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REDUCING THE INCIDENCE OF MAMMALS ON PUBLIC HIGHWAYS USING CHEMICAL REPELLENT

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Abstract. In Lithuania, one of the measures to reduce the number of wildlife-vehicle accidents (WVA) is the fencing of highways. However, any gaps in the fencing have the potential to become an animal crossing site and consequently are likely to lead to increased WVA. Attempting to reduce the number of animals venturing onto roads, trials with the chemical repellent Wam Porocol® were conducted. This was the first such investigation in Lithuania. The effectiveness of Wam Porocol® was investigated over a six-month period in five gaps in the fencing, with five parallel control places without repellent also checked. In total, 11 mammal species (nine wild and two domestic) were registered, the most frequent of which were roe deer (32 cases), red foxes (18), raccoon dogs (16), red deer and martens (14 of each), plus domestic dogs (13 cases). Hoofed animals accounted for 42.1% of the total, with wild and domestic carnivores totalling 57%. It was found that, on average, every gap in the fencing allows the passage of 300–400 mammals onto the highway annually. Applying repellent, these numbers were reduced to 170–240 animals annually. Thus, the repellent Wam Porocol® reduced the number of mammals venturing onto highways by 42%. The daily average of gap-crossing mammal numbers was significantly lower ($p < 0.025$) using repellent than in control places.

Keywords: mammals, repellent, Wam Porocol®, wildlife-vehicle accidents (WVA).

1. Introduction

Animal-vehicle collisions are a common phenomenon worldwide, causing injury or death to millions of animals and hundreds of human passengers each year. Earlier, each year about one million vertebrate animals were killed on the roads of North America (Forman, Alexander 1998). Up to 1995, about 200 human fatalities were registered yearly in the USA with costs of over one billion dollars, and these figures are not declining significantly (Litvaitis, Tash 2008).

In Europe, the number of wildlife-vehicle accidents (WVA) with ungulates was estimated at about 500 000 per year, with 300 human fatalities and over 30 000 human injuries, along with over one billion dollars of damage (Groot Bruinderink, Hazebroek 1996).

The numbers of WVA have been increasing in the last decade in America (Knapp 2004) and in Europe (Balčiauskas 2009; Pokorny 2006). For example, recent number of WVA in America, involving deer is estimated at about 1.5 mln per year (Sullivan, Mesmer 2003).

According to *Lithuanian Road Administration under the Ministry of Transport and Communications in Lithuania* there are 1738.5 km of main roads and 4946.5 km of national roads. From these, 484.3 km of main roads are fenced, plus 14 wildlife underpasses have been built and are functioning. The numbers of WVA in Lithuania have been registered since 2002 and show an increasing trend of occurrence (official data show an increase from 259 in 2002 to 499 in 2005 and 978 in 2008 (Balčiauskas, Balčiauskienė 2008; Balčiauskas 2009).

To reduce the WVA number, various countries have tried different strategies the most frequent including management of roadside habitats, vegetation removal, warning signs, interactive warning signs, speed limitation, roadside fencing, underground passages and culverts for wildlife crossing, as well as green bridges and viaducts over the highways. Other means include road lighting, beam reflectors, deer whistles, ultrasound, noise barriers and olfactory repellents (Knapp 2004; Magnus 2006; Putman *et al.* 2004; Rea 2003).

Roadside fencing with mesh is recognized as the most effective WVA prevention measure (Knapp 2004). The effectiveness of fencing has been assessed as leading to reductions in WVA from 20% (Clevenger *et al.* 2001) and, according *North Jersey Transportation Planning Authority*, up to 60–97%. In British Columbia, over 450 km of fencing has been installed and at those locations animal-vehicle collisions have declined significantly. In some cases,

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they have been eliminated (Sielecki 2001). In France, for instance, fencing is required on all federal highways. Fencing is the main technique used in France, Germany, Slovenia and the Netherlands. Fencing must be accompanied by animal crossing structures to provide connectivity for populations.

Highway fencing has been used in Lithuania since 2003. Over 170 km of fences were installed in 2008, over 130 km in 2009 and over 169 km more is planned for 2010. The greatest lengths of roadside fencing are along the highways A1 Vilnius–Kaunas–Klaipėda, A2 Vilnius–Panevėžys, A16 Vilnius–Prienai–Marijampolė, A11 Šiauliai–Palanga, A6 Kaunas–Zarasai–Daugpilis, and along the national road No. 102 Vilnius–Švenčionys–Zarasai. Gaps in the fenced sections arise due to byroads, gates, fence breaks caused by fallen trees and branches and, recently, due to fence theft. Gaps make fencing senseless. As fence repair takes time, one of the simplest measures to keep mammals away form the gaps could be chemical repellents.

Chemical as well as other repellents for scaring mammals away from the highways were never employed in Lithuania. Chemical repellents for ungulates were used in the forestry and for protection of valuable tree saplings only.

2. Repellents used to control mammals

Repellent use is based on the importance of the olfactory sense to mammals. Olfactory repellents involve odorous chemical or organic compound applications along roadways to act as deterrents to wildlife. Their testing started several decades ago (Fraser, Hristienko 1982). Repellents were listed as a measure for reducing WVA numbers also in later publications (Groot Bruinderink, Hazebroek 1996; Lavsund, Sandegren 1991; Pokorny 2006; Sielecki 2001), though these publications all lacked numerical assessment of repellent effectiveness.

The mechanism of repellent action relies on a change of wildlife behaviour. Animals are stopped at the roadside, either taking time to pass the repellent or, in the best case scenario, the odour deterring them entering and crossing the road. If the odour is strong, the repellent can be useful as a short-term prevention measure (Magnus 2006). This was the conclusion of investigation – animals should be deterred from entering gaps until the fence is repaired.

The effectiveness of repellents remains unclear as several authors consider them ineffective measures (Knapp 2004). Hedlund and co-authors, for example, categorized reflectors, roadside lighting, intercept feeding and repellents as methods with limited demonstrated effectiveness (Hedlund *et al.* 2003). Again, no strong evidence for the effects of permanent warning signs, light mirrors, scent or acoustic fencing on the number of kills per crossing was mentioned for studies in Europe (Groot Bruinderink, Hazebroek 1996).

Still, as it was reported by *US Dept of Transportation*, testing of olfactory repellents for mammals continued. Repellents containing mixed scent (human, predator and other unpleasant odours) were tested in Europe – the aim was to raise animal awareness or keep them away from roads. Repellents were sprayed along roadsides as long-lasting foam. First results were promising.

Tests have been conducted on olfactory and chemical repellents, including capsaicinoids, animal odours and animal products, garlic, particulates, soaps, thiram, bittering agents, natural predator excretions and putrescent egg. The last two have shown most promise for keeping ungulates away from roadways, but they have not been adequately tested (Knapp 2005; Putman *et al.* 2004) or have been referred to as "somewhat effective" (Putman *et al.* 2004 , Trocmé *et al.* 2003). In the case of positive results, usage was referred to as not practical because of the need to repeat applications (Trocmé *et al.* 2003), especially after rain or other precipitation (Farrell *et al.* 2002). Thus, the usage of repellents is still regarded as experimental (Knapp 2005)

The future development of olfactory repellent measures requires further study of wildlife behavioural responses in a range of species and for the potential for animal habituation (Knapp 2005).

3. Material and methods

Investigations were carried out at ten sites between April and October 2009. Four sites were located along the highway A1 Vilnius–Kaunas and six on the highway A2 Vilnius–Panevėžys (Fig. 1). Sites were selected with respect to surrounding habitat (forests and meadows, details in the Table 1) to ensure an equal possibility of passage. On the other hand, number of gaps in the highway fence is limited, hence, the control and treatment sites were chosen trying to fit into nearest 100 km from Vilnius depending on finances available for investigation. On random base, these sites were divided between control sites (no repellent) and treated sites (with repellent) (Table 1). One to two repellent columns were used per site. Sites were checked 12 times.

The authors of this article used Wam Porocol® synthetic active odour substance in durable plastic evaporator columns, recommended for use on roads with high levels of game passage. According to the *Catalogue of*

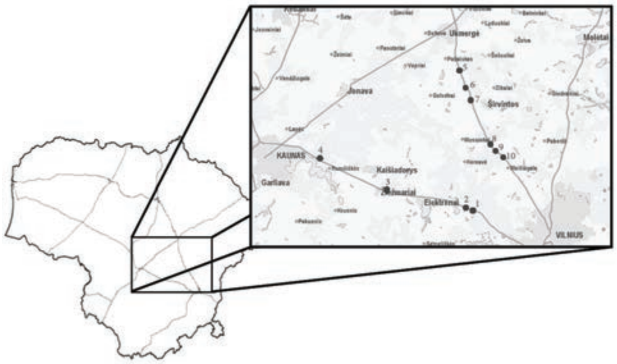

Fig. 1. Placement of investigation sites. Site numbers correspond to Table 1

Table 1. Characteristic of investigation sites. Site numbers correspond to Fig. 1

Site No.	Placement	Habitat	Gap width, m	Category	No. of columns
1	A1, 33.1 km, 55°45′21.7″ N, 24°53′23.1″ E	F/M	5	C	
2	A1, 34.6 km, 54°45′35.4″ N, 24°51′57.4″ E	F/M	5	T	1
3	A1, 60.7 km, 54°48′31.5″ N, 24°28′32.1″ E	F/A	3	T	1–2
4	A1, 86.1 km, 54°54′24.6″ N, 24°07′08.3″ E	F/F	12	C	
5	A2, 59.1 km, 55°07′58.4″ N, 24°50′03.6″ E	M/M	4	T	2
6	A2, 53.4 km, 55°05′11.3″ N, 24°52′05.4″ E	M/A	4	C	
7	A2, 49.8 km, 55°03′24.9″ N, 24°53′26.1″ E	M/M	4	T	2
8	A2, 34.5 km, 54°55′53.2″ N, 24°59′01.9″ E	M/M	4	C	
9	A2, 33.0 km, 54°55′10.8″ N, 24°59′42.8″ E	M/M	4	T	2
10	A2, 29.6 km, 54°54′05.0″ N, 25°02‘16.2″ E	M/M	4	C	

Note: F – forest; M – meadow; A – agricultural land; C – control; T – treatment.

Chemical Substances (presented in http://chemicaland21.com) main component in the repellent is 3-Methylbutyric acid $(CH_3)_2CHCH_2COOH$) (synonyms – isvaleric acid, isopentanoic acid), CAS No. 503-74-2, EINECS No. 207-975-3. Toxicity for rats LD50 is 2ml/kg (oral), method of assessment OECD 401. Physical state of this branched fatty acid is liquid, soluble in water (25 g/l), soluble in alcohol, and almost organic solvents including ethers. It has a strong pungent sweaty smell. It melts at –29 °C and boils at 176 °C).

Rods with repellent columns were placed in five sites on 4 April 2009. Rods were placed ca 30 m from the highway. In sites No. 2 and No. 3 gaps in the fence were near lush vegetation, thus, one column could be used and placed near the gap. In other sites, two columns were placed at a greater distance. Both columns were placed in-line with the fence, 8–20 m to each other. On 2 June a second column was additionally placed at site No. 3.

Sites were checked every second week. After thorough visual inspection of the gap and surrounding area, all mammal tracks were identified and recorded. Mammals not passing the gaps, with or without repellent columns, were recorded separately and were not included in the evaluation. In Table 2 these cases are marked with asterisk. In three cases columns with repellent were stolen. Mammals that passed through the gaps in such cases are marked with two asterisks and are also excluded from statistics. When these sites were checked, columns were replaced, i.e. max every two weeks.

Putting repellent in the form of columns excluded influence of rain and other negative weather conditions, as vapour-producing part was completely covered. It was also presumed that negative weather impacts were the same in nearest treatment and control sites, thus, results were comparable independently of weather impact.

Data was processed with *Statistica 6.0* software, using average ± standard error (SE), differences were evaluated using Student's *t* for independent samples.

The aim of this research was to assess the effectiveness of Wam Porocol® repellent for the control of mammals passing onto the road through gaps in protective fence.

4. Results

Between April and September 2009, 113 individual mammals were registered, either passing through the gaps onto the highway or walking near the gaps but not crossing through (Table 2). Out of 11 mammal species, nine were wild and two domestic. The most frequent were roe deer (28.1% of all registered mammals), foxes (15.8%), raccoon dogs and martens (each 13.2%) and red deer and domestic dogs (each 12.3%). Number of other animals was much smaller. Badgers come to the highway rarely (1.8%), moose, wild boar, European hare and domestic cats had only single registrations each (0.9%).

Among mammals, 42.1% were ungulates. These animals (moose, red deer, roe deer, wild boar) pose highest threat in WVA because of the large body mass and long legs. In the 14 cases where tracks of red deer were found, only four animals passed through the gaps (two in control sites, the other two in treated sites). Wild and domestic carnivores comprised 57.0% of the total mammal count. Only one brown hare (0.9%) was registered during investigation. The results of gap checking are presented in the Table 2.

It was found that gaps in control sites were used on average (± SE) by 0.95 ± 0.13 individual mammals daily. The total number of registered individuals was from four (sites No. 1, 3) to 20 (site No. 8). Generalizing, every gap allows 347 ± 49 (300–400) individual mammals to enter the highway annually. At site No. 8 the average daily number of mammals reaching the highway was 1.67 ± 0.28, or 606 ± 104 (500–700) per year.

In treated sites the number of mammals registered during investigation varied from 0 (site No. 2) to 13 (site No. 3). On average, the daily number of registered mammals was 0.57 ± 0.10 individuals. Generalizing, every gap with repellent thus allows 207 ± 36 (170–240) individual mammals to reach the highway. Statistically, the average number of mammals reaching the highway at the Wam Porocol® treatment sites was significantly smaller than in control sites (0.57 ± 0.10 and 0.95 ± 0.13 individuals per site, respectively; Student's $t = 2.31$, $df = 118$, $p < 0.025$). Nevertheless, in site No. 3, despite repellent treatment and

Table 2. Gap usage by mammals in control (C) and treatment (T) sites in 2009

Date (no) of checking	Site No.									
	1 (C)	2 (T)	3 (T)	4 (C)	5 (T)	6 (C)	7 (T)	8 (C)	9 (T)	10 (C)
04.17 (1)	–	–	RO, F*	–	2 RO*	RD, F, C	F, RE*	D, F	–	2 RO, F, RD
04.28 (2)	–	–	RO, B, F	–	RO	F	RO, RE	F	RO	RO, RE
05.13 (3)	F, RO	–	D, RO	D, F	–	RO	4 RE**	MO, 2 RO, D	–	RE
06.02 (4)	–	–	RO, F	–	2 RO	2 RO	RE	RO, F	–	D, RO
06.17 (5)	–	**	RO*	D	2 RO*	–	RO*, RE*	M, RE*	RE	F
07.03 (6)	–	**	F	D	F	–	D	RD, M	–	–
07.16 (7)	–	–	–	–	–	–	–	–	–	–
07.22 (8)	–	–	–	–	RD	M, RO	M, D	RO, D	–	M, D
08.05 (9)	M	–	BH	–	–	RD	–	M	–	–
08.21 (10)	RO	–	RD	–	D	RD	RE*	M, F	M, F	RD, M
09.03 (11)	–	M*	RO*, RE*, RD*, F*, B*	–	–	RO	RD	RD, WB*	–	–
09.15 (12)	–	–	RD, RO	–	M, RD	RD	RD	M, RD	M	D

Note: * – animals come to the gap but do not pass it; ** – repellent column was missing for the short time; MO – moose, RE – red deer, RO – roe deer, WB – wild boar, RD – raccoon dog, F – fox, B – badger, M – marten, BH – brown hare, D – dog, C – cat

having the smallest gap width (only 3 m), the average daily number of mammals that passed through the gap was 1.08 ± 0.29, equating to 395 ± 105 (390–500) individuals per year.

Of the mammals that actually passed through the gaps ungulates comprised 32.9%. In the control sites their number was from 0 (site No. 4) to 7 (site No. 10) or on average 0.31 ± 0.08 individuals daily. Generally, the annual number of ungulates passing through each gap to the highway was 113 ± 29 (85–140) animals. The most frequent ungulates passing through gaps in control sites were roe deer (84%). Red deer were less frequent (10%). Moose was registered only once (5% from the total of 19 ungulates). In the treated sites, the number of registered ungulates was from 0 (site No. 2) to 5 (site No. 3), i.e., 0.18 ± 0.05 individuals daily. Generally speaking, the annual number of ungulates passing through gaps with repellent was 66 ± 18 (50–85) individuals. Out of 11 registered animals 81% were roe deer and 19% red deer. Thus, using repellent, the number of ungulates passing through gaps in the fencing onto the highway was reduced by 42%.

In site No. 3, where 13 individual mammals passed through the gap even with the use of repellent (Table 2), the repellent doze was doubled by arranging a second column. When using one column, the average number of mammals passing through the gap was 2.0 ± 0.41 daily, equating to 730 ± 149 per year. After doubling the doze the numbers of passing mammals were reduced to 0.63 ± 0.26 daily, or 230 ± 95 per year. This is a reduction of about three times and it is significant (Student's $t = 2.82$, $df = 10$, $p < 0.01$). Thus, single-column treatment may not guarantee the deterrence of mammals from the gap. Depending on the wind direction the smell may not reach the gap at all. Double-column treatment significantly increased a positive result.

5. Discussion

Results have revealed positive influence of repellent Wam Porocol® keeping in control gaps in the fences on highway sides and reducing number of gap passing mammals by 42%. This could be significant reduction of the roadkills. Official roadkill data, registered by the *Lithuanian Police Traffic Supervision Service* for April–October 2009, show that on the highway A1 between Vilnius and Kaunas 23 wild mammals were killed (3 moose, 2 roe deer, 4 wild boar and in 14 cases species was not identified). On the highway A2 road kill number was 33 wild animals in the same period of 2009 (2 moose, 22 roe deer, 3 wild boar, 1 European hare, 1 red fox and in 4 cases species was not identified).

Safety is considered as one of the primary requirements for the roads in Lithuania (Ratkevičiūtė *et al.* 2007) but none of the authors covered possibilities for reduction of WVA and road kills. So far, the only measures used were fences on the highway sides (Balčiauskas, Balčiauskienė 2008) and underpasses for the wild animals (Balčiauskas, Balčiauskienė 2007). Influence of these measures is significant but diminished by insufficient maintenance of fences and crossing structures (Balčiauskas 2009).

Thus, the study is of significant scientific novelty, as it shows possibility to reduce number of wildlife-vehicle accidents in a relatively simple and cost-effective way. None of scientific estimations were presented in the analysed literature, pointing out just abstract positive effectiveness of chemical repellents (Groot Bruinderink, Hazebroek 1996; Hedlund *et al.* 2003; Knapp 2005; Lavsund,

Table 3. Comparison of Wam Porocol® with other commercial repellents (based on Trent *et al.* 2001)

Product (manufacturer or seller)	Mode	Active ingredient
Detour (Sudbury Consumer Products Co.)	Conditioned avoidance	7% thiram (non-systemic dimethyl dithiocarbamate)
Deerbuster‘s Coyote Urine Sachet (Trident Enterprises)	Fear	50% coyote urine
Wolfin (Pro Cell Bioteknik)	Fear	Di (N-alkyl) sulphides
Deerbuster‘s Deer and Insect Repellent (Trident Enterprises)	Fear	99.3% garlic juice
Deer Away Big Game Repellent Powder (IntAgra, Inc.)	Fear	36% putrescent whole egg solids
Deer Away Big Game Repellent Spray (IntAgra, Inc.)	Fear	4.93% putrescent whole egg solids
Bye Deer (Security Products Co.)	Fear	85% sodium salts of mixed fatty acids
Hinder (Pace International LP)	Fear	0.66% ammonium soaps of higher fatty acids
Plantskydd (Tree World)	Fear	87% edible animal protein (in concentrate)
Deer Stopper (Landscape Plus)	Multiple	3.8% thiram, 0.05% capsaicin, 1.17% egg solids
Plant Pro-Tec (Plant Pro-Tec)	Multiple	10% oil of garlic, 3% capsaicin and related compounds
Dr. T‘s Deer Blocker (Dr. T‘s Nature Products)	Multiple	3.12% putrescent whole eggs, 0.0006% capsaicin, 0.0006% garlic
N.I.M.B.Y (DMX Industries)	Multiple	0.027% capsaicin and capsaicinoid products, 4.3% castor oil
Wam Porocol® (Witasek GmbH)	Fear	3-Methylbutyric acid

Sandegren 1991; Magnus 2006; Pokorny 2006; Putman *et al.* 2004; Sielecki 2001; Trocmé *et al.* 2003).

In Lithuania, this research was the first one which used chemical repellent vapour for scaring mammals from the highways. The used active ingredient was 3-Methylbutyric acid, with low toxicity (2 mg/kg of body mass for rats) in oral exposition, thus, unlikely to be harmful in vapour phase. According to *Agritura and Beikircher Grünland GmbH* for fish the LC50 toxicity is 100–1000 mg/l for 96 h exposition, tested on the goldfish. Biological degradability is over 65, EC0 toxicity to bacteria – over 1000 mg/l.

Comparison of Wam Porocol® with other commercial repellents with fear, conditioned avoidance or multiple mode (Table 3), data from (Trent *et al.* 2001), was done. Fear inducing repellents worked good, especially those with decaying protein and emitting sulphurous odours. The investigation showed much longer life of the Wam Porocol® repellent (up to 16 weeks). None of the other compared repellents eliminated deer longer than 11 weeks in winter and even shorter period in spring (Trent *et al.* 2001).

Results revealed also some practical elements of repellent use (use of double column) targeted to increase effectiveness. Research should be continued by investigating other possibilities of repellent use, for example, long lasting odour granules on the roadsides.

6. Conclusions

Treatment of gaps in highway fencing with the chemical repellent Wam Porocol® reduced mammal penetration by 42% compared to control sites. The average number of mammals passing through the gaps daily was significantly lower, 0.57 ± 0.10 vs. 0.95 ± 0.13 individuals ($p < 0.025$).

On average, 300 to 400 mammals pass through each gap in the fence onto the highway annually in control sites. Treatment with repellent reduces this number to 170–240. About 30% of these animals are ungulates posing the highest threat in wildlife-vehicle accidents.

Despite small gap width, two repellent columns should be used, placed both sides of the gap. Such placement ensures better coverage regardless of wind direction. In investigation, a second column reduced the number of gap-passing mammals by about three times.

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