakes, *Hierophis viridiflavus* (Lacépède, 1789) emerging from a communal oviposition site in central Italy (see also Filippi et al., 2007; Luiselli et al., 2011). More specifically, we used a capture-mark-recapture (CMR) approach and a 17-year dataset to determine (i) how far hatchlings disperse from their birth site during the first year of life, and (ii) whether body size at birth influences distance moved from the birth site.

The western whip snake, *Hierophis* (=*Coluber*) *viridiflavus* is a medium-sized (up to 150 cm long), oviparous, colubrid snake which feeds mainly upon lizards and small rodents (Rugiero & Luiselli, 1995; Vignoli et al., 2011). At the study area, this snake is active above-ground from March to November, and most of the females reproduce every year at communal oviposition sites to which they regularly return (Filippi et al., 2007; Corti et al., 2011; Luiselli et al., 2011).

The study took place at Oriolo Romano (Province of Viterbo, about 400 m above sea level), 60 km north of Rome. The oviposition site was characterized by a partially dilapidated building (5.0 x 3.5 m, height 5 m) bordered by thorny vegetation (mainly *Rubus* spp.) and surrounded by cultivated fields and small oak woodlands. The climate of the study area is Mediterranean, with hot, dry summers, cool, wet winters and mild, wet springs and autumns (Tomaselli et al., 1973).

The data were collected as part of a study at a communal nesting site (hereby CNS), between 10 and 30 June in 1990–1997 and 2001–2009, and in March–April 2002–2009 (see details in Filippi et al., 2007; Luiselli et al., 2011). The study area consisted of a core area and a peripheral area. The size of the core area used for the capture-mark-recapture study was 3 ha, the CNS being situated in the centre (Luiselli et al., 2011). At the core area, field effort per year was at least 12 days (0800 –1800 hours) in 1990–1997 and in 2001, and at least 24–28 days (0800–1800 hours) in 2002–2009, with three people independently searching for snakes each day. Thus, the overall field effort was approximately 360 man-hours per year in 1990–1997 and in 2001, and 720–840 man-hours in 2002–2009. Additional searches, with effort time more irregularly distributed across the year, were also performed in the peripheral area surrounding the core area. The core area (where effort time was recorded) and the peripheral area encompassed 9.3 ha, with the CNS situated approximately in the centre.

Snakes were captured by hand, and individually marked by ventral scale clipping for future identification. Hatching individuals were captured on their emergence from the nest; however, given the relatively intricate and spiny vegetation at the CNS and their small size (about 20 cm in total length) coupled with escaping ability, we were able to effectively capture only an undefined portion of the newborn snakes in each year. Offspring snakes captured at the CNS were weighed to the nearest 0.5 g with an electronic balance before being individually marked and released.

This paper investigates the distances travelled from the CNS by juveniles which were captured and marked as offspring at the CNS, and then recaptured one year later. Sexes were not distinguished because it is problematic

Correspondence: Luca Luiselli, Centre of Environmental Studies Demetra s.r.l., via Olona 7, 00198 Roma, Italy; *E-mail:* lucamlu@tin.it

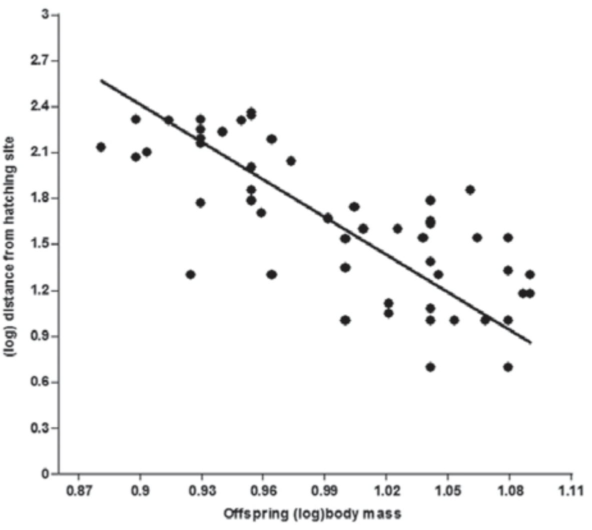

Fig. 1. Relationships between weight at birth and distance moved from the birth site in one-year-old snakes at the study area. For the statistical details, see the text.

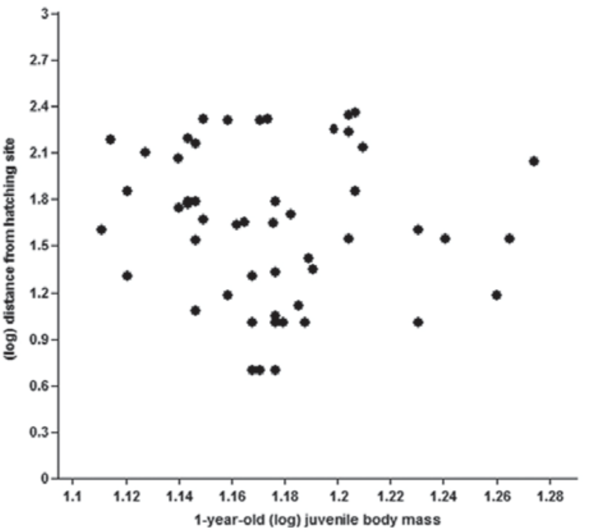

Fig. 2. Relationships between weight of 1-year-old juveniles and distance moved from the birth site in one-year-old snakes at the study area. For the statistical details, see the text.

to correctly identify sex in offspring and juvenile *H. viridiflavus* (although it may be possible by eversion of hemipenes, Luiselli et al., unpublished observations). The site of capture of each individual snake was recorded on a map, and its linear distance from the CNS was calculated by GIS (precision ±1 m).

We correlated distances moved with body mass by performing a linear correlation analysis (Pearson's correlation coefficient) between log body mass at birth and log linear distance from its first recapture site in the year following its birth and the CNS. We only considered the first recapture event to avoid a possible bias through disturbance effects by the previous capture. Body mass of juvenile snakes was recorded both when a given individual emerged as hatchling from the CNS and when it was re-captured one year later. We correlated the data on weight (at hatching and at one year of age) with the distance from CNS to test whether differences in weight at birth affect dispersal which in turn may affect body mass accumulation. The linear regressions between hatchling mass and distance from CNS, as well as one-year-old juvenile mass and distance from CNS were compared through a one-way ANCOVA (heterogeneity of slopes test). All analyses were performed with SPSS (version 8.0) statistical software, with alpha assessed at 5% and all tests being two tailed. Nonparametric statistics were used when normality was not achieved in the examined variables.

Overall, we incorporated data from 56 juvenile snakes. The mean distance covered was 68±9 m (range 5–225 m) and the median distance was 41.5 m. Juveniles which were heavier at birth dispersed less than lighter individuals (r=-0.752, r^2=0.566, P<0.001; Fig. 1). Interestingly, we found no differences in body mass between 1-year old juveniles recaptured at various distance from hatchling site (r=-0.089, r^2=0.008, P=0.513; Fig. 2), suggesting that the initial difference in body weight was not maintained one year later. The slopes of the linear regressions (Fig. 1 and Fig. 2) differed significantly from each other (one-way ANCOVA: F=7.196, P=0.0085).

Our study documented that lighter hatchlings dispersed more from their birth place than heavier ones, whereas after one year this difference disappeared. This pattern can be interpreted as an adaptive dispersal behaviour: hatchlings which emerged heavier, i.e. in a better body condition were less inclined to move far from their birth site because they did not need to feed in order to build a sufficient fat reserve to survive hibernation (which, at the study area, typically starts about two months after the last hatchings). However, it should be mentioned that the possibility of considering more than one hatchling from the same clutch could represent a potential bias because the data may not be fully independent.

Previous studies demonstrated that offspring size influence neonatal survival in many animals (Sinervo, 1990; Stearns, 1992), including temperate zone snakes (Bonnet, 1997). In addition, extensive dispersal is costly both energetically and in terms of survival (e.g., Christian & Tracy, 1981; Clobert et al., 1994; Van Vuren & Armitage, 1994), and therefore hatchlings which are in good body condition should minimize these costs by resting close to their birth site. On the other hand, lighter hatchlings should probably disperse far from their nesting site to increase the probability to find prey of appropriate size (small lacertids: *Podarcis muralis*; Rugiero & Luiselli, 1995; Capizzi & Luiselli, 1996), thus exposing themselves to higher survival costs. We did not collect data about the differential survival rate between heavy and light hatchlings, and therefore could not estimate survival costs for the light hatchlings deciding to disperse far from their birth site. However, that there was no difference in body mass between formerly heavy and formerly light individuals the following spring suggests that the decision to disperse from the birth site supports the growth of small and light individuals.

Acknowledgements: We are grateful to C. Anibaldi, D. Capizzi and A. Ceccarelli for collaboration in the field. Snakes were captured under authorization of the Regione Lazio (Dipartimento Ambiente e Protezione Civile) and the Riserva Naturale Regionale Monterano. We are also indebted to R. Federer for the English revision, Attilio and Emilio (the Bandiera brothers), Elizabeth Eckstein and Ugo Foscolo for having inspired this study with their lives.

REFERENCES

Angelici, F.M., Effah, C., Inyang, M.A. & Luiselli, L. (2000). A preliminary radiotracking study of movements, activity patterns and habitat use of free-ranging Gaboon vipers, *Bitis gabonica*. *Revue d'Ecologie* (*Terre et Vie*) 55, 45–55.

Bonnet, X. (1997). Influence of size on survival in newborn asp vipers (*Vipera aspis*): preliminary results. *Amphibia-Reptilia* 18, 107–112.

Capizzi, D. & Luiselli, L. (1996). Feeding relationships and competitive interactions between phylogenetically unrelated predators (owls and snakes). *Acta Oecologica* 17, 265–284.

Carfagno, G.L.F. & Weatherhead, P.J. (2006). Intraspecific and interspecific variation in use of forest-edge habitat by snakes. *Canadian Journal of Zoology* 84, 1440–1452.

Christian, K.A. & Tracy, C.R. (1981). The effect of the thermal environment on the ability of hatchling Galapagos land iguanas to avoid predation during dispersal. *Oecologia* 49, 218–223.

Clobert, J., Massot, M., Lecomte, J., Sorci, G., de Fraipont, M. & Barbault, R. (1994). Determinants of dispersal behavior: the common lizard as a case study. In: *Lizard Ecology. Historical and Experimental Perspectives*, 183–206. Vitt, L.J.& Pianka, E.R. (eds). Princeton University Press, Princeton, NJ.

Corti, C., Capula, M., Luiselli, L., Razzetti, E. & Sindaco, R. (2011). Fauna d'Italia: Reptilia. Vol. XLV. Bologna: Edizioni Calderini Il Sole 24 ORE Editoria Specializzata S.r.l.

Filippi, E., Anibaldi, C., Capizzi, D., Ceccarelli, A., Capula, M. & Luiselli, L. (2007). Long-term fidelity to communal oviposition sites in *Hierophis viridiflavus*. *Herpetological Journal* 17, 7–13.

Gomille, A. (2002). Die Äskulapnatter– *Elaphe longissima*. Frankfurt am Main: Edition Chimaira.

Gordon, D.M. & Cook, F.R. (1980). An aggregation of gravid snakes in the Quebec Laurentians. *Canadian Field Naturalist* 94, 456–457.

Keogh, J.S., Webb, J.K. & Shine, R. (2007). Spatial genetic analysis and long-term mark–recapture data demonstrate male-biased dispersal in a snake. *Biology Letters* 3, 33–35.

Luiselli, L., Rugiero, L. & Capula, M. (2011). Are communal nesting counts as useful as ordinary mark-recapture data for estimating population size in snakes? *Herpetological Journal* 21, 73-81.

Madsen, T. (1984). Movements, home range size and habitat use of radio-tracked grass snakes (*Natrix natrix*) in southern Sweden. *Copeia* 1984, 707–713.

Madsen, T. (1987). Cost of reproduction and female life-history tactics in a population of grass snakes, *Natrix natrix*, in southern Sweden. *Oikos* 49, 129–132.

Rugiero, L. & Luiselli, L. (1995). Food habits of the snake *Coluber viridiflavus* in relation to prey availability. *Amphibia-Reptilia* 16, 407–411.

Saint Girons, H. (1981). Quelques observations sur la dispersion des noveau-nés chez Viperaberuset *Vipera aspis* dans la bocage atlantique (Reptilia: Viperidae). *Amphibia-Reptilia* 2, 269–272.

Shine, R., Elphick, M. J., Harlow, P.S., Moore, I.T., Lemaster, M.P. &Mason, R.T. (2001). Movements, mating, and dispersal of red-sided garter snakes (*Thamnophissirta lisparietalis*) from a communal den in Manitoba. *Copeia* 2001, 82–91.

Sinervo, B. (1990). The evolution of maternal investment in lizards: an experimental and comparative analysis of egg size and its effects on offspring performance. *Evolution* 44, 279–294.

Stearns, S.C. (1992). The evolution of life-histories. Oxford: Oxford University Press.

Tomaselli, R., Balduzzi, A. & Filipello, S. (1973). Carta Bioclimatica d'Italia. Rome: Ministero Agricoltura e Foreste.

Van Vuren, D. & Armitage, K.B. (1994). Survival of dispersing and philopatric Yellow-Bellied Marmots: What is the cost of dispersal? *Oikos* 69, 179–181.

Vignoli, L., Luiselli, L.& Capula, M. (2011). Colubridae. In: *Reptilia*, 472. Corti, C., Capula, M., Luiselli, L., Razzetti, E., Sindaco, R. (eds). Fauna d'Italia Vol. XLV. Bologna: Edizioni Calderini Il Sole 24 ORE Editoria Specializzata S.r.l.

Webb, J.K. & Whiting, M.J. (2005). Why don't small snakes bask? Juvenile broad-headed snakes trade thermal benefits for safety. *Oikos* 110, 515–522.

Accepted: 18 March 2012