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MORTALITY OF AMPHIBIANS ON THE ROADS OF LVIV REGION (UKRAINE): TREND FOR THE LAST DECADE

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Mortality of Amphibians on the Roads of Lviv Region (Ukraine): Trend for the Last Decade. Reshetylo, O., Stakh, V., Osiyeva, A.-A., Dykyy, I., Andriyishyn, B., Panchuk, M., Tsaryk, I. — 69 road sections with amphibian mortality known from 2006 in Lviv Region (Western Ukraine) were repeatedly surveyed in 2017. 2078 dead individuals of nine amphibian species were detected and identified on the road surface (*Triturus cristatus*, *Bombina bombina*, *Pelobates fuscus*, *Bufo bufo*, *Hyla orientalis*, *Rana temporaria*, *Rana arvalis*, *Pelophylax ridibundus* and *Pelophylax esculentus*). The most numerous victims appeared to be *B. bufo* (72.8 %) and *R. temporaria* (22.6 %) which is almost the same as in 2006 (90.5 % together). However, the qualitative and quantitative composition has decreased in a decade (compare 3555 individuals of 13 amphibian species in 2006). As we suppose, the main reasons for amphibian population decline in the region are contamination, degradation and disappearance of the breeding ponds as well as the increased traffic intensity. According to the estimation of our research four *B. bufo* populations are under the excessive influence of roads and transportation, and need to be protected. One of these road sections was fenced up by temporary amphibian fences during the breeding migration (April 2018). Amphibian mortality on the fenced road section dropped down instantly: over thousand individuals of *B. bufo* and *R. temporaria* were caught alive into the bucket-traps and safely moved across the road.
Key words: roads, landscape fragmentation, amphibians, migrations, mortality, protection.

Introduction

Automobile main roads are one of the widespread artificial barriers in the environment. They fragment it and isolate some sites. This leads not only to the habitat degradation, but to the significant road mortality of animals during their migrations. It causes also the decrease of animal population number (e. g., Forman, Alexander, 1998; Seiler, 2001; Dodd et al., 2003; Zagorodniuk, 2006; Andrews et al., 2008; Smirnov, Skilskyi, 2010; Carvalho, Mira, 2011; Jakes et al., 2018; Seidler et al., 2018). The analysis of wide spectrum of literature combined with our own professional experience point out the obvious negative influence of transportation infrastructure on amphibian populations (e. g., Langton, 1989; Ashley, Robinson, 1996; Cooke, Sparks, 2004; Mazerolle, 2008; Reshetylo, Mykitchak, 2008; Elżanowski et al., 2009; Reshetylo, Briggs, 2010; Reshetylo, 2011; Brzeziński et al., 2012; Osiyeva et al., 2017). They are very sensitive to this kind of impact because of their biotic peculiarities and come to 70–88 % of all the road victims among terrestrial vertebrates (Puky, 2003; Glista et al.,

2008). Annual mass migrations are typical only for amphibians in contrast to the rest of terrestrial vertebrates. The distance of these migrations between breeding, feeding and hibernating sites usually is longer than the size of landscape patches fragmented by the roads. Inevitable conflict between amphibians and road transportation complicates their life cycle and negatively impact their population stability (Blaustein et al., 1994; Carr, Fahrig, 2001; Gibbs, Shriver, 2005; Novitskiy, 2005; Stakh et al., 2017). Such a conflict complicates not only the biotic program realization for amphibian species, but traffic safety as well (e. g., Reh, Seitz, 1990; Vnukova, 2011; Lytvynenko, 2013).

There are not enough empirical data of road amphibian mortality in Ukraine nowadays. So, we have full confidence of the urgency and necessity of this type of the research in this country, because huge amount of amphibians are killed by vehicular traffic every year, and the scale of this process is growing rapidly (e.g., Reshetylo, Mykitchak, 2008; Reshetylo, Dykyy, 2011; Krasun, Reshetylo, 2016). It will give us the knowledge of modern status of amphibian communities and dynamic processes which take place in their populations (Reshetylo, Stakh, 2018). It is important also to propose some mitigation measures to protect amphibians as a vulnerable component of the ecosystem.

The evaluation of modern level and character of roads impact on the condition of amphibian populations, its comparison with 2006 data (Reshetylo, Mykitchak, 2008) and the proposition of reasonable mitigation measures on the main roads of Lviv Region are the goals of this work.

Material and methods

The research of amphibian road mortality was realized on the main roads of Lviv Region (M06, M09, M10, M11, H02, H09, H13, P15, T1412, T1413, T1420, T1423, T1425) during the activity season of amphibians (March–November) in 2017. Total length of the investigated routes made up 1250 km (fig. 1). Amphibian mortality data were collected uniformly three times per season during the periods of their high migration activity. We did it evenly on 69 research road sections which were the same as in 2006 to compare them after (fig. 2). All the crushed individuals were removed from the road surface immediately after the identification to avoid the repeated count.

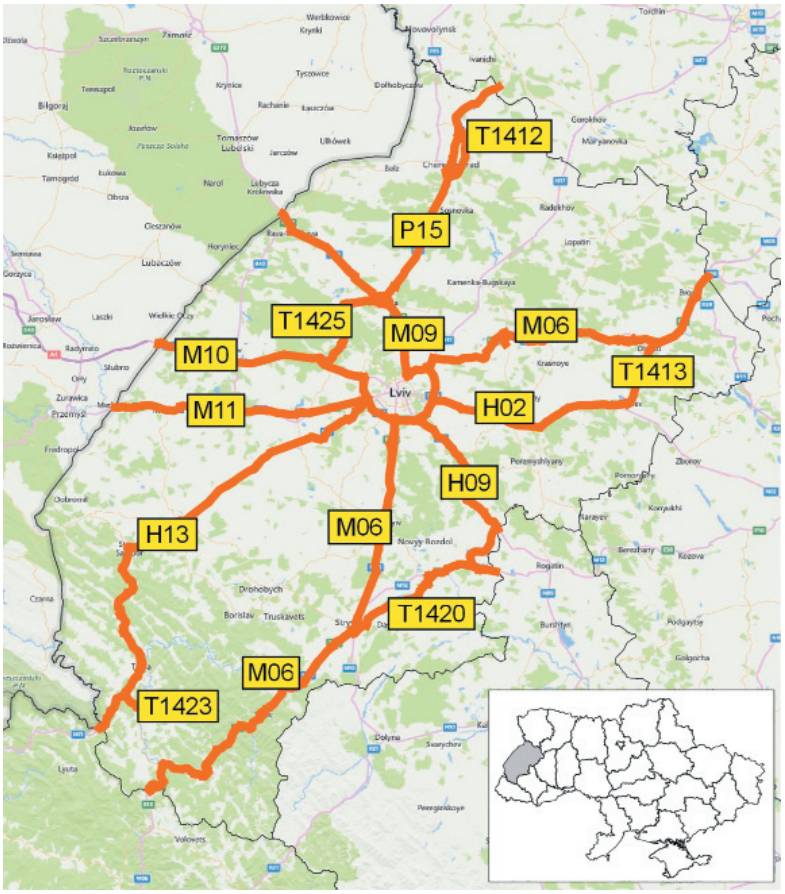

Fig. 1. Investigated roads of Lviv Region.

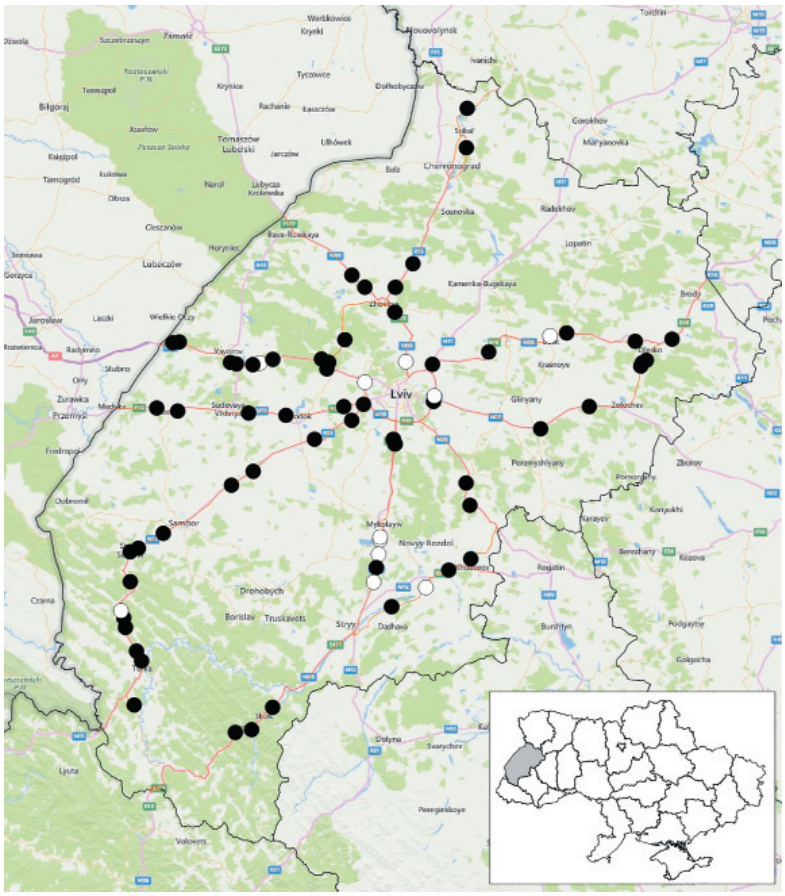

Fig. 2. Surveyed road sections of Lviv Region (open circles indicate sections with no amphibian mortality).

For the realization of the research tasks both common herpetological methods (Heyer et al., 1994; Berninghausen, 1995; Pysanets, 2007) and specific methods were used; they are as follows, the registration of amphibians from the vehicle on the road transects (Sutherland et al., 2010), localization of the breeding ponds using breeding choruses (Fahrig et al., 1995), estimating the population number of amphibians by the regression method (Vogel, Puky, 1995). Besides, typical sex ratios for the different amphibian species and female fecundity (Juszczyk, 1987), the generalized rates of natural mortality at different life stages (Van Gelder, 1973; Vonesh, De la Cruz, 2002) were taken into account as well. This was to be used for the estimation of actual population number relative to road mortality and its critical level for every species of the research.

The main research criteria taken into account on every surveyed road section are (Reshetylo, Mykitchak, 2007, 2008): a) qualitative and quantitative composition of crushed amphibians, b) traffic intensity within the road section, c) availability of amphibian breeding ponds and distance to the nearest of them from the road section, d) population number.

Traffic intensity was estimated by the direct vehicle count per time unit followed by recalculation into 24-hour intensity (Hels, Buchwald, 2001).

Scientific names of mentioned species of amphibians are given according to AmphibiaWeb. 2018 (https://amphibiaweb.org).

Results and discussion

We recorded amphibian mortality in 58 sites and did not found any dead amphibians in 11 sites on the investigated roads of Lviv Region (fig. 2). 2078 individuals of 9 amphibian species identified were found crushed on the road surface along the activity season of 2017. The Common Toad and the Common Frog prevailed greatly among the victims (95 %, table 1). Total dominance of these amphibian species as road victims confirms the fact of

Table 1. Species composition and number of amphibians crushed on the surveyed roads of Lviv Region

	Species	2006		2017	
		Number, ind.	%	Number, ind.	%
1	*Lissotriton vulgaris* (Linnaeus, 1758)	50	1.41	–	–
2	*Lissotriton montandoni* (Boulenger, 1880)	1	0.03	–	–
3	*Triturus cristatus* (Laurenti, 1768)	65	1.83	8	0.38
4	*Bombina bombina* (Linnaeus, 1761)	12	0.34	9	0.43
5	*Bombina variegata* (Linnaeus, 1758)	29	0.82	–	–
6	*Pelobates fuscus* (Laurenti, 1768)	46	1.29	16	0.77
7	*Bufo bufo* (Linnaeus, 1758)	2131	59.94	1513	72.81
8	*Bufotes viridis* (Laurenti, 1768)	2	0.06	–	–
9	*Hyla orientalis* Bedriaga, 1890	15	0.42	2	0,10
10	*Rana temporaria* Linnaeus, 1758	1085	30.52	470	22.62
11	*Rana arvalis* Nilsson, 1842	8	0.22	2	0.10
12	*Pelophylax ridibundus* (Pallas, 1771)	86	2.42	18	0.87
13	*Pelophylax esculentus* (Linnaeus, 1758)	25	0.70	40	1.92
Total		3555	100	2078	100

their abundance. Being the most numerous and distributed species in amphibian communities in the region the Common Toad and the Common Frog have shown the similar result obtained on the same road sections in 2006 (Reshetylo, Mykitchak, 2008). The mentioned species occur in almost each sample site and their mortality rate is one of the highest compared to the rest of amphibian species.

We can declare the decrease of both qualitative and quantitative compositions of dead amphibians on the road sections comparing 2006 and 2017 survey results. Among the negative environmental factors which permanently impact amphibian populations and can be concerned with their decline are, e. g. disappearance of breeding sites, habitat transformation, water contamination etc. The only species that has shown an increase in road mortality is the Edible Frog (*Pelophylax esculentus*), which at the same time has become more common and numerous in the amphibian communities since then (Reshetylo, Stakh, 2018). It is important to notice also the absolute lack of *Lissotriton vulgaris* and *Bombina variegata* among the road victims in 2017, while they were rather abundant and numerous the decade ago (table 1). In 2017 we dip-netted some larvae of the species and heard the choruses of *Bombina variegata* in the several ponds only. Probably, such a

Table 2. Traffic intensity on the surveyed road sections

Road number	Average per season, vehicles/day		Average by road category, vehicles/day	
	2006	2017	2006	2017
M06	7786	14 003	7300	10713
M09	6537	12 199		
M10	5451	9315		
M11	9425	7336		
H02	7158	4792	4033	6624
H09	1975	13 332		
H13	2796	3751		
P15	4201	4619		
T1412	1294	785	908	929
T1413	771	1014		
T1420	996	1551		
T1423	1020	552		
T1425	460	744		

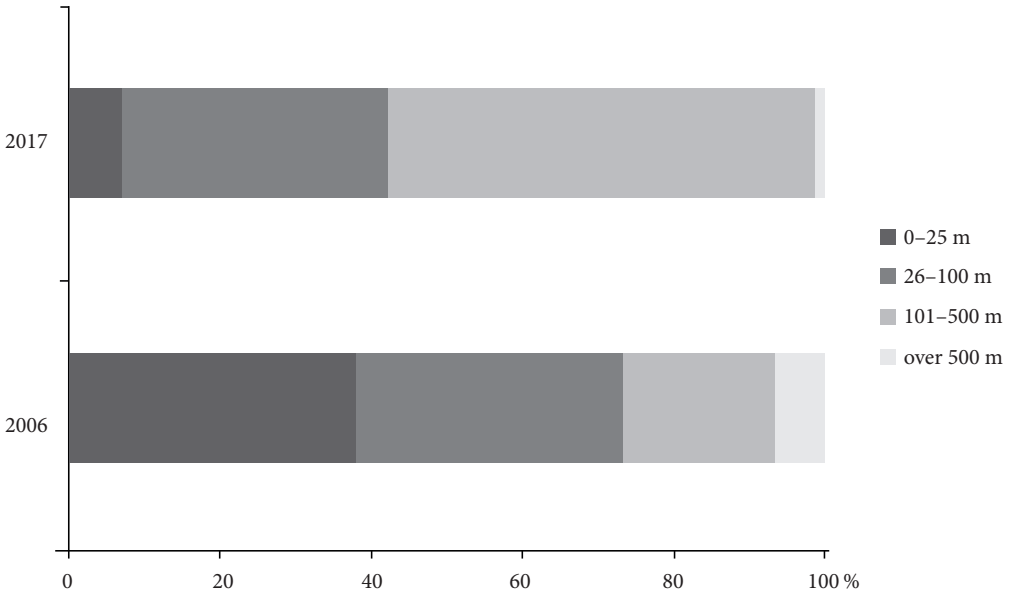

Fig. 3. The distribution of amphibian mortality (%) based on the distance between their breeding habitat and the nearest road section.

decrease might be caused by landscape transformation, breeding pond succession, population structure dynamics and traffic intensity. By the way, the latter factor has increased considerably for the last decade (table 2). It affects individual mortality and results in amphibian population decline. According to our results the traffic intensity has exceeded 10 thousand vehicles per day on average what makes 47 % increase for the most busy roads of Lviv Region (M category: roads of international importance). The similar tendency is obvious also for the roads of national and regional importance (H and P categories): the average traffic intensity has increased for 64 %. The only local roads (T category) haven't shown any significant change in the traffic intensity over the last decade. Nevertheless, it has not secured the same mortality level (i. e. population number): it dropped for 12 % in total and for 23 % per one road section on average. It seems that in spite of the same level of traffic intensity the amphibian populations have become less numerous. We analyzed the correlation between pond-road distance and amphibian mortality in support (fig. 3). Previously we found out that short distance between the breeding pond and the nearest road section impacts amphibians considerably (Reshetylo, Mykitchak, 2007, 2008). As a result the part of the most frequent road-kills (0–25 m pond-road distance category) has decreased greatly since 2006, while 101–500 m category has increased accordingly for the same time. This is due to severe decline of amphibian populations located close to the road as we can assume. Supporting this assumption the considerable degradation of the breeding ponds nearest to the road compared to their condition in 2006 was noticed during 2017 survey (fig. 4).

Using the algorithm of road impact level estimation for the amphibian populations (Reshetylo, Mykitchak, 2008) the analyzed data were distributed into three impact groups: low, middle and high (fig. 5). The obtained distribution shows that the part of high influence road sections decreased significantly compare to 2006 and makes up only 2 %; middle and low impact sections are almost equal and come to 51 and 47 %, accordingly. In 2006 we had 10 % of high influence road sections, 56 % of middle ones, and 34 % — low. In spite of this, such a positive tendency is not the evidence of population recover. Quite the contrary it confirms the habitat loss and the decrease of population number. Hence, they lead to the reduction of amphibian road-kills due to their population expiration.

Fig. 4. The example of degradation of amphibian breeding pond (Strilkovychi village; 49.497690 23.141543).

We believe that the obtained results are important for the development of regional conservation programs, particularly for the efficient protection of amphibian populations. Amphibian fences along the roads are usually used for that purpose as mitigation measures. There are temporary and permanent types of amphibian fences of different design. Both of them stop amphibians crossing the road freely.

Permanent concrete fences and tunnels when installed alternately direct amphibians and allow them cross the road safely every way any time. Bucket-traps as the integral part of temporary plastic fences must be dug in along. They serve for collecting amphibians alive when trying to cross the road. The traps have to be checked twice per day and all the amphibians found in them have to be carried across the road and released. Such an approach ensures zero-level road mortality which supports the population and let amphibians complete the migration successfully.

Involving volunteers into the action is very important, especially during amphibian mass migrations in spring. This is to achieve several significant goals. First goal is the scientific data collection support. The next one is the amphibian fences installation help. And the last, but not the least aspect of such cooperation is eco-educational/ nature conservative goal, especially when school children and university students are involved.

Thus, on the basis of estimation of amphibian relative mortality in the region we found out four *B. bufo* populations under the excessive influence of roads and transportation. One of these endangered road sections is located on the southern limit of Roztochia Nature Reserve; 49.9138350 23.759594 (fig. 5, red spot on the 2017 map). It was the only one in 2017 under the high road influence and was selected for the implementation of mitigation mea-

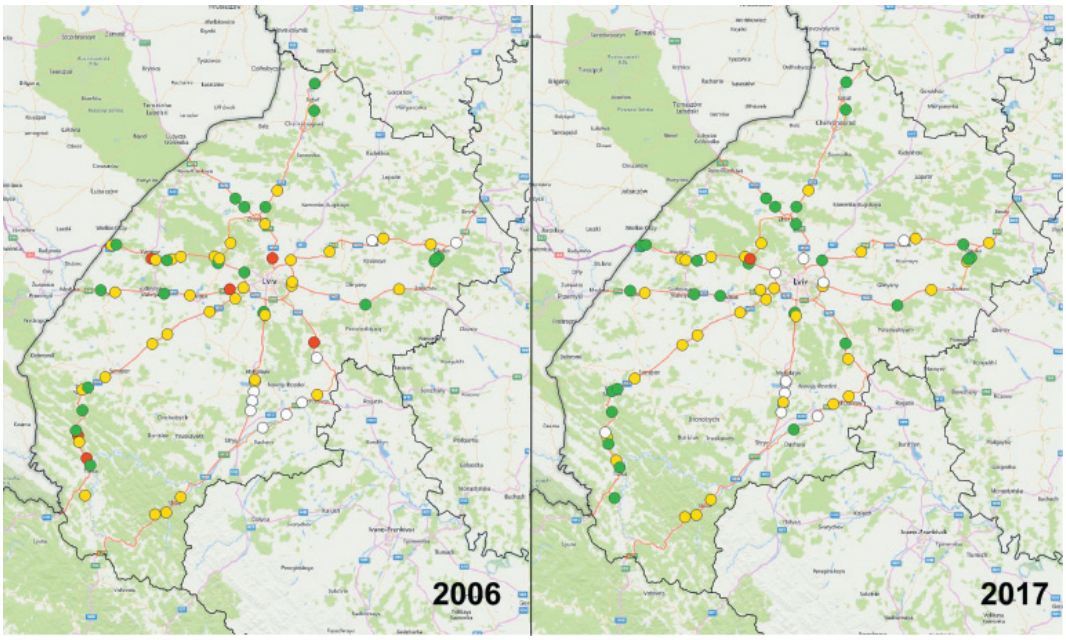

Fig. 5. The distribution of investigated sites under the traffic influence on amphibians on the surveyed roads of Lviv Region (green circle — low level impact, yellow — middle, red — high, white — no amphibian mortality).

sures. 200 m section of this road (T1425) was fenced up by temporary amphibian fences during the amphibian breeding migration in April 2018 (fig. 6). Amphibian mortality on the fenced road section dropped down instantly: over thousand individuals of *B. bufo* and *R. temporaria* were caught alive into the bucket-traps and safely moved across the road by schoolchildren of Ivano-Frankove (Yavoriv District of Lviv Region) and other volunteers engaged to that work.

Fig. 6. Amphibian fences with bucket-traps along T1425 road section in Roztochia Nature Reserve (April, 2018).

Conclusions

Mortality of nine amphibian species on the roads of Lviv Region (2078 individuals) was estimated during the season of 2017. Quantitative and qualitative composition of the victims is compared to the same research in 2006 (3555 ind. of 13 species). The part of rare, ecologically demanding and low number species has decreased considerably (*Lissotriton montandoni, L. vulgaris, Triturus cristatus, Bombina bombina, Pelobates fuscus, Hyla orientalis* etc.), while the proportion of ecologically undemanding and high number species has increased (*Bufo bufo, Pelophylax esculentus* etc.). So, the Common Toad and the Common Frog are still prevailing in the amphibian communities. It is confirmed by the total number and abundance of their road-kills (95 and 93 %, accordingly). We suggest that such a decreasing trend is tightly connected to the decrease of amphibian populations, first of all because of their habitat decline due to the local anthropogenic activity. Besides, the continuous increase in traffic intensity, unfavourable climatic changes, and amphibian habitats decline (breeding ponds mainly) can lead to the exhaustion of species composition of amphibian communities and their structure simplification. We believe that qualitative and quantitative composition of crushed amphibians on the road surface is the most sensitive and time-saving indicator of amphibian community status. It reflects the changes in community structure instantly.

The estimated index of population relative mortality for the investigated road sections has shown its critical level for four *B. bufo* populations. According to our results the populations have to be protected and monitored after to witness the positive effect of mitigation measures applied. The pilot amphibian fences installed on T1425 road section in Roztochia Nature Reserve have proved their efficiency in amphibian conservation as road mortality of amphibians decreased instantly.

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References

Andrews, K. M., Gibbons, J. W., Jochimsen, D. M. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. *In*: Mitchell, J. C., Jung Brown, R. E., Bartholomew, B., eds. *Urban herpetology*. Society for the Study of Amphibians and Reptiles, Salt Lake City, 121–143.

Ashley, P. E., Robinson, J. T. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. *Canadian Field-Naturalist*, **110**, 403–412.

Berninghausen, F. 1995. *Amphibienführer mit Feldbestimmungsschlüssel für die Larven*. NABU-Landesverband Niedersachsen, Hannover, 1–39.

Blaustein, A. R., Wake, D. B., Sousa, W. P. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology*, **8**, 60–71.

Brzeziński, M., Eliava, G., Żmihorski, M. 2012. Road mortality of pond-breeding amphibians during spring migrations in the Mazurian Lakeland, NE Poland. *European Journal of Wildlife Research*, **58**, 685–693.

Carr, L. W., Fahrig, L. 2001. Effect of road traffic on two amphibian species of differing vagility. *Conservation Biology*, **15**. 1071–1078.

Carvalho, F., Mira, A. 2011. Comparing annual vertebrate road kills over two time periods, 9 years apart: a case study in Mediterranean farmland. *European Journal of Wildlife Research*, **57**, 157–174.

Cooke, A. S., Sparks, T. H. 2004. Population declines of Common Toads (*Bufo bufo*): the contribution of road traffic and monitoring value of casualty counts. *Herpetological Bulletin*, **88**, 13–26.

Dodd, N. L., Gagnon, J. W., Schweinsburg, R. E. 2003. Evaluation of measures to minimize wildlife-vehicle collisions and maintain wildlife permeability across highways in Arizona, USA. *In*: Irwin, C. L., Garet, P., McDermott, K. P., eds. *Proceedings of the International Conference on Ecology and Transportation "Animal-vehicle collision reduction"*. Center for Transportation and the Environment, North Carolina University, Raleigh, NC, 353–354.

Elżanowski, A., Ciesiołkiewicz, J., Kaczor, M., Radwańska, J., Urban, R. 2009. Amphibian road mortality in Europe: a meta-analysis with new data from Poland. *European Journal of Wildlife Research*, **55**, 33–43.

Fahrig, L., Pedlar, J. H., Pope, Sh. E., Taylor, P. D., Wegner, J. F. 1995. Effect of road traffic on amphibian density. *Biological Conservation,* **73**, 177–182.

Forman, R. T., Alexander, L. E. 1998. Roads and their major ecological effects. *Annual review of ecology and systematics*, **29**, 207–231.

Gibbs, J. P., Shriver, W. G. 2005. Can road mortality limit populations of pool-breeding amphibians? *Wetlands Ecology and Management*, **13**, 281–289.

Glista, D. J., De Vault, T. L., De Woody, J. A. 2008. Vertebrate road mortality predominantly impacts amphibians. *Herpetological Conservation and Biology*, **3**, 77–87.

Hels, T., Buchwald, E. 2001. The effect of road kills on amphibian populations. *Biological Conservation*, **99**, 331–340.

Heyer, W. R., Donnelly, M. A., McDiarmid, R. W., Hayek, L.-A. C., Foster, M. S. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians.* Smithsonian Institution Press, Washington, DC, 1–384.

https://amphibiaweb.org — AmphibiaWeb. University of California, Berkeley, CA, USA. Accessed 12 Nov 2018.

Jakes, A. F., Jones, P. F., Paige, L. C., Seidler, R. G., Huijser, M. P. 2018. A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation*, **227**, 310–318.

Juszczyk, W. 1987. *Płazy i gady krajowe*. Wydawnictwo Naukowe PWN, Warszawa, Vol. 1, 1–240.

Krasun, I. V., Reshetylo, O. S. 2016. Amphibian mortality on the roads in the outskirts of Lviv. *In*: *Abstracts of IV International scientific conference of students, post-graduate students and young scientists "Fundamental and applied research in biology and ecology"*. DRUK, Vinnytsia, 128–129 [In Ukrainian].

Langton, T. E. S. 1989. Reasons for preventing amphibian mortality on roads. *In:* Langton, T. E. S., ed. *Amphibians and roads*. ACO Polymer Products, Shefford, 75–80.

Lytvynenko, T. P. 2013. Environmental design principles of highways. *Scientific Bulletin of Poltava National Technical University*, **4** (39), 122–131 [In Ukrainian].

Mazerolle, M. J. 2008. Amphibian road mortality in response to nightly variations in traffic intensity. *Herpetologica*, **60**, 45–53.

Novitskiy, R. V. 2005. The assessment of amphibian mortality scale on the roads of Belarus during their spring and autumn migrations. *In*: *Proceedings of the Conference of Ukrainian Herpetological Society*. Kyiv, 122–124 [In Russian].

Osiyeva, A.-A. O., Stakh, V. O., Reshetylo, O. S. 2017. Mortality of amphibians on the roads of Roztochia during their autumn migrations. *In*: *Abstracts of scientific conference "Status and biodiversity of ecosystems of Shatsk National Nature Park and other nature conservative territories"*. Spolom, Lviv, 89–90 [In Ukrainian].

Puky, M. 2003. Amphibian mitigation measures in Central Europe. *In:* Irwin, C. L., Garret, P., McDermott, K. P., eds. *Proceedings of the International Conference on Ecology and Transportation "Animal-vehicle collision reduction"*. Center for Transportation and the Environment, North Carolina University, Raleigh, NC, 413–429.

Pysanets, Ye. M. 2007. *Amphibians of Ukraine (guidebook for the determination of amphibians of Ukraine and neighbor countries)*. Rayevsky Publishing House, Kyiv, 1–192 [In Ukrainian].

Reh, W., Seitz, A. 1990. The Influence of Land Use on the Genetic Structure of the Common Frog *Rana temporaria*. *Biological Conservation*, 1990, **54** (3), 239–249.

Reshetylo, O. 2011. Estimation of railroad hydrotechnical system influence precast concrete perforated drainage troughts on amphibians and the mitigation measures. *In*: Zamachowski, W., ed. *Biologia płazów i gadów: ochrona herpetofauny*. Wydawnictwo Naukowe Uniwersytetu Pedagogicznego, Kraków, 97–107.

Reshetylo, O., Briggs, L. 2010. Diversity of amphibians in the places of road and rail investments in Poland. *In*: *Materiały z X Ogólnopolskiej Konferencji Herpetologicznej*. Uniwersytet Pedagogiczny, Kraków, 103–109.

Reshetylo, O., Dykyy, I. 2011. Records of the Natterjack Toad (*Bufo calamita* Laur., 1768) on the roads within Shatsk National Nature Park. *In*: *Proceedings of the scientific conference "Status and biodiversity of ecosystems of Shatsk National Nature Park".* Spolom, Lviv, 29–30 [In Ukrainian].

Reshetylo, O. S., Mykitchak, T. I. 2007. The evaluation criteria of road impact on amphibian mortality. *In: Proceedings of the scientific conferences "Modern problems of nature conservation activity" and "Biodiversity threat factors: their indication and threat minimization"*. Spolom, Lviv, 31–33 [In Ukrainian].

Reshetylo, O. S., Mykitchak, T. I. 2008. Road Mortality of Amphibians (Amphibia) in Lviv Region: Problem Status and Estimating Criteria. *Vestnik Zoologii*, **42** (4), 315–323 [In Ukrainian].

Reshetylo, O., Stakh, V. 2018. Amphibian mortality on the roads as index of batrachocoenoses status (on the example of mountain roads of Lviv province). *In*: *Proceedings of the All-Ukrainian Scientific Conference "Significance and prospects of stationary research for studying and conservation of biodiversity" devoted to the 60th anniversary of Kostyantyn Malynovsky High-Mountain Pozhyzhevska Biological Station.* ATB, Lviv, 97–99 [In Ukrainian].

Seidler, R. G., Green, D. S., Beckmann, J. P. 2018. Highways, crossing structures and risk: Behaviors of Greater Yellowstone pronghorn elucidate efficacy of road mitigation. *Global Ecology and Conservation*, **15**, e00416.

Seiler, A. 2001. Ecological effects of roads: a review. *Introductory Research Essay*, **9**, 1–40.

Smirnov, N. A., Skilskyi, I. V. 2010. Mortality of terrestrial vertebrates on the model road section in lowland part of Bukovyna. *In*: *Abstracts of International Scientific Conference "Animal research and protection problems in natural and anthropogenic ecosystems"*. DrukArt, Chernivtsi, 116–118 [In Ukrainian].

Stakh, V., Reshetylo, O., Andriyishyn, B., Dykyy, I., Osiyeva, A.-A. 2017. *Amphibians' road mortality: causes, modern status of the problem and its solutions*. Kolo, Drohobych, 1–24 [In Ukrainian].

Sutherland, R. W., Dunning, P. R., Baker, W. M. 2010. Amphibian encounter rates on roads with different amounts of traffic and urbanization. *Conservation Biology*, **24**, 1626–1635.

van Gelder, J. J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo bufo* L. *Oecologia*, **13**, 93–95.

Vnukova, N. V. 2011. Highway influence on the eco-safety of "car-road-environment" system. *East-European journal of advanced technologies*, **5/3** (53), 43–36 [In Ukrainian].

Vogel, Z., Puky, M. 1995. A fast environmental impact assessment method for the evaluation of road construction effects on amphibian communities. *In*: Llorente, G. A., Montori, A., Santos, X. and Carretero, M. A., eds. *Scientia Herpetologica*, Barcelona, 349–351.

Vonesh, J. R., De la Cruz, O. 2002. Complex life cycles and density dependence: assessing the contribution of egg mortality to amphibian declines. *Oecologia*, **133**, 325–333.

Zagorodniuk, I. 2006. Animal mortality on roads: assessment of vehicle traffic influence on the populations of wild and domestic animals. *In*: Zagorodniuk, I., ed. *Proceedings of the 8th Theriological School "Fauna in the anthropogenic environment"*. Luhansk, 120–125 [In Ukrainian].

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