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ROAD MORTALITY OF AMPHIBIANS AND REPTILES ALONG TWO ROADS IN THE CARNIC ALPS (FRIULI, NORTH-EASTERN ITALY) BEFORE AND AFTER ASPHALTING

GIANLUCA RASSATI
Via Udine 9 – 33028 Tolmezzo (Italy) itassar@tiscali.it

Riassunto – Mortalità stradale di anfibi e rettili lungo due strade nelle Alpi Carniche (Friuli) prima e dopo l'asfaltatura
Percorrendo a piedi un transetto di 1.5 Km lungo due strade nelle Alpi Carniche sono state rilevate tutte le carcasse di anfibi e rettili nel 2000 e nel 2001, e, dopo la asfaltatura nel 2009 e nel 2010. Nel primo periodo la mortalità stradale ha interessato 2 specie in entrambe le strade mentre nel 2009 e 2010 ha coinvolto 7 specie in una strada e 5 specie nell'altra. Il numero totale di carcasse per chilometro (Indice chilometrico di abbondanza-IKA) nel 2000-2001 era 10 (Media 1.25 ± 0.56 DS), nel secondo periodo era 158.67 (Media 19.83 ± 11.17 DS). Le specie più colpite sono state *Salamandra salamandra* (IKA totale nel 2000-2001: 4.67; nel 2009-2010: 83.33) e *Bufo bufo* (IKA totale nel 2000-2001: 2.67; nel 2009-2010: 36.67). Gli altri 5 taxa hanno fatto rilevare tassi di investimento molto inferiori. Tutti gli indici hanno evidenziato un forte aumento della mortalità stradale con le strade asfaltate con coinvolgimento anche di specie dotate di un notevole grado di attenzione e di risposta al pericolo immediato (e.g. l'arrivo di un veicolo) quali *Podarcis muralis* e *Lacerta viridis*. Questo è stato determinato dall'aumento di oltre 18 volte del numero di veicoli transitanti che, inoltre, viaggiano a velocità molto più elevata. La realizzazione sulle Alpi Carniche, negli ultimi decenni, di un elevato numero di strade e la asfaltatura, pure di alcune già esistenti, alla luce dei dati raccolti induce a ritenere che la loro realizzazione ed asfaltatura debba essere, in fase preliminare, attentamente valutata ed in fase progettuale debbano essere tenuti in considerazione gli aspetti che possono mitigare l'impatto con la fauna. Si conclude indicando alcune misure atte a ridurre l'incidenza del traffico stradale.
Parole chiave: Anfibi, Rettili, Salamandra pezzata, *Salamandra salamandra*, Rospo comune, *Bufo bufo*, Alpi Carniche, Friuli, Italia Nord-orientale, Strada, Mortalità stradale, Traffico stradale

Abstract – During surveys along a 1.5 km transect in two roads in the Carnic Alps, all the carcasses of amphibians and reptiles were recorded first in 2000 and 2001 and then in 2009 and 2010 after the roads had been asphalted. In the first period the road mortality involved two species in both roads, while in 2009-2010 seven species were recorded in one road and five species in the other. The total number of carcasses per kilometre (kilometric abundance index-KAI) in 2000-2001 was 10 (mean 1.25 ± 0.56 SD), while in the second period it was 158.67 (mean 19.83 ± 11.17 SD). The most affected species were *Salamandra salamandra* (total KAI in 2000-2001: 4.67; in 2009-2010: 83.33) and *Bufo bufo* (total KAI in 2000-2001: 2.67; in 2009-2010: 36.67). The other five taxa had much lower mortality rates. All the indices showed a sharp increase in road mortality with asphalting of the roads, with the involvement also of species with a high degree of attention and responsiveness to immediate danger (e.g. the arrival of a vehicle) such as *Podarcis muralis* and *Lacerta viridis*. This was due to the over 18-fold increase of the number of passing vehicles, which also travelled at much higher speed. Numerous roads have been constructed in the Carnic Alps in recent decades, and many of the already existing and the newly built roads have been asphalted. However, the data collected in the present study suggest that their construction and asphalting should be carefully evaluated in the preliminary phase and that aspects that might mitigate the impact on fauna must be taken into account in the planning phase. Finally, some measures aimed at reducing the impact of road traffic are indicated.
Key words: Amphibians, Reptiles, Fire salamander, *Salamandra salamandra*, Common toad, *Bufo bufo*, Carnic Alps, Friuli, North-eastern Italy, Road, Road mortality, Road traffic.

1. – Introduction

In the mountains, road construction greatly increases the possibility of anthropizing areas that may even be very far from inhabited centres. Within a short time after

the opening of new roads, zones previously with little or no human presence see a more or less continuous flow of people and they become "new territories to be explored" by many individuals who are often not educated in the proper approach to the natural environment. This phenomenon is accentuated when the roads are asphalted and there is an increase of transits, particularly with motor vehicles. This has more or less serious repercussions on the animal species, and may have a significant impact (cf. e.g. FAHRIG *et al.*, 1995; ASHLEY & ROBINSON, 1996; VOS, 1997; ELZANOWSKI *et al.*, 2009; FAHRIG & RYTWINSKI, 2009; HARTEL *et al.*, 2009). Particularly in the case of amphibians, road building can lead to the destruction of breeding sites. In any case, the increased human presence has both indirect (e.g. disturbance, waste) and direct effects (e.g. collisions), reducing the resilience and adaptive capacity of populations and species (SELVA *et al.*, 2011). Road mortality can be a significant factor in the decline of amphibian and reptile populations (GLISTA *et al.*, 2008). Even roads in zones without an elevated flow of vehicles, and thus apparently "safe", can have a high number of collisions with animals. Indeed animals which because of their characteristics and the need to cross roads to reach breeding sites or because they are attracted to roads that make it easier to find food or to move about are very much exposed to road mortality. Therefore, it was decided to verify the incidence of road mortality of amphibians and reptiles along two roads in an Alpine zone, also in relation to the type of road surface.

2. – Study areas and Methods

Both roads are situated in the Degano Valley (Carnic Alps, Friuli, North-eastern Italy). They have a variable slope with some flat stretches and other steeper ones, and they were paved with asphalt in the first decade of this century.

The first (low road; 425-485 m a.s.l.; 46°27'N, 12°52'E) is in the valley floor close to the main river and crosses a small stream; it passes through a wood of European beech *Fagus sylvatica*, Norway spruce *Picea abies*, European ash *Fraxinus excelsior*, Hop-hornbeam *Ostrya carpinifolia*, Small-leaved lime *Tilia cordata*, Wych elm *Ulmus glabra* and Black locust *Robinia pseudacacia*.

The second (high road; 950-1045 m a.s.l.; 46°27'N, 12°50'E) runs along the right slope of the valley and is intersected by a stream; it passes through a wood of *Fagus sylvatica* in which there are some *Picea abies* plantations.

The study was conducted on foot along a 1.5 km transect during which all the carcasses of amphibians and reptiles were recorded. Surveys were carried out on both roads on the same day in both April and October in 2000 and 2001 (when the roads were not paved) and in 2009 and 2010. Two days before the surveys, the transects were travelled in order to remove animal remains so as to avoid the recording of old remains. For each species, the kilometric abundance index, expressed as the number of carcasses per kilometre (KAI), and the percentage frequency (F%: = n/N x 100; n = number of carcasses of the species, N = total number of carcasses) were calculated. For the Fire salamander *Salamandra salamandra*, the species with the highest number of road deaths, the maximum number of carcasses/100 m was also recorded in Octo-

ber of 2009 and 2010. The vehicles passing in the hour following the beginning of each survey were counted.

3. – Results

In 2000 and 2001, the road mortality involved two species in both roads, while in 2009 and 2010 seven species were recorded in the low road and five in the high road (Tabs. 1, 2, 3).

Considering all the species, in the case of mortality the KAI in the first study period varied from 0.67 to 1.33 in the low road and was 0.67 in the high road; in 2009 and 2010, the KAI varied from 0.67 to 22 in the low road and from 0.67 to 20.67 in the other road (Tabs. 1, 2).

Remains of unidentified species were found in half of the surveys in the first study period with KAI of 0.67, but in all surveys in the second period with KAI varying from 2.67 to 9.33 in the low road and from 0.67 to 4.67 in the other road (Tabs. 1, 2).

Table 1 - KAI (Number of carcasses per kilometre) in the period 2000-2001
Tabella 1 - IKA (Numero di carcasse per chilometro) nel periodo 2000-2001

	Low road				High road						
	2000		2001		2000		2001				
	Apr	Oct	Apr	Oct	Apr	Oct	Apr	Oct	**Total**	**Mean**	**SD**
Salamandra salamandra	0.67	1.33	0	1.33	0	0.67	0	0.67	**4.67**	**0.58**	**0.56**
Bufo bufo	0	0.67	1.33	0	0.67	0	0	0	**2.67**	**0.33**	**0.50**
Unidentified species	0.67	0	0.67	0	0	0	0.67	0.67	**2.67**	**0.33**	**0.36**
Total	**1.33**	**2**	**2**	**1.33**	**0.67**	**0.67**	**0.67**	**1.33**	**10**	**1.25**	**0.56**

Table 2 - KAI (Number of carcasses per kilometre) in the period 2009-2010
Tabella 2 - IKA (Numero di carcasse per chilometro) nel periodo 2009-2010

	Low road				High road						
	2009		2010		2009		2010				
	Apr	Oct	Apr	Oct	Apr	Oct	Apr	Oct	**Total**	**Mean**	**SD**
Salamandra salamandra	4	18.67	4	22	2.67	20.67	2	9.33	**83.33**	**10.42**	**8.63**
Bufo bufo	20	5.33	2	2	1.33	4	0.67	1.33	**36.67**	**4.58**	**6.42**
Rana temporaria	0.67	0	1.33	0	0	0.67	0.67	0	**3.33**	**0.42**	**0.50**
Anguis fragilis	0	0.67	0	0	0.67	0	0	0	**1.33**	**0.17**	**0.31**
Lacerta viridis complex	0	0	0.67	0	0	0	0	0	**0.67**	**0.08**	**0.24**
Podarcis muralis	0	0.67	0.67	0.67	0	0	0.67	0	**2.67**	**0.33**	**0.36**
Natrix natrix	0	0	0.67	0	0	0	0	0	**0.67**	**0.08**	**0.24**
Unidentified species	9.33	4.67	2.67	3.33	4.67	2.67	2	0.67	**30**	**3.75**	**2.62**
Total	**34**	**30**	**12**	**28**	**9.33**	**28**	**6**	**11.33**	**158.67**	**19.83**	**11.17**

Considering only the two species with the greatest road mortality, namely *S. salamandra* and the Common toad *Bufo bufo*, in 2000-2001 the mean KAI was respectively 0.58 ± 0.56 SD and 0.33 ± 0.50 SD, while in the second period it was

respectively 10.42 ± 8.63 SD and 4.58 ± 6.42 SD. The road mortality of unidentified species was also lower in the first period: 0.33 ± 0.36 SD vs 3.75 ± 2.62 SD (Tabs. 1, 2).

Considering all the surveys and all the species, in 2000-2001 the total KAI was 10 (mean 1.25 ± 0.56 SD), while the highest KAI per single species was 1.33 (*S. salamandra*, *B. bufo*) and per single survey it was 2 (October 2000, April 2001) (Tab. 1); in 2009-2010 the total KAI was 158.67 (mean 19.83 ± 11.17 SD), while the highest KAI per single species was 22 (*S. salamandra*) and per single survey it was 34 (April 2009) (Tab. 2).

The maximum number of carcasses/100 m of *S. salamandra* in October of 2009-2010 was 5 in both roads.

The road mortality was similar in April and October in the first period but higher in October in the second period (Tabs. 1, 2).

In both periods, *S. salamandra* was the species on which the road traffic had the greatest impact, followed by *B. bufo* (Tab. 3). Much lower mortality rates were recorded for the other taxa (Tab. 3).

In total, 7 vehicles passed in 2000-2001, while 129 vehicles passed in the other study period (including 5 motorcycles) (Tab. 4).

Table 3 - Percentage frequency of carcasses per single species in the two considered periods
Tabella 3 - Frequenza percentuale di carcasse per singola specie nei due periodi considerati

	2000-2001	2009-2010
Salamandra salamandra	46.67	52.52
Bufo bufo	26.67	23.11
Rana temporaria		2.10
Anguis fragilis		0.84
Lacerta viridis complex		0.42
Podarcis muralis		1.68
Natrix natrix		0.42
Unidentified species	26.67	18.91

Table 4 - Number of vehicles passing in the hour following the beginning of the survey
Tabella 4 - Numero di veicoli transitanti nell'ora successiva all'inizio dell'uscita

	Low road				High road				**Total**
	Apr 2000	Oct 2000	Apr 2001	Oct 2001	Apr 2000	Oct 2000	Apr 2001	Oct 2001	
Vehicles/h	1	0	2	1	0	1	1	1	**7**
	Apr 2009	Oct 2009	Apr 2010	Oct 2010	Apr 2009	Oct 2009	Apr 2010	Oct 2010	
Vehicles/h	24	25	29	20	6	10	4	11	**129**

4. – Discussion

All the indices show a strong increase in road mortality after the asphalting of the two roads. There is an increase of the number of species killed, with the involvement also of those with a high degree of attention and responsiveness to immediate danger (e.g. the arrival of a vehicle) such as the Common wall lizard *Podarcis muralis* and the European green lizard *Lacerta viridis* complex (Tabs. 2, 3). There is also an

A Fire salamander. Will it be able to cross the road? - Salamandra pezzata. Riuscirà ad attraversare la strada?
(Photo G. Rassati)

Common toads run over. Bottom left, the remains of a pair - Rospi comuni investiti.
In basso a sinistra si notano i resti di una coppia (Photo G. Rassati)

Carcass of a shrew - Cadavere di Toporagno
(Photo G. Rassati)

Remains of a European green lizard that has been run over - Resti di Ramarro investito
(Photo G. Rassati)

exponential increase in the number of carcasses, which in the case of *S. salamandra* is almost 15 times greater in the low road and 26 times in the high road, while in the case of *B. bufo* the value is almost 15 times greater in the low road and 11 times in the other road (Tabs. 1, 2). In 2009-2010, carcasses of Shrews *Sorex* spp. (the only mammal found) were also recorded, with a total KAI of 1.33 in the low road and 2 in the other road, whereas no carcasses of that taxon were found in the first study period. While it is possible that the remains of the mammal were specimens that died for reasons other than collision with a vehicle, these data are in agreement with what occurred for amphibians and reptiles. This is most likely due to the over 18-fold increase in the number of vehicles passing (Tab. 4), which also travel at much higher speed on the paved roads. In addition, the asphalt also encourages the passage of bicycles, observed only in the low road in the second period, which may have a role, albeit minimal, in collisions, especially with species such as *S. salamandra*. An increase in traffic is recognized as a factor influencing the decline of amphibian populations worldwide (PUKY, 2006) and had already been indicated as one of the causes of the increased mortality of *S. salamandra* in recent decades in mountain zones (RASSATI, 2012). Confirmation that the herpetofauna constitutes the majority of road mortality victims (ASHLEY & ROBINSON, 1996; SMITH & DODD, 2003; GLISTA *et al.*, 2008) comes from the absence of bird carcasses, in addition to the finding of only a single species of mammals.

S. salamandra was the most affected species, with almost half of the collisions

A Common frog on an asphalted road - Rana temporaria su strada asfaltata
(Photo G. Rassati)

in 2000-2001 and over half in the subsequent period, while *B. bufo* was second with about ¼ of the collisions in both periods (Tab. 3). These two species tend to be attracted to the asphalt, for example to move about and to hunt, and to not move even in the case of passing vehicles. Moreover, the first species is very slow-moving, especially in the case of low temperature. *B. bufo* crosses the low road also to reach the Degano where it breeds: this is responsible for the high mortality in April 2009. The higher mortality of *S. salamandra* in October is attributable, at least in part, to the fact that in the high road a higher number of vehicles pass in this period, also due to hunting activities. The high mortality of *S. salamandra* in October is clearly highlighted by the fact that in 100 m it was possible to find also a carcass on average every 20 m. Road mortality is a significant additional source of mortality also for the American species the Spotted salamander *Ambystoma maculatum* (GIBBS & SHRIVER, 2005). *B. bufo* often presents high road mortality rates (cf. e.g. ORŁOWSKI G., 2007; SANTOS *et al.*, 2007; HARTEL *et al.*, 2009). Also in a study conducted in Tuscany, amphibians were the most affected class of vertebrates, especially *B. bufo* (SCOCCIANTI *et al.*, 2001).

The other species run over (Tabs. 1, 2, 3) include taxa that are rather common above all in valley floor zones, and thus with a good probability of falling victim to road mortality. However, with the exception of the Common frog *Rana temporaria*, very vulnerable when it must reach breeding sites, and *P. muralis*, numerous along the low road, these are species with smaller populations which usually cross roads only occasionally. Nonetheless, they also fall victim to road traffic, even if it is of low intensity like that along the two surveyed roads.

In addition to the species reported in Tables 1, 2 and 3, the zones traversed by the roads host other species such as the Western whip snake *Hierophis viridiflavus* and the Aesculapian snake *Zamenis longissimus* (RASSATI, 2002, 2005, 2012): their limited number and the absence of the former along the zone of the high road meant that they were not road mortality victims in the study periods.

Numerous roads have been constructed in the Carnic Alps in recent decades. Moreover, many of the already existing and the newly built roads have been asphalted. This has increased the fragmentation of habitats and has reduced the degree of environmental connectivity: factors that favour the decline of populations (FAHRIG *et al.*, 1995; VOS, 1997; CUSHMAN, 2006).

The results of the present study indicate that, even in the presence of a linear infrastructure and a low number of passing vehicles, there may be a strong direct impact as a result of asphalting, especially on some species of amphibians. Roads, even if not paved, also have an indirect impact on other species because of the resulting human disturbance, e.g. the Capercaillie *Tetrao urogallus* (cf. e.g. RASSATI, 2009). It would be interesting to extend this type of investigation to various types of roads to determine if the results of this study are common to other contexts.

In light of the findings and the fact that even small animals such as amphibians crossing the road can be the cause of road accidents with consequences for man (LANGTON, 1989), it is necessary that the construction of roads and their asphalting be carefully evaluated in the preliminary phase and that aspects that might mitigate the impact on fauna be taken into account in the planning phase. It would also be ap-

propriate that new roads be built only as a result of an effective and proven necessity. This would avoid creating works that in the end are not economically affordable, may pose a hydrogeological risk, and are also incompatible with the conservation of biodiversity. To this end, it is essential to preserve large areas with an intact and unfragmented habitat, especially in Europe characterized by a human-dominated landscape (SELVA *et al.*, 2011).

At present, in order to reduce the impact it would be necessary to identify roads in which to regulate or prohibit road access completely or in certain periods of the year, such as the breeding season when even a very small number of cars can be deleterious (KUHN, 1984). More caution should be taken in the issuing of transit permits and the relative concessions should be made only when truly necessary. Therefore, the asphalting of Alpine roads should be limited, since from both the legislative and practical point of view it is much more difficult to prohibit or limit motorized vehicle traffic. Instead, areas in which to ban the construction of roads should be identified as soon as possible. Finally, it would be very appropriate to inform the public about the problem, and drivers should be made aware of proper driving behaviour, which also excludes the possibility of deliberately choosing to kill an animal.

For implementation of what has just been reported, the duty of legislators is to duly consider the natural dynamics, that of public authorities to tackle the question from a purely technical point of view and that of the community to make an effort to be sensitive to the needs of wildlife.

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