Life history, population characteristics and conservation of the Hungarian meadow viper (*Vipera ursinii rakosiensis*)

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Abstract. During a continuous population study of *Vipera ursinii rakosiensis*, 79 specimens were measured in the field, between 1993 and 1997. Body length and body mass of six juveniles were compared to those of 43 more specimens which were kept during their first winter in terraria. Significant differences were found in favour of the juveniles kept in captivity, whereas a comparison with earlier data from 1953 showed a strong decline in juvenile body mass. Based on body size, three age classes could be distinguished in the study population. The annual activity and reproductive cycle of the Hungarian meadow viper is described for the first time. A comparison to other European populations of Orsini's viper revealed a remarkably higher clutch size in *Vipera ursinii rakosiensis*, which is explained by the larger body size of females in the particular population.

Introduction

The Hungarian meadow viper (*Vipera ursinii rakosiensis* Méhely, 1893) is a small-sized (total length is about 60 cm) lowland steppe form of the *Vipera ursinii* species group. Since the *Vipera ursinii* species complex is explained in different ways by the modern morphological and biochemical research results, the systematic status of *Vipera ursinii rakosiensis* is still unresolved, and the subspecific rank can only be considered as provisional (Vancea et al., 1985; Joger at al., 1992; Nilson et al., 1993).

The Hungarian meadow viper (*Vipera ursinii rakosiensis*) is one of the most threatened snakes in Europe (Takács et al., 1987; Corbett, 1989; Korsós, 1992). The former distribution of the meadow viper included the easternmost part of Austria, Hungary, Transylvania (Romania), and northern Bulgaria (Dely and Janisch, 1959). Populations today only exist in two regions of Hungary (in the Great Hungarian Plain between the rivers Danube and Tisza, and in the Hanság Nature Reserve, northwestern corner of the country), from all the other territories it is most probably extinct (Korsós, 1992; Péchy et al., 1996). Since

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1974, the meadow viper has received full legal protection in Hungary where and since then it has been one of the most strictly protected species. Theoretical nature conservation value of one specimen is 500,000 HUF (ca. 1,960 EUR). Parts of the distribution area are also protected; however, most of this area is not governmental property, which poses great problems for conservation to be effective through habitat protection. The animal is listed in the 1996 IUCN Red List of Threatened Animals as “threatened”, appears on the CITES Appendix I and the Berne Convention Appendix II. Even two recommendations of the Council of Europe emphasise its strict protection in Hungary. It is also included in the programme of the Hungarian National Biodiversity Monitoring System (Korsós, 1997). The sensitivity of this snake to habitat alteration and human disturbance is quite dramatic. Populations are subject to short term (cold winter, high soil water level, etc.) as well as long term natural threats (isolation, genetic drift, inbreeding, etc.). However, the meadow viper is immediately and most significantly threatened by human agricultural activities, like intensive grazing, burning, machine mowing, etc (see more details in Korsós and Fülöp, 1994; Péchy et al., 1996). The biology of the Hungarian meadow viper is poorly known, in part due to its rarity in nature.

In the frame of the conservation program of the Hungarian meadow viper a continuous population study in the Kiskunság area (southeast of Budapest, Hungary) is being carried out since 1993. The goal of this project was to collect as many data as possible about the life history and population characteristics of this threatened snake. The program also included a population reinforcement experiment with the support of the Hungarian Ministry of Environment (Nechay and Péchy, 1994), which aimed at the improvement of the survival chances of a selected population by helping the juvenile specimens to get over their first winter in captivity.

The aim of this paper is to summarise results on the annual activity of the species, with a comparison of data obtained from captivity and from the wild. The age structure, and annual activity cycle is described of the selected population, and compared to two other European Alpine populations of *Vipera ursinii*.

Material and methods

Altogether, 79 meadow vipers (25 males, 48 females, 6 juveniles) were measured in the Dabas-Gyón study area between 1993 and 1997. The typical vegetation of the habitat consisted of a wet, closed grassland (drying wet meadow = *Molinietum*) plant community of uneven structure, characterised by the grass species *Molinia coerulea*, *Schoenus nigricans*, *Chrysopogon gryllus* and *Stipa* sp. The structure of the vegetation is arranged into microlayers, interspaced by tussocks of grass of different ages. The density of possible prey items (insects: large-sized orthopterans, and young lizards: *Lacerta agilis*, *L. viridis* and *Podarcis taurica*) is often high. For more details see Újvári and Korsós (1997).

Table 1. Number of captures of *V. u. rakosiensis* in Dabas-Gyón.

	Males	Females	Juveniles	Recaptures
1993	7	5	27 (7)[a]	1
1994	7	14	14 (1)[b]	2
1995	11	22	2[c]	4
1996	–	5	4	1
1997	–	2	2	1
Total	25	48	49 (8)	9

[a] Born from three females in captivity; five died immediately, two during the winter period. Twenty-seven were released in May 1994.
[b] Eleven were caught in September 1994, four were born from a female in captivity. One juvenile female died during the winter. Fourteen juveniles were released on the original spot in May 1995.
[c] Caught in August 1995 and released in May 1996.

Data also originated from a population reinforcement program. In autumn 1993 and 1994, gravid females were collected and kept in terraria until they gave birth. The young were housed in an enclosed part of the Zoological Garden, Budapest until the subsequent spring. The furnishing of the terraria imitated natural habitat (grass and soil were collected on the original locality), and to minimize the disturbance of the animals only one person was allowed into the room during feeding times. To avoid the association of food with human presence no record was kept of the exact food consumption of juveniles. Insects (large-sized orthopterans) and newborn rodents were provided ad libitum, i.e. for all neonates more food was available than they could utilize. These 30 juveniles, together with 13 more caught in the autumn and handled in the same way during winter, were released in good condition in May of the subsequent year at the original collecting locality (table 1).

Body weight and total length at the juveniles maintained in captivity were measured once in every month during the winter. They were also measured at the date of their release, and the data were compared to those by Lányi (1957). In the course of our study not all morphological data were consequently noted, hence the number of specimens included in an analysis of a given morphological character might differ.

Results

Body size comparison

Change of body mass and body length of the meadow viper juveniles during their first winter is plotted in figures 1 and 2 (repeated measures of the same specimens on the same day). For average body mass and length, there were no statistical differences between neonate females ($\bar{x} = 3.0$ g, $s = 0.13$, $\bar{x} = 150.3$ mm, $s = 1.56$) and males ($\bar{x} = 2.9$ g, $s = 0.35$, $\bar{x} = 148.0$ mm, $s = 2.5$). Using regression analysis (Sutherland, 1996) the growth rate of the captive specimens showed an allometric relation: for body mass the correlation was exponential (x = month, $y = 2.32e^{0.16x}$, $r^2 = 0.9665$, $t = 15.19$;

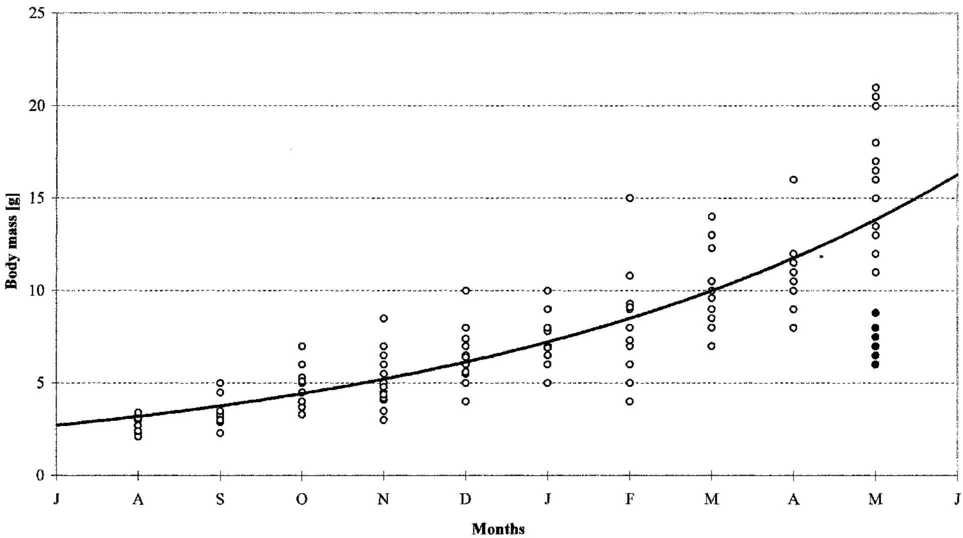

Figure 1. Body mass of juveniles during winter (open circles = specimens kept in terraria; filled dots = measured in the field, after hibernation).

Table 2. Comparison of captive and *in situ* specimens after their first winter (mean ± standard deviation, sample size).

	Body mass [g]	Body length [mm]
Kept in terraria	15.7 ± 2.97 (18)	287.0 ± 27.88 (18)
Measured in the field	6.8 ± 1.91 (9)	203.8 ± 28.39 (10)

$P < 0.1\%$, $df = 8$), whereas for body length was linear (x = month, y = 13.16x + 127.39, $r^2 = 0.9701$, $t = 16.11$, $P < 0.1\%$, $df = 8$). Measurements of the captive specimens at the date of the release were compared with those measured in the field in May (table 2; fig. 1 and 2: open circles and filled dots, respectively). The differences significant (body mass: $t = 7.41$, $P < 0.1\%$, $df = 23$; body length: $t = 6.64$; $P < 0.1\%$, $df = 23$). The terrarium specimens gained an average 8.9 g and 84 mm increase during the winter.

A comparison of our measurements on juveniles born in with literature data from 1953 (Lányi, 1957) show a conspicuous difference in juvenile body size. While the body mass of the juveniles forty years ago appeared to be significantly higher than today ($t = 3.07$; $P < 1\%$; $df = 23$; fig. 3), their total length was found to be smaller though on a lower significance level ($t = 2.17$; $P < 5\%$; $df = 25$; fig. 3).

Age classes

On the basis of the body mass-body length ratio as well as the capture-recapture data, three age groups can clearly be identified in the Dabas-Gyón population (fig. 4). The first

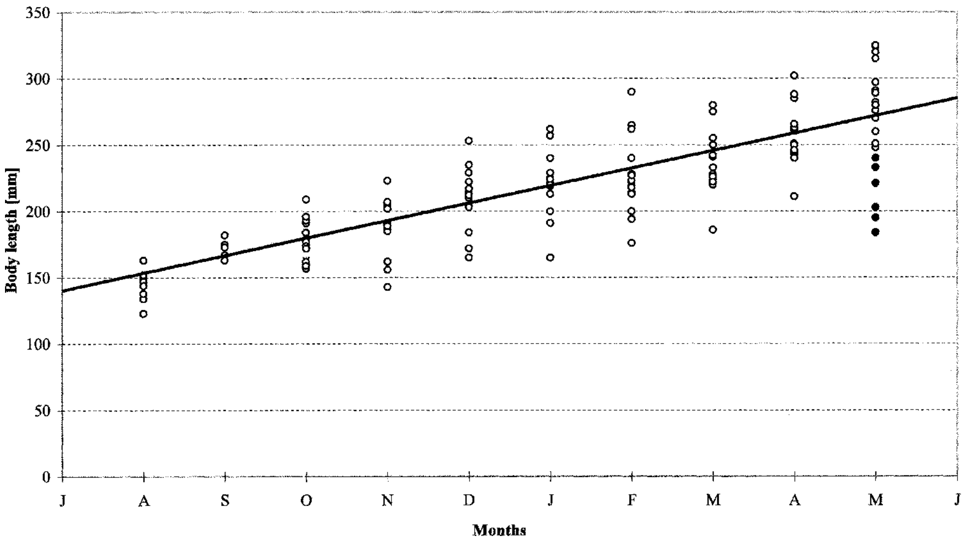

Figure 2. Body length of juveniles during winter (open circles = specimens kept in terraria; filled dots = measured in the field, after hibernation).

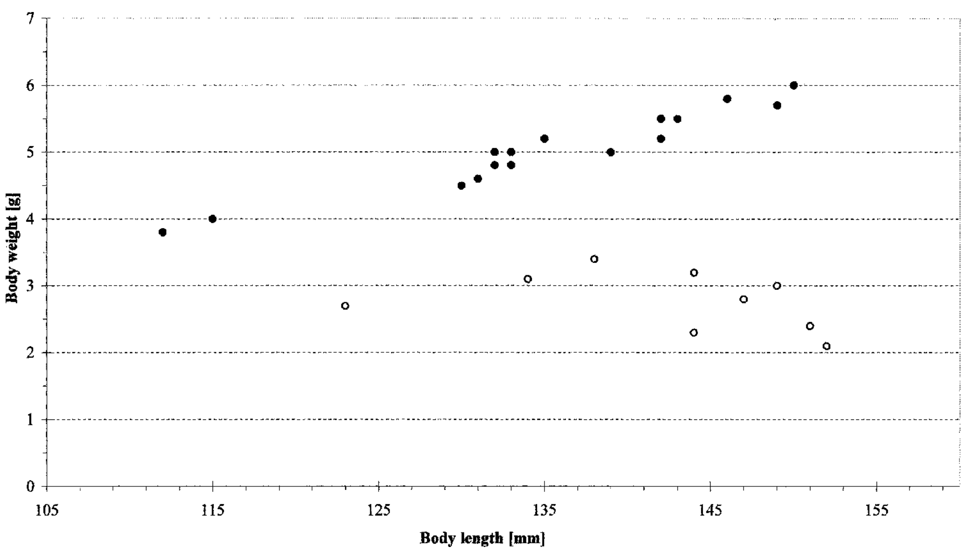

Figure 3. Comparison of neonatal viper's body mass and body length (open circles = own data; filled dots = data from Lányi, 1957).

group includes the newborns and juveniles that have hibernated only once. The members assigned to the second group have reached a larger body mass during their first summer, hence this class contains specimens that have survived their first feeding period and a

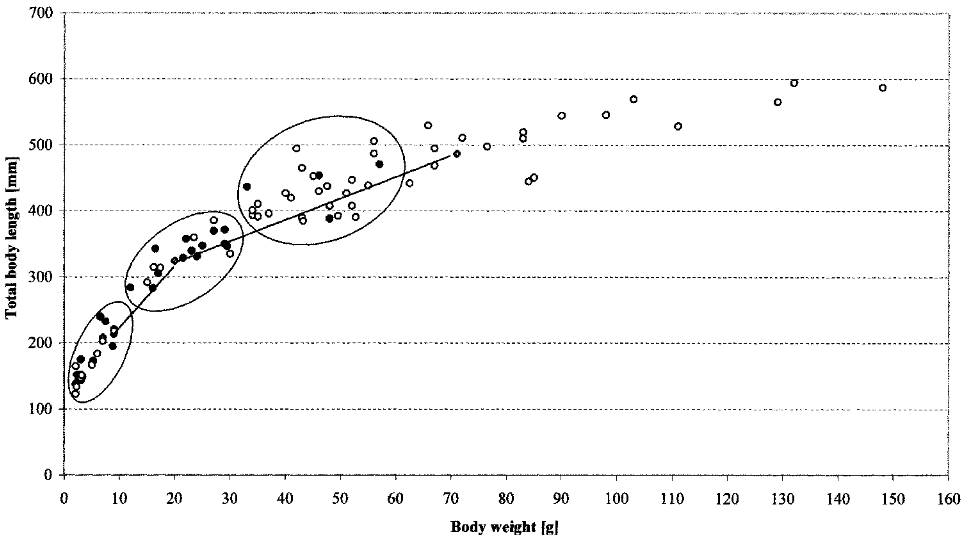

Figure 4. Age groups based on body length plotted against body mass (open circles = female; filled dots = males, the three grey diamonds connected with a black line represent one specimen which was recaptured).

second hibernation. The vipers assigned to the third class have survived for two active and three overwintering periods. This last group (aged of the 2-3 calendar year) reaches adult size and can be differentiated from the older individuals only by body mass. The rest of the adults comprises all individuals with more than 60 g and 450 mm, and cannot be reliably split into further age groups.

One specimen was caught as neonate in September (fig. 4), kept and fed in captivity during the winter, released in the subsequent spring, then recaptured in the summer of the same year. Its body mass was duplicated, hence it "jumped" into the third age class. This was the only recapture from the juveniles released in the population reinforcement program.

Males in the Dabas-Gyón population were considerably smaller than females, and the population was dominated by a high number of old females (fig. 4).

Annual activity pattern

The capture and observation data have been analysed and annual activity drawn up on their basis. Males, females, and even juveniles emerged from the hibernation together in late March. Mating took place in the first half of May, parturition at the end of July, August, or beginning of September, depending on the weather. Hibernation began in the middle of October, but specimens were occasionally observed even in November, although their movements were virtually stopped, and they only went to bask occasionally to the surface at the spot of hibernation (Újvári and Korsós, 1999).

Discussion

Body size comparison

Juvenile males and females did not differ in their body size at birth, which is in accordance with viviparous snake species (*Vipera berus*, Völkl, 1989; *Coronella austriaca*, Luiselli et al., 1996). In *C. austriaca* the individual body size variation was retained even 12 months after birth (Luiselli et al., 1996). In our study the larger body size advantage of the specimens kept in terraria compared to the juveniles hibernating in natural circumstances was due to the artificial ad libitum feeding conditions. Juvenile snakes may benefit from their larger body size, by being less susceptible to predation, or may enjoying a higher foraging success (Völkl, 1989; Biella and Völkl, 1993; Forsman and Lindell, 1996). This may help to increase the survival chances of this meadow viper population. Although it is an unverified belief that juveniles suffer from high mortality during their first winter, it can be clearly accepted that body size is a strong determinant of juvenile survival success (Völkl, 1989; Forsman and Lindell, 1996). The survival of neonates during the first winter depends on the growth after birth too, as shown by Völkl (1989) in the case of *V. berus*. He found that an increase of 25% over birth weight was required for a successful hibernation.

The comparison of our measurements on juveniles born in terraria with literature data from 1953 (Lányi, 1957) showed a conspicuous difference in juvenile body size. This phenomenon may be explained by the different body condition of females, or by unknown environmental factors. Regarding the first, it is widely accepted that the reproductive output of mature females increases with body size (Saint Girons and Naulleau, 1981; Blem, 1982; Farrell et al., 1995; Luiselli et al., 1996). Litter size and clutch mass were usually found significantly correlated with female snout-vent length (Andrén and Nilson, 1983; Farrell et al., 1995, Luiselli et al., 1996), although Saint Girons and Naulleau (1981) found no relationship between the body weight values of offspring and their mothers in some European vipers.

The number of neonates of *V. ursinii rakosiensis* is remarkably higher than that of their Alpine relatives (*Vipera ursinii ursinii*) (Baron, 1997), whereas the body length is only slightly longer in the Dabas-Gyón population (table 3). Regarding body mass, the low values dominate, except for the data of Lányi (1957).

Considering reproductive success in European vipers, Saint Girons and Naulleau (1981) observe that the difference among species depends not only upon the size of the parents, but also upon the feeding habits and feeding success of juveniles. Species consuming mainly invertebrates (grasshoppers) and lizards produce more numerous but smaller sized offspring, whereas those eating small mammals have smaller clutches of larger juveniles. While the first case is true for *Vipera ursinii*, the latter concerns e.g. *Vipera berus* and *Vipera aspis*. Within the *Vipera ursinii* species complex, on the other hand, the larger Hungarian meadow viper have more numerous but smaller hatchlings than the nominal Alpine subspecies with smaller body size.

Table 3. Comparison of neonatal Orsini's vipers in Europe (mean ± standard deviation, sample size).

Subspecies	Clutch size	Body mass [g]	Body length [mm]	Locality	Source
Vipera u. rakosiensis	11.3 ± 3.1(3)	2.78 ± 0.36 (9)	143.82 ± 6.6 (11)	Dabas-Gyón, Hungary	own data
Vipera u. rakosiensis	5-7	5.03 ± 0.44 (16)	135.25 ± 8.03 (16)	Ócsa, Hungary	Lányi (1957)
Vipera u. ursinii	3.83 ± 1.53 (12)	2.74 ± 0.47 (26)	136.3 ± 0.77 (26)	Mont-Ventoux, Montagnes de Lures, France	Saint Girons and Naulleau (1981)
Vipera u. ursinii	4.03 ± 0.13 (91)	2.98 ± 0.34 (25)	136.4 ± 0.79 (58)	Mont-Ventoux, France	Baron et al. (1996)
Vipera u. ursinii	4; 1 (2)	2.1-2.3 (5)	≈ 118-120[a] (5)	Abruzzo, Italy	Luiselli (1990)

[a] Read from a graph in the paper.

Age classes and annual activity pattern

From the recapture data we conclude that the age groups are defined by the active feeding period during summer. The first age class includes hence the neonatals from the end of summer and the same indviduals after their first hibernation (they practically do not grow during the winter). Exact age of males in the third and of females in the fourth class cannot be estimated using only body mass or body length measurements.

The phenomenon that the Dabas-Gyón population is dominated by a high number of old females may have an advantage in the larger clutch size produced by old females, because large females exhibit a higher ratio of reproductive activity (Burkett, 1966). They are gravid also more frequently than smaller ones, which parallels data relative to alpine adders *Vipera berus* (Capula and Luiselli, 1994). However, this estimate may be biased if reproductive females modify their behaviour (Luiselli et al., 1996), e.g. if they bask in such a way that they are easier to observe. Gravid females of *Vipera ursinii ursinii* often gather on sunny spots of the hillside (Baron, 1997). Usually large (or old) males are more difficult to find, except in the mating season when they move around to look for the females.

Comparing the annual activity cycle of the Hungarian meadow viper to two Alpine *Vipera ursinii ursinii* populations in Mont Ventoux, France (Baron et al., 1996; Baron, 1997) and in Abruzzo, Italy (Luiselli, 1990) some difference was found. According to the observations by Baron (1997), females of *V. u. ursinii* on Mont Ventoux emerge from hibernation later than males, at the beginning of May, and juveniles come out almost one month later, when appropriately sized (over 16 mm) food supply is abundant. In certain Central and Northern European populations of *Vipera berus*, males emerge earlier than females, too, for completing spermatogenesis (Biella and Völkl, 1993). Contrary to the French population, Hungarian and Italian males, females, and even juveniles emerge from the hibernation together, which is similar to some populations of *Vipera berus* (Viitanen, 1967; Prestt, 1971; Nilson, 1980) and *Vipera aspis* (Duguy, 1958). In the case of Hungarian vipers this phenomenon could be explained by the fact that food for them is provided in high abundance of crickets (*Gryllus campestris*) overwintering as adult-sized larvae. The longer active period found for both females, males and juveniles (7 months in the Hungarian and Italian populations, 5-6-3,5 in the French population) can be a consequence of the geographical and climatic differences.

The reproductive cycle of viviparous viperids in the temperate region is generally considered to be biennial (Aldridge, 1979; Tegelström and Höggren, 1994; Höggren and Tegelström, 1995, 1996), although there is discussion about it based on observations that approximately 50% of mature females in a given population reproduce yearly (Blem, 1982). However, according to Luiselli (1990), Baron et al. (1996), and Baron (1997) Orsini's viper also has a biennial reproductive cycle. Although the females mate every year, fecundation takes place only when body conditions are appropriate (usually every second year). The same phenomenon has been described also in other European snakes, in *Vipera berus* (Luiselli, 1993, 1995), *Coluber viridiflavus* and *Elaphe longissima* (Capula et al., 1995), and may have crucial consequences for snake reproductive systems (Capula and Luiselli, 1997). One clutch may hence originate from different males. The number of neonatals is usually between five and twelve. Larger clutch sizes (e.g. 19) are quite rare, and may be due to genetic diversion (Janisch, 1993). Timing of the different events of the annual reproductive cycle of European vipers may vary according to weather conditions, and, to a lesser extent, habitat structure (Saint Girons, 1992).

Conservation aspects

The results obtained thus far reveal that the monitored population is healthy and capable of surviving in case the environmental conditions remain unchanged. Although the meadow itself is state property and has supported the largest known *Vipera ursinii rakosiensis* population in the world, it is still not officially protected. Localised fires resulting from NATO excercises in the past were followed by a huge fire caused by a family trying to light a shell in 1997. Due to an apparent misunderstanding, another area of habitat has since been short mown. With better managing this habitat could regain its original plant cover, but the effects on the Hungarian meadow viper need to be monitored closely. Unfortunately, conservation measures are usually not based on long-term ecological research, and a venomous snake has low priority when other nature conservation values in the habitat are considered (plants and birds, for instance). Habitat protection is often in conflict with the interests of local farmers, military training, or ecotourism. A population reinforcement program launched as an immediate protection measure has proved useless in three years′ practice. As a consequence of all of these facts, according to a continuous monitoring since 1984, the populations of the Hungarian meadow viper are in constant decline, and facing an immediate risk of extinction. All these results indicate that scientific research has provided nature conservation with a better knowledge for a more effective protection and positive proposals for the optimal management of the habitat available, so a more effective implementation of nature conservation measures would be possible. An Action Plan is to be presented as the framework for future research and nature conservation activities. The proposal for the ten-year project is aimed at a complex protection of the viper together with its habitat on the highest priority with a scientifically sound research background.

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