ÖGH Herpetozoa
Austrian Herpetological Society

Herpetozoa 38: 61–69 (2025)
DOI 10.3897/herpetozoa.38.e145691

Dolichophis caspius road mortality at its northern distribution range limit: the lower Olt River valley, southern Romania

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https://zoobank.org/849A69B0-A31E-41FD-AD88-20029D2AF68E

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Academic editor: Johannes Foufopoulos ♦ **Received** 31 December 2024 ♦ **Accepted** 16 February 2025 ♦ **Published** 17 March 2025

Abstract

Dolichophis caspius is frequently affected by road mortality, with many victims recorded also in Romania. Although some regions in the country have a presumptive high risk of road mortality, there is no certain data from all regions. In 2021 and 2024, we analyzed this species' road mortality at its northern distribution range limit (lower Olt River valley, southern Romania). We identified 66 road-killed *D. caspius* over the course of eight days. Most victims (62.12%) were juveniles. The high number of road-killed juveniles is a consequence of the road`s features, which crosses many small human settlements (villages) and has numerous curves and speed enforcement cameras; therefore, the speed is reduced to 50 km/h. Consequently, the small-sized road-killed juveniles were easier to observe, as compared to roads of higher speeds, where they can be easily missed. The high number of juveniles indicates that in the region there are large populations that reproduce, as they are probably favored by climate warming. Although the absolute number of road-killed juveniles was higher at the end of summer and autumn, the ratio of juveniles and adults was the same in spring. The differences in road mortality on different days, even of the same month, indicate the importance of local microclimate conditions for the activity and road mortality of *D. caspius*. The lower Olt River valley region has a high risk of road mortality for this species, as it shows the scale of this phenomenon by highlighting the impact on juveniles.

Key Words

age, conservation, distribution range, habitats, loess walls, populations, season, speed

Snakes are frequent victims of road mortality, as highlighted by many studies (e.g., Bonnet et al. 1999; Shepard et al. 2008; Meek 2009; Maschio et al. 2016; Lutterschmidt et al. 2019). Nevertheless, snake road mortality is not uniform, as its intensity is associated with different habitat conditions from road vicinity (e.g., Ciesiołkiewicz et al. 2006; Shepard et al. 2008; Sucea et al. 2023; Jones et al. 2024; Szabolcs et al. 2024). Not all snake species are equally susceptible to road traffic, as they have different road mortality probabilities depending on multiple factors (see Andrews and Gibbons 2005). One species particularly affected by vehicular traffic is the Caspian whipsnake, *Dolichophis caspius* (e.g., Tok et al. 2011; Kambourova-Ivanova et al. 2012; Pulev et al. 2019; Smirnov et al. 2023; Kouris et al. 2024). According to a recent review, *D. caspius* seems to be one of the most frequently road-killed snake species in Europe (Morelli et al. 2024). *D. caspius* is affected by road mortality also in Romania, where a lot of information has been collected on this topic (e.g., Covaciu-Marcov and David 2010; Covaciu-Marcov et al. 2012, 2020; Ferenți et al. 2011; Sahlean et al. 2019), data which were recently evaluated in a review (Sahlean et al. 2024). According to this, 270 road-killed Caspian whipsnakes were registered in Romania in the past (Sahlean et al. 2024). Still, despite the large volume of

data contained in the review, in the country, there are areas with high demonstrated numbers of road fatalities and high risk of mortality, but also areas with a potentially high risk of road mortality but with no information about this phenomenon, which indicates insufficient studies (Sahlean et al. 2024). According to that model, the regions with higher road mortality risk are those with dense road networks, flat terrains, and open agricultural areas (Sahlean et al. 2024). At the same time, the data from Romania shows a clear prevalence of road-killed Caspian whipsnake adults (Sahlean et al. 2024). However, in the case of other snakes, juveniles were more affected than adults (e.g., Ciesiołkiewicz et al. 2006; Kovar et al. 2014; McCardle et al. 2022). Thus, because in the case of this species the road mortality victims are usually adults and there are two peaks of road mortality per year, new studies are necessary to verify if, in the autumn, there will be more road-killed juveniles (Sahlean et al. 2024), as in Romania the offspring hatches in August (Sahlean and Strugariu 2018). Previous data came largely from major high-speed roads (national roads), which might have introduced a detection bias toward larger individuals, as adults are prone to road traffic exposure (Sahlean et al. 2024). Therefore, considering road impact in all age groups is important, as juvenile road mortality had the same impact on the population level as that of adults (Keevil et al. 2023). At the same time, road fatalities appear more frequent on roads near loess walls, presumably because such areas harbor more dense snake populations, given that this is one of the optimal habitats for the species in an otherwise agriculturally dominated area (e.g., Covaciu-Marcov et al. 2012, 2020). Therefore, we hypothesized that this would also apply to other regions at the northern distribution range limit of *D. caspius* with loess walls and roads, and that the road mortality of this species would also be intense. Simultaneously, the second hypothesis was that if the juveniles of other snake species have high road mortality (e.g., Ciesiołkiewicz et al. 2006; Kovar et al. 2014; McCardle et al. 2022), so does *D. caspius*. To verify these predictions, we chose to study a local road with low traffic and low speed from southern Romania. Therefore, our objectives were: 1. to quantify road fatalities of *D. caspius* in a region considered of high risk of road mortality but with no data about it (Sahlean et al. 2024), namely the lower Olt River valley in southern Romania, 2. to establish the intensity of road mortality according to the age of snakes, time of year, and locality.

The field activity took place in 2021 and 2024. The studied road is an asphalt county road (DJ 456), with one lane in each direction and is extremely curved. It follows the lower course of the Olt River, one of the most important rivers from Romania, which flows into the Danube near Turnu Măgurele town (Ujvári 1972). The study targeted a section of road of approximately 53 kilometers, between Turnu Măgurele (43°45'30"N, 24°51'33"E, 34 m altitude) and the intersection of the county road and the national road to Bucharest (44°07'11"N, 24°35'34"E, 68 m altitude), near the locality of Drăgănești-Olt (Fig. 1). The region belongs to Boian Plain (Mândruț 2006), a mostly flat area with cereal-cultivated agricultural lands,

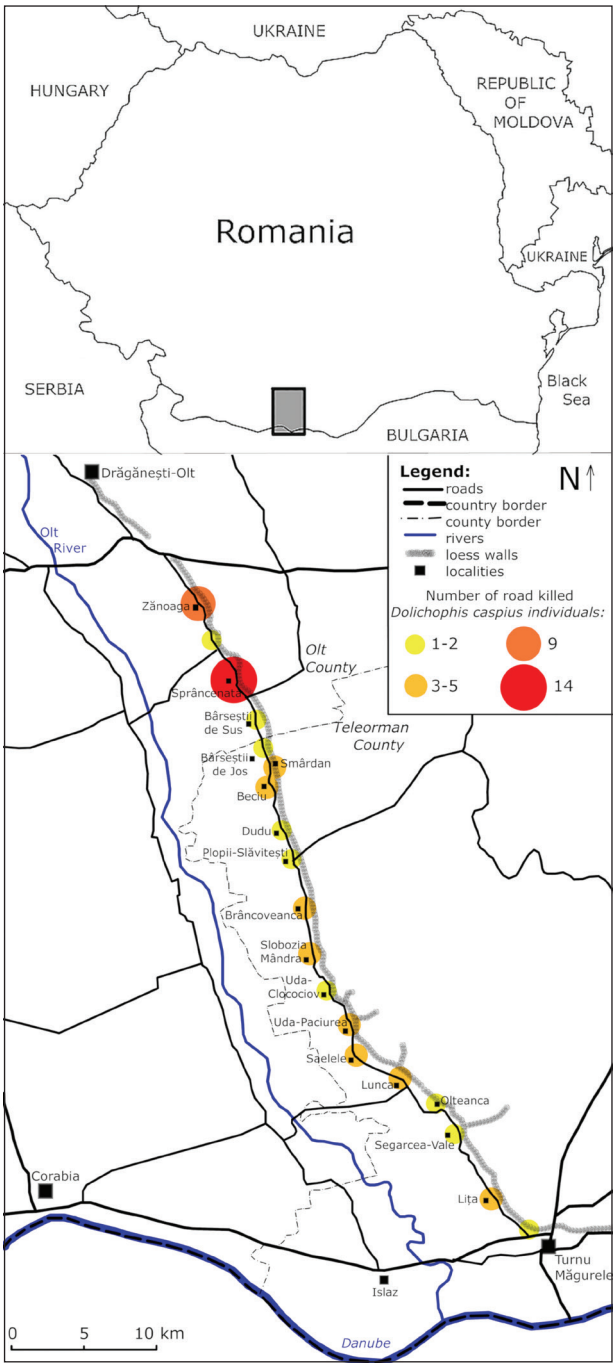

Figure 1. Distribution and abundance of road-killed *D. caspius* individuals in the lower Olt River valley, southern Romania.

considered a farming area par excellence (Vijulie et al. 2013a). Nevertheless, eastwards of the Olt River, the road is flanked throughout the entire studied distance by loess walls, sometimes almost vertical, where numerous springs are formed (Grecu et al. 2015). The height difference between the base and the top of the loess walls can reach 50–60 m (Vijulie et al. 2013b), and the loessial deposits from the region usually get 20–30 m thick (Vijulie (Nedeloaea) 2006). In the Boian Plain, the human settlements are situated predominantly in the valleys of rivers, like the Olt River (Vijulie (Nedeloaea) 2006). As a consequence, more than 90% of the studied road is inside numerous

small villages, and is surrounded by traditional houses, gardens, vineyards, farms, and some forest remnants in the northern areas. We conducted eight days of field surveys during the two years of study (Table 1). On each date, the road was traveled in both directions, in a car traveling at 50 km/h. At that speed even small road-killed snakes were observed, a fact already noted (Köhler et al. 2016). The road-killed snakes were observed by the two passengers from the front seats of the moving car. We stopped the car for each road-killed snake. The species was identified on-site (not all corpses were of *D. caspius*). The corpses that were relatively well preserved were collected and conserved. We also spotted alive snakes along the way which hid immediately after the car stopped. As we aimed to establish the ratio of juveniles, the corpses were divided into two age categories: adults and juveniles (juveniles being defined as having been born in the summer of either in the current or the previous year, which have shorter length and juvenile coloration - see Fuhn and Vancea 1961). The data were processed according to age class, period, and provenance location (as we aimed to establish potential hotspots and hot times of road mortality). We calculated the percentage abundance of the road-killed snakes, both for age classes, periods, and localities. The distribution records were represented on a map (Fig. 1) with the free program GIMP (GIMP Development Team 2019). On this map, we marked the locations where we recorded road-killed *D. caspius* individuals and the number of corpses, to highlight the road mortality hot spots (Fig. 1).

We identified 69 *D. caspius* individuals on the road from the Olt River lower valley (Table 1). Among these, only three individuals were found alive, all of which were juveniles. Among the road-killed individuals, 25 were adults (37.87%), and 41 (62.12%) were juveniles (from the same year or the previous one). All road-killed Caspian whipsnakes were observed on the road's asphalted part; the road did not have an unpaved shoulder, therefore, in most cases, it is in direct contact with the surrounding habitats. Most snakes were freshly killed by cars (Fig. 2) (including individuals who still had reflex movements when we found them). However, we also encountered old corpses, some consisting of only skin remnants and bones, which had stayed on the road for a few days and had been dried by the sun and damaged by the repeated passing of cars. The Caspian whipsnake road mortality presented important differences across seasons. The highest number of victims (20) was observed at the end of August 2024, most of them being juveniles. The lowest victim count (one adult) was recorded at the end of May 2021, but at the beginning of the same month, we recorded 11 victims (Fig. 3). While in absolute abundance, the number of juveniles was higher at the end of the summer and in autumn, in relative abundance, the juveniles' percentage abundance was very high also in the spring (on 31 August 2024, the juvenile percentage abundance was 85%, and on 28 April 2024, their percentage abundance was 83.33%). Road mortality of *D. caspius* presented not only high fatality periods but also hot spots. Thus, high road mortality was registered on the northern sectors of the studied road, near Sprâncenata and Zănoaga localities, in areas where small forest fragments still survive on the loess walls (Fig. 1).

The number of road-killed Caspian whipsnakes (66) reported here is not as high as in other cases of snake road mortality (e.g., Bonnet et al. 1999; Shepard et al. 2008; Eberhardt et al. 2013; Maschio et al. 2016; Lutterschmidt et al. 2019). Nevertheless, it represents almost a quarter of the previous number of victims (270) identified across the entire Romanian distributional range of the species over the last 20 years (Sahlean et al. 2024). In the past, most road-killed Caspian whipsnakes were identified in Dobrudja and the Jiu River meadow between Craiova and Bechet (Sahlean et al. 2024).

Table 1. Number of road killed *D. caspius* individuals in the lower Olt River valley, southern Romania (A – adults, J – Juveniles, * - alive individuals, Tr – Teleorman County, Ot – Olt County).

		2021				2024			
		04 V	29 V	11 IX	02 X	28 IV	01 V	31 VIII	28 IX
Tr	Turnu Măgurele	1A							
	Lița							3J	
	Segarcea Vale							1J	
	Olteanca	1J							
	Lunca				1A, 1J			1J	
	Saelele					1J		2J	
	Uda-Paciurea			1A, 2J				2J	
	Uda-Clocociov						1A	1A	
	Slobozia Mândra			1J	1A, 1J				
	Brâncoveanca	1A		1J	1A	1J			1A
	Plopii-Slăvitești						1J		
	Dudu			1J			1J		
	Beciu	2A		1J				1J	
	Smârdan					1J	1A, 1J	2J	
	Bârseștii de Jos / Smârdan	1A							
Ot	Bârseștii de Sus	1A		1J					
	Sprâncenata	4A		2J, 1J*	1J	2J, 1J*	1A	2A, 1J	1J, 1J*
	Sprâncenata / Zănoaga						1A		
	Zănoaga		1A	2J		1A	1A	4J	

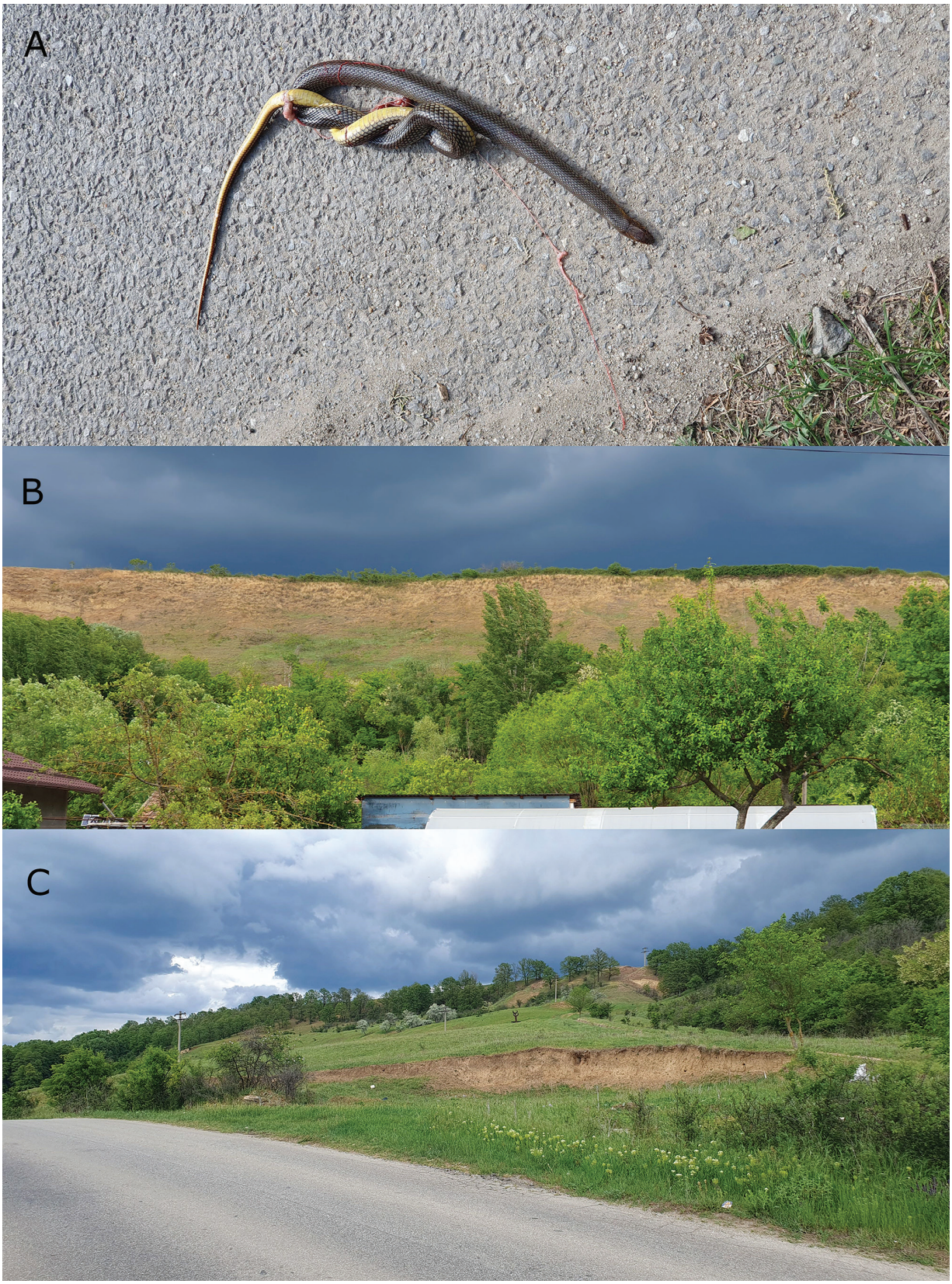

Figure 2. Road-killed *D. caspius* individual (**A**), and the typical loess walls inhabited by the species (**B, C**) in the lower Olt River valley, southern Romania.

But this fact is probably a study bias because both Dobrudja (e.g., Andrei 2002; Covaciu-Marcov et al. 2006; Iftime and Iftime 2006, 2018; Strugariu et al. 2008) and the Jiu River meadow (e.g., Covaciu-Marcov et al. 2018; Cupșa et al. 2021, 2023) are the focus of many studies, including on *D. caspius* (Covaciu-Marcov et al. 2020). Therefore, this reflects sampling effort intensity rather than reality. Although the road along the lower Olt River

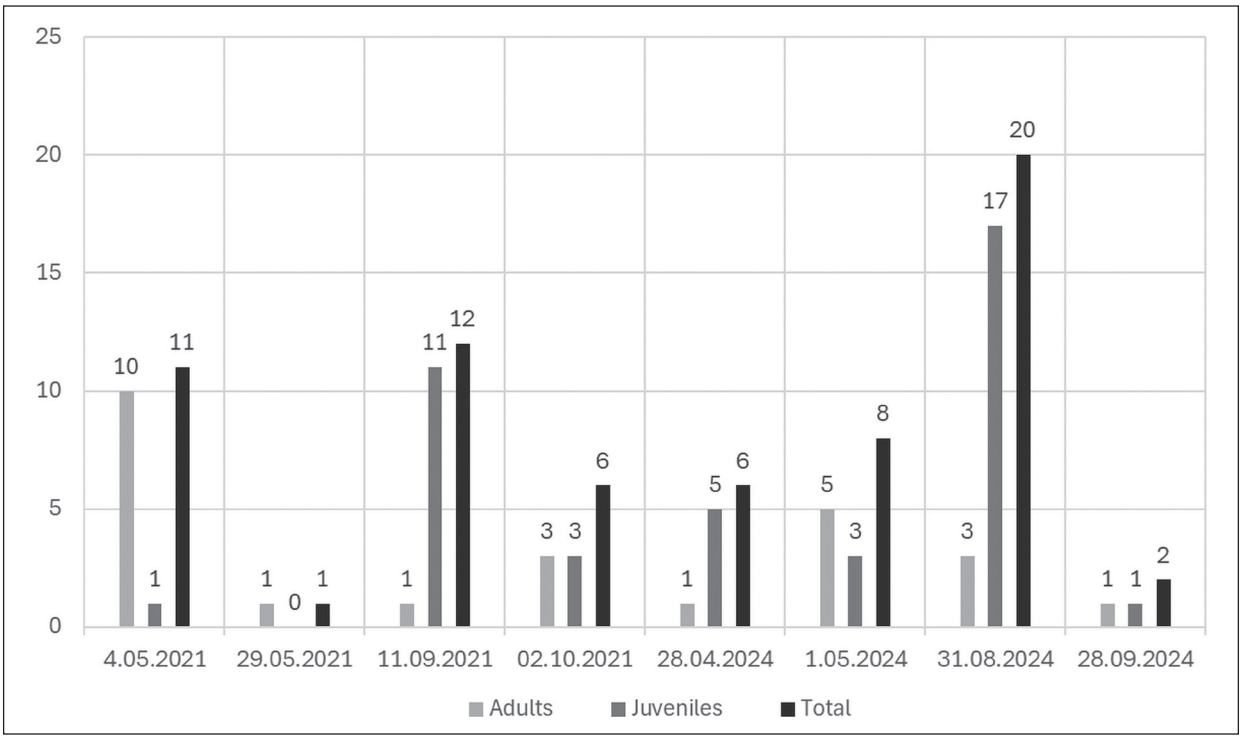

Figure 3. The number of road-killed *D. caspius* individuals on different dates.

valley seems to pose a high risk of road mortality for this species (Sahlean et al. 2024), there were very few records of the species in the region in the past (only three), and they were not road-killed individuals (Covaciu-Marcov and David 2010; Sahlean et al. 2010; Covaciu-Marcov et al. 2020). This lack of data on road mortality is also evident in a recent review (Sahlean et al. 2024), although there existed informal reports from local people regarding snake road fatalities (Covaciu-Marcov and David 2010). This fact shows how incomplete the data are about the road mortality of *D. caspius* for which this human impact seems relatively well known (see Sahlean et al. 2024). This also highlights the importance of small regions with optimal conditions for this species, as even on a small surface of its distribution range in Romania, we recorded a high number of road-killed individuals.

In the past, only 11 road-killed *D. caspius* juveniles were reported among 150 adult snakes (Sahlean et al. 2024). In contrast in this study, in the Olt River valley alone, we report more juveniles than adults killed by passing traffic. The number of road-killed juveniles was much lower than that of adults in other areas as well (Pulev et al. 2019). While in the past, most road-killed individuals were located on high-speed national roads (Sahlean et al. 2024), here, all corpses were retrieved from a local county road. Thus, the high number of road-killed juveniles is probably a consequence of the features of the road analyzed, which passes through numerous localities and has a lot of curves and speed enforcement cameras. These conditions reduced the traveling speed to only 50 km/h. Thus, the small corpses of the juveniles (an average of 21.92 cm at hatching - Sahlean and Strugariu 2018) were more easily observed compared to roads of higher speeds. At the same time, previous data also included information obtained from amateur naturalists, who easily observed larger snakes rather than small juveniles (Sahlean et al. 2024). Furthermore, in this case, the traffic is reduced, usually with small vehicles, as it is known that higher traffic eliminates the corpses off the roads faster (e.g., Ratton et al. 2014; Bénard et al. 2024). The ratio of juveniles and adults was possibly biased also in previous datasets (Sahlean et al. 2024), which underestimates the impact. Nevertheless, probably not the number of killed juveniles in the Olt River valley was higher than in other cases, but they were easily observed due to special traffic conditions. Other authors also mentioned that in the case of snakes, small carcasses could be more challenging to encounter (Szabolcs et al. 2024). Nevertheless, recent data suggests that the risk of road mortality is similar regardless of age or sex in the case of two congener snake species (Szabolcs et al. 2024). Thus, our study addresses the need for studies to establish if road-killed juveniles are more numerous in autumn (Sahlean et al. 2024). The answer is that they are indeed more numerous in autumn, but they are also killed by road traffic in spring and summer, even if they usually remain unnoticed.

At the same time, the large number of juveniles from Olt River valley clearly shows the existence of large breeding populations in the region. These data could suggest that *D. caspius* expands its distribution range, as the species probably benefits from the human alteration of areas from southern Romania and primarily from a warming climate, as previously suggested (Covaciu-Marcov et al. 2020). Due to climate warming, winter activity has recently been observed in this species in south-eastern Europe (Bjelica et al. 2023), and its range has expanded to the north (Smirnov et al. 2023). The species likes warm conditions (Pulev et al. 2019), and the lower Olt River

meadow is one of the warmest regions of Romania (Mândruț 2006). Moreover, recent years are getting warmer; the winter of 2023/2024 was the warmest in the Oltenia region in recorded history (Marinică et al. 2024). The presence of *D. caspius* is related to the existence of loess walls as in other cases in southern Romania (e.g., Covaciu-Marcov et al. 2012, 2020), so its available habitats are limited. Although in southern Romania, the loess is widely distributed (e.g., Smalley and Leach 1978; Grecu et al. 2015), areas with loess walls are still few, and this is the only region where steep walls are present in Boian Plain (Vijulie (Nedeloaea) 2006). Thus, although the surroundings of the road seem like a region with lots of suitable habitats matching the species requirements, in the upper parts of the loess walls (situated only on the eastern side of the river), the situation changes to almost exclusively agricultural fields (Vijulie (Nedeloaea) 2006; Vijulie et al. 2013a). Under these circumstances, the Caspian whipsnakes are limited to this narrow habitat strip, like in the Danube meadow (Ferenți et al. 2011; Covaciu-Marcov et al. 2012, 2020), which probably pushes them to the road situated at the bottom of the loess walls.

Although it is most likely that the road mortality of Caspian whipsnakes is more intense in areas with flat terrains (Sahlean et al. 2024), these findings should be interpreted with a bit more nuance. There are flat terrains in the lower Olt meadow, but close nearby, there are also loess walls, which determine the presence of *D. caspius*, as they are an important habitat for this species in southern Romania (e.g., Covaciu-Marcov et al. 2012, 2020). Also, in contrast to the strictly agricultural neighboring regions (Vijulie (Nedeloaea) 2006, Vijulie et al. 2013a), there are even some forest fragments in the vicinity of the road, especially at the northern limit, where the road mortality intensity is higher. Even though it seems that the species prefers open, flat areas with farmlands in Romania (Sahlean et al. 2024), in other zones from the northern limit of the distribution range, the species prefers dry, rocky regions of rare forests (Teffo et al. 2023). This fact does not show a preference but rather the plasticity of the species. In southern Romania, habitats like this are not typical, but, for example, in the northern part of the studied area, there are small forest fragments on loess walls, and many corpses have been observed in that region. Probably, if the Caspian whipsnakes had dry, rocky forested areas at their disposal (Teffo et al. 2023), they would have selected those habitats, which was observed in Romania too, in the Danube Gorge, where such habitats are common and the species is also a victim of road mortality (Covaciu-Marcov et al. 2022).

On the road from Olt River valley, the highest number of victims was recorded in August. Also, in other cases at the northern limit of the distribution range, this species engaged in longer-distance movements in August than in other summer and autumn months (Teffo et al. 2023). The number of dead snakes was the highest in spring and autumn for other species (Szabolcs et al. 2024), and our fieldwork took place in those periods. However, the differences between different field trips were extremely high, even if they took place in the same season (even in the same month, see Fig. 3), in different years, or the same year. Therefore, the local differences of microperiod, microhabitat, and climatic differences from one day (or one night) to another are probably at least as important for the snakes` activity and road mortality. This, of course, did not diminish the importance of other factors that generally shape road mortality, such as the habitats surrounding the road, period of the year, traffic intensity, speed, etc. (e.g., Ciesiołkiewicz et al. 2006; Eberhardt et al. 2013; Covaciu-Marcov et al. 2022; Cupșa et al. 2024; Jones et al. 2024). All those factors can modify the intensity of road mortality, even for different sectors of the studied road. Nevertheless, at least some factors remain constant along this road. Thus, on the entire studied road length, the speed is about the same (around 50 km/hour), the traffic intensity is about the same (slightly higher near Turnu Măgurele town), the weather conditions were the same along the road, as in each field trip the road was traveled on the same day. Consequently, the only factors which could cause differences in road mortality across road sectors are the surrounding habitats, which were also very important in shaping road mortality in other studies (e.g., Covaciu-Marcov et al. 2022; Cupșa et al. 2024). Thus, the region with the highest number of road-killed Caspian whipsnakes also has the highest diversity of roadside habitats, including some forest patches.

Although the large body size exposes the Caspian whipsnakes to road mortality (Sahlean et al. 2024), in this case, the juveniles were the most common victims, even though they are considered more difficult to be killed on the roads and to be noticed afterward (Pulev et al. 2019). The maximum travel distance/day for this species is, on average, over 36 m, but the longest daily traveled distance is 226 m (Teffo et al. 2023). Nevertheless, this distance might be underestimated, as only the extreme points and not the swings between them were identified (Teffo et al. 2023). In this case, not only the number of road-killed individuals in the lower Olt River valley is very high, but also, at 1 km of the road on loess walls, some individuals are not directly exposed to road pressure, as they usually do not end up in contact with the road, which has conservation implications. Probably only some individuals are pushed from the optimum habitat areas to the road, which confirms that snakes are more vulnerable when they leave their usual home range (Bonnet et al. 1999). Although, in other cases, the species avoided residential areas (Teffo et al. 2023), here, the corpses were often identified in localities, at only 3, 4 m from houses. However, this case is different because, in the lower Olt River valley, there are small, traditional villages with houses and gardens in the immediate vicinity of the loess walls, so the localities and the snakes` habitats are in contact.

These data also show the limitations of opportunistic studies for global ecological interpretations. Our study might also be biased by the low vehicular speed on this particular road, because the adults of this fast snake spe-

cies, the fastest one in Romania (Fuhn and Vancea 1961), can probably avoid cars, unlike the juveniles, which are smaller and slower. The high number of road-killed snakes is a consequence of the neighboring habitats and the road features. Our results confirm that there are regions that are not adequately studied, as the dataset is biased depending on accessibility, but also that the roads in the area are a danger for this snake (Sahlean et al. 2024). Moreover, the number of victims could be an underestimate because of the short persistence of the snake carcasses on the road (usually around one day), especially for small individuals (e.g., Santos et al. 2011; Cabrera-Casas et al. 2020), as 70% of the corpses are eliminated by scavengers in less than one day (Degregorio et al. 2011). The number of victims is likely high, as the region is a hot spot of road mortality for this snake species at its northern distribution range limit. Even though *D. caspius* seems to be, at present, benefiting from human activities and the warming climate in Romania (Covaciu-Marcov et al. 2020), the impact of road traffic on its populations is nevertheless obvious. In this context, some mitigation measures would become necessary, although the difficulty of establishing such measures has already been discussed regarding this species (Covaciu-Marcov et al. 2012, 2020). Moreover, the present data demonstrate that the assumption that this fast snake can avoid cars traveling at low speeds (Covaciu-Marcov et al. 2012) is not always correct. In other cases, barrier fences and ecopassages did reduce road mortality of a specific snake species, but those barrier fences did not work for other snake species (Colley et al. 2017). Nevertheless, that particular species has different ecology and behavior and a low daily movement average (Moore and Gillingham 2006) compared to *D. caspius*, as the Caspian whipsnake is a fast and agile climber (Fuhn and Vancea 1961). At the same time, installing barrier fences and ecopassages is possible in a natural, forested protected area (Colley et al. 2017) but impractical on a 53 km-long road inside localities. Also, larger snakes can readily scale across barrier fences (Macpherson et al. 2001), and *D. caspius* is a long snake (Fuhn and Vancea 1961). Thus, maybe a simpler and more efficient solution would be to install wildlife warning signs, as they have already been used for other snake species (Colley et al. 2017). It was suggested to install such signs in road mortality hot spots, as warning signs depicting snakes reduced the impact upon them (see Collinson et al. 2019). Nevertheless, wildlife warning signs were considered ineffective in the case of other reptiles (Seburn and McCurdy-Adams 2019). Even in Romania, such warning signs were recently suggested in a protected area (Cupșa et al. 2024), and they were subsequently installed in the field (personal observation). Thus, warning signs showing a Caspian whipsnake could be readily installed in the lower Olt River valley, especially near road mortality hotspots. Nevertheless, in this case, their effect will probably be exactly the opposite, as in many cases, drivers intentionally run over snakes they observe on the roads (e.g., Langley et al. 1989; Secco et al. 2014), and *D. caspius* is anyway directly killed by the local people in the lower Olt River region (Covaciu-Marcov and David 2010).

Acknowledgment

We want to thank Diana L. Delibaltov for improving the manuscript's language.

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