NOTES ON THE NATURAL HISTORY OF THE SMOOTH SNAKE, *CORONELLA AUSTRIACA*, IN THE SWISS ALPS

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The Smooth Snake *(Coronella austriaca)* is a small sized (generally less than 70 cm long), live-bearing colubrid which is currently threatened in several European regions (Corbett, 1989). Throughout the Alpine massif this species is still widespread and locally abundant, generally at altitudes ranging between 600 and 2000 m a.s.l. (Ortner, 1978; Barbieri *et al.*, 1994). In the Swiss Alps it is abundant up to altitudes of 2100 m a.s.l., but the same is not true on the plains where it is increasingly disappearing due to habitat destruction (Hofer, 1993). Although the ecology of the Smooth Snake has been studied in detail in other European regions (especially in Great Britain: e.g. see Spellerberg & Phelps, 1977; Goddard, 1984; Gent & Spellerberg, 1992), it still remains, due to its secretiveness, one of the least known of the Alpine snakes. In fact, apart from very detailed research on the ecology and reproductive biology of Italian Smooth Snakes (Luiselli, Capula & Shine, 1995), no other study has been published on alpine populations of this taxon. Obviously this lack of knowledge is quite serious because it prevents the establishment of firm, functional conservation measures to prevent its continued decline. In this paper we present some data on the basic biology of a mountainous population of Smooth Snakes inhabiting an alpine region of western Switzerland. These data were collected during a long-term study on the sympatric vipers *Vipera aspis* and *V. berus* (Monney, 1993; Money *et al.*, 1995).

Data given here was collected by one of us (JCM) between 1988 and 1992 in a Prealpine area of western Switzerland situated at about 1400-1600 m a.s.l. (Bernese Oberland). The study area, about 40 ha, is a southeastern facing slope including two torrential alluvial cones. There are both *(Molinion)* and dry *(Cynosurion)* meadows including some man-made stonepiles, grassy and rocky areas dominated by *Calamagrostis varia, Picea abies* woods, *Salix* sp. and *Alnus* sp. groves. Three sympatric snakes occur in the area *(V. aspis, V. berus, C. austriaca)* but only the former two are common and widespread. Two lizards *(Anguis fragilis, Lacerta vivipara)* and three amphibians *(Salamandra atra, Rana temporaria, Bufo bufo)* are also found. When a smooth snake was encountered in the field, it was individually marked by "scale-clipping", and the lesion resulting from this procedure was immediately disinfected by Acutol (liquid). The number of subcaudals (SC), the snout-vent- (SVL), tail- (tL) and total lengths (TL) were measured immediately on capture. Moreover, the body weight was also measured if no recent trophic activity was detected (i.e. if no food remains were found in the stomachs). Food habits were studied by collection and laboratory analysis of faecal pellets by Monney's (1990) method. Movements were calculated by noting the exact location at which each snake was encountered on an accurate map of the study area (1: 5,000), which was divided into areas of 5 x 5 m. The displacements were then measured as a straight line between the location areas on the map. The reproductive status and the clutch size of the females were determined by palpation of the ovarian follicles and embryos during July and August. Data were analysed with StatView software (Abacus concepts, Inc., Berkeley, CA, 1992), and

α was assessed at 5%. In all tests performed, the hypothesis was that H_0: $\mu 1 = \mu 2$, H_a: $\mu 1 \neq \mu 2$. In the text the means are followed by ± one standard deviation.

Smooth Snakes were very elusive and apparently rare in the study area. Throughout the research period we captured and marked only 20 different individuals, that were re-encountered a total of 68 times (versus over 3000 "contacts" with each of the two sympatric *Vipera* species). The number of adult males exceeded that of adult females (apparent sex-ration = 1.56 : 1), but the difference was not statistically significant (binomial test, $P > 0.1$). Two juveniles were also encountered. The estimated density was about 0.5 adults per ha, i.e. about half of the density of *V. berus* and one third of the density of *V. aspis* in the study area.

Smooth Snakes were encountered in all habitat types within the study area, but most of the observations occurred along the stony banks of a torrential alluvial cone. In general these snakes selected dry spots and, like *V. aspis*, exploited wet meadows less intensively than *V. berus*. Pregnant females frequently used the same gestation sites of both *Vipera* species : these were always stony, well exposed, sunny, eastern-southeastern facing places. The vegetation cover of these sites was usually sparse, although in most cases there were some bushes and grassy areas. Pregnant females spent more time in the open than other females: this is evidenced by the fact that 81% of our female observations were of gravid individuals. Conversely, males were more readily seen during springtime, when they searched for mates. Both sexes were also frequently seen during the moulting phases, when they showed a high thermophily in addition to sedentary habits.

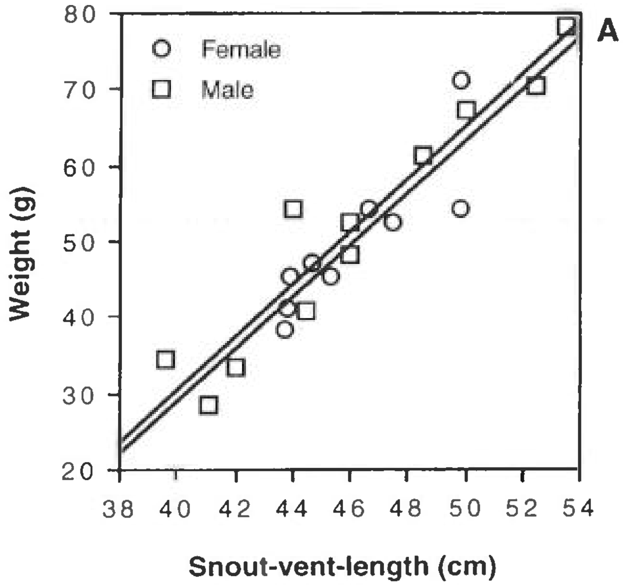
The duration of the annual activity appeared to be shorter than that of the two sympatric vipers (see Monney, 1995; Monney *et al.*, 1995): earliest males were found above-ground while sloughing at the beginning of May, while no female was observed in the open before early June. Thus, we suggest a prenuptial male moulting may exist in this population, although more information about underground spring activity would be necessary to prove this. With the exception of one female (9 June 1991), first ova were detected by palpation of the abdomen usually in mid June. Parturitions occurred during September.

Table 1

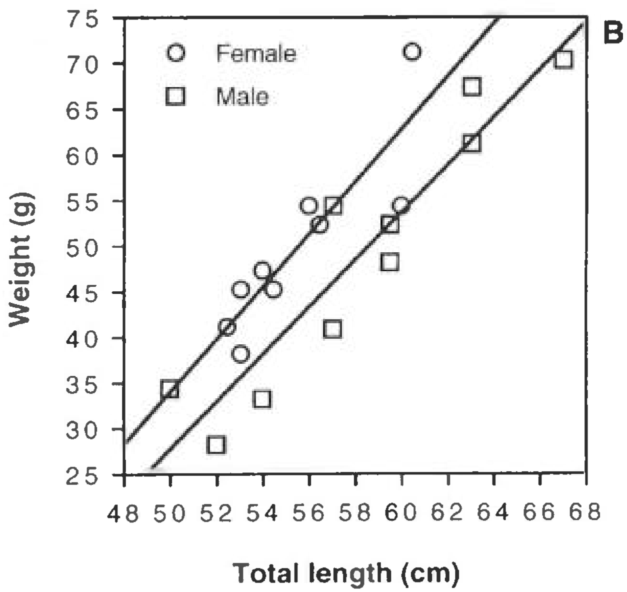
Average total length (TL, in cm), snout-vent length (SVL, in cm), tail length (tL, in cm), body weight (W, in g), and number of subcaudals (SC) in males and females *Coronella austriaca* from the Bernese Oberland (west Switzerland). Numbers in parentheses indicate standard deviations. For statistical comparisons, see text.

Sex	TL	SVL	tL	W	SC
Males	58.20 (5.30)	46.15 (4.56)	12.78 (1.37)	51.41 (16.48)	56.60 (2.32)
Females	55.55 (2.98)	46.15 (2.49)	9.40 (0.58)	49.66 (9.74)	49.86 (1.86)

Morphometric characteristics and body sizes of male and female *C. austriaca* are given in Table 1. The relationships between SVL and body weight (Figure 1A) and between TL and body weight (Figure 1B) were highly significant in both sexes (in all cases Spearman's rank correlation, $r > 0.9$, $P < 0.01$). The two sexes did not differ significantly in TL ($t = 1.318$, $df = 17$, $P = 0.205$), SVL ($t = 0.01$, $df = 18$, $P = 0.999$), and body weight ($t = -0.279$, $df = 18$, $P = 0.783$). The tail was significantly longer in males than females ($t = -6.838$, $df = 17$, $P < 0.001$), and the number of subcaudals was significantly greater in males than females ($t = -6.368$, $df = 15$, $P < 0.001$). Pooling together males and females, SC was significantly correlated with tL (Spearman's $r = 0.79$, $P = 0.001$, Figure 2). The ratio "tL/SVL" (females: 0.204; males: 0.281) was significantly different between sexes ($t = 14.311$, $df = 17$, $P < 0.0001$).



Weight (g) = -107.462 + 3.404 * Snout-vent-length (cm); R^2 = .757 (Female)
Weight (g) = -108.038 + 3.455 * Snout-vent-length (cm); R^2 = .913 (Male)



Weight (g) = -111.15 + 2.895 * Total length (cm); R^2 = .785 (Female)
Weight (g) = -102.096 + 2.592 * Total length (cm); R^2 = .877 (Male)

Fig. 1. A: Relationship between snout-vent length and body weight in male and female Smooth Snakes from the study area; B: relationship between total length and body weight in male and female Smooth Snakes from the study area.

Only eight out of 68 (11.76%) encountered specimens provided faecal pellets useful for dietary analyses. Common lizards *(L. vivipara)* constituted 62.5% of the total prey, while small mammals (a single Microtidae and two newborn indetermined rodents) accounted for the remaining 37.5% of the diet.

Our data on Smooth Snake movements are rather scarce, and we can present only preliminary observations. In general the movement rates per day were small (< 8 m/ day): for instance, the male No. 7 moved 225 m between 1.6.1991 and 23.8.1991 (x = 4.24 m per day). This was evident also during the mating season: for instance, the male No. 9 moved 115 m from 6.5.1990 to 30.5.1990 (x = 4.79 m per day). The monitored females were highly sedentary during pregnancy: the female No. 1 moved 0 m between 30.6.1991 and 7.8.1991, and the female No. 7 moved only 5 m between 8.7.1992 and 4.8.1992 (x = 0.18 m per day). The snakes were highly sedentary also during the moulting periods: the male No. 7 moved less than 5 m between 9.8.1989 and 22.8.1989. Some individuals showed seasonal migrations from hibernacula to summer areas: e.g. a male No. 3 moved 85 m from the hibernaculum (situated in the torrent banks) to the summer habitat (a grassy pasture), and the female No. 5 moved 215 m between 8.7.1992 and 4.8.1992 (x = 7.96 m per day), from her foraging area situated along a marsh, to her gestation site situated in a stony torrent bank. It is interesting that in this latter case the gestation site was also the hibernaculum for the female. When searching for prey, however, the Smooth Snakes showed sometimes relatively long displacements: the female No. 6 moved 140 m from 27.7.1991 to 1.8.1991 (x = 28 m per day), when she finally obtained food. Site fidelity among years appeared to be very variable depending on the individuals: the male No. 7 was observed 14 times between 9.8.1989 and 23.8.1991 along a transect 90 m long of a torrent; the male No. 9 was observed four times between 6.5.1990 and 9.6.1992 along a transect 115 m long of the same torrent; the male No. 6 was observed two times between 23.6.1989 and 18.7.1991 in two spots far less than 80 m each from the other, and the female No. 1 was found pregnant in both summer 1989 and 1991 in the same spot. Conversely other specimens moved remarkably between years: the male No. 6 covered 475 m of distance (from 1760 m a.s.l. to 1510 m a.s.l.) between 6.8.1989 and 17.8.1990.

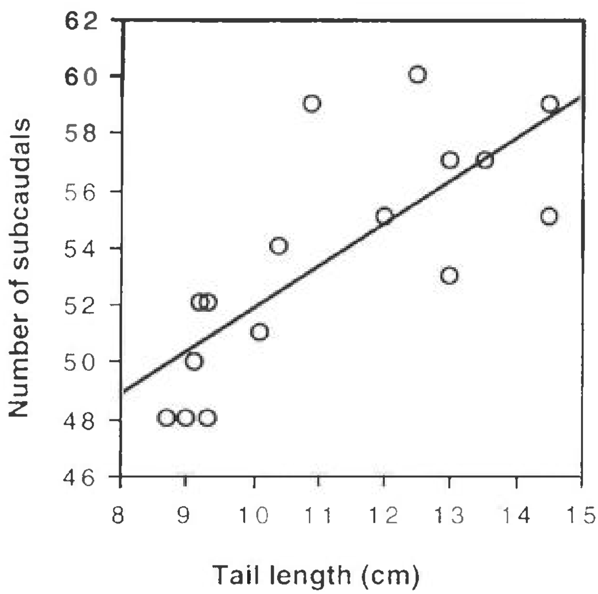


Fig. 2. Relationship between tail length and number of subcaudals in the Smooth Snakes from the study area. Males and females are considered together.

The exact frequency of reproduction was determined only in two females: female No. 1 was gravid in 1989 (with 3 embryos in the abdomen, when measured 53 cm TL and 45 g weight), not-gravid in 1990 (when she weighed only 35 g), and was newly pregnant in 1991 (with 6 embryos in the abdomen, when measured 54 cm TL and 47 g weight). Another female was not gravid in 1991, but it was pregnant the next year. These observations suggest a biennial female frequency of reproduction. Female fecundity averaged 6 ± 1.55 young (range from 3 to 7, *n* females = 6). There was a trend (but statistically not-significant) for fecundity to be correlated with female size (Spearman's $r = 0.78$, $P = 0.07$; Figure 3).

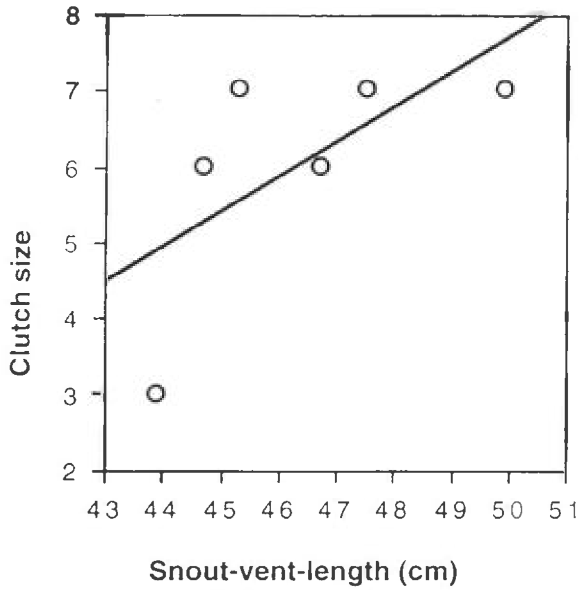


Fig. 3. Relationship between female size (SVL) and fecundity in the Smooth Snakes from the study area.

The basic biology (density, body sizes of males and females, reproductive cycle and fecundity, food habits) of the Smooth Snakes studied here resembled that of conspecifics of other European regions (e.g. France: Duguy, 1961; Britain: Goddard, 1981; Spellerberg & Phelps, 1977; Gent, 1988; Spellerberg, 1988; Austria: Waitzmann & Sandmayer, 1990; Sweden: Andrén & Nilson, 1992; Italy: Luiselli et al., 1995). In fact, also in our population the population density was low, the males and the females attained very similar sizes, the diet consisted of lizards and juvenile rodents, the reproductive cycle of the females was biennial (for an exception see Duguy, 1961, that reported annual cycles in French Smooth Snakes), and the fecundity was rather low. The males had (1) longer tails and (2) greater number of subcaudals than females. While point (1) seems to be rather universal not only in Smooth Snakes but also in other European colubrids (Feriche, Pleguezuelos & Cerro, 1993), point (2) seems to be not so general: in British *C. austriaca,* for instance, both sexes usually have 52-55 subcaudals (T. Gent, personal comm.). The low *C. austriaca* density at the study area might be due to the presence of two sympatric viper species, which have diets similar to that of Smooth Snakes (Monney, 1993). In this regard, Spellerberg & Phelps (1977) suggested that interspecific competition may occur between *C. austriaca* and *V. berus* in southern England. Clutch size and frequency of reproduction of our Smooth Snakes were nearly identical to those of conspecifics from the eastern Italian Alps (Luiselli *et al.,* 1995). Contrary to these latter, however, the females in our population showed no statistically significant correlation between fecundity and female body size, but this probably depended merely on the small size of the sample examined. In fact, the sole female was gravid in two different years produced more young (six versus three) at the second reproduction, when she was 1 cm longer. Moreover, the movement rates of the Swiss Smooth Snakes were similar to those of radiotracked individuals from southern Britain (Gent, 1988; Gent & Spellerberg, 1993): in fact, although some individuals may show relatively large movements during some part of the annual activity cycle (e.g. when searching for prey), the daily movement rates were small in most cases. The general movement patterns (e.g. stationary habits of moulting individuals, lack of site fidelity in some but not in other individuals, etc.) also resembled those of British Smooth Snakes (Gent, 1988), but in these latter there were no significant differences in mobility of gravid and non-gravid individuals (Gent, 1988). Seasonal migrations have been observed also in other *C. austriaca* populations (Strijibosch & Van Gelder, 1993; T. Gent, personal comm.), but this did not seem to be 'universal' and predictable behaviour in most of the animals in a population (Gent, 1988).

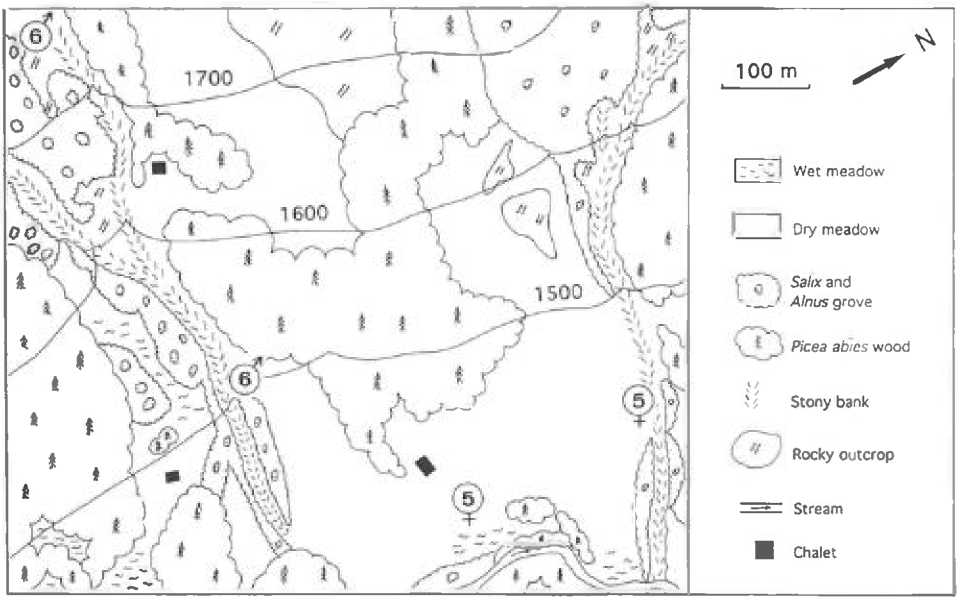


Fig. 4. Movements of two individuals (male No. 6 and female No. 5 throughout the study area. The male moved 475m and the female moved 245 m.

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