COST EFFICIENCY OF RABIES ORAL VACCINATION STRATEGIES IMPLEMENTED IN LATVIA FROM 1991 TO 2011

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ABSTRACT
Rabies has been a serious animal and public health threat in Latvia since 19th century. Foxes and raccoon dogs are main rabies virus reservoirs in Latvia since 1963. Oral vaccination of wildlife (ORV) has been recognized as an effective tool to eliminate rabies in several countries in Europe. Despite of the implementation of three different ORV strategies in Latvia since 1991 rabies cases are still detected. The aim of this study was to analyse cost efficiency of ORV strategies implemented in Latvia. The results of our study reveal that only large-scale ORV strategy decreased rabies cases continuously comparing to other strategies and is therefore considered as cost-effective.

KEY WORDS: costs, rabies, red fox, raccoon dog, oral vaccination.

INTRODUCTION
Rabies is the most important viral zoonosis from global perspective (Thulke et al., 2008). Red foxes (*Vulpes vulpes*) were the main rabies virus reservoir in Europe (Anonymous, 2002). Since oral rabies vaccination (ORV) of wildlife was started successfully in Switzerland in 1977 (Wandeler et al., 1988), ORV programs were initiated in Austria, Belgium, Czechoslovakia, East Germany, France, Hungary, Italy, Luxemburg, the Netherlands and Slovenia (Rosatte et al., 2007). As a result of ORV campaigns, that were co-financed by European Union the rabies situation in European countries has greatly improved since 1989 (Müller 2000, Pastoret et al., 2004).

Rabies has been endemic in Latvia since 19th century. Since 1963 rabies cases were mostly observed in wildlife (Westerling et al., 2004). Rabies cases are still detected in Latvia and neighbouring Baltic countries, Russian Federation and Belarus. Red fox is the main reservoir for rabies virus in Latvia. The raccoon dog *(Nyctereutes procyonoides)* is second most affected wildlife species and appears to play an important role in rabies epidemiology in Latvia (Oļševskis et al., 2011). Different ORV strategies were implemented in Latvia following the first ORV campaign whish was initiated in 1991. The cost efficiency of rabies elimination in Latvia has not been analysed so far.

The objective of this study was to analyse and compare cost efficiency of three oral rabies vaccination strategies implemented in Latvia from 1991 to 2011.

MATERIAL AND METHODS
Between 1991 and 2011, three different ORV strategies were implemented by Food and Veterinary Service depending on resources available at the time:

Strategy 1 – patchwork vaccination (1991-1997). Vaccine baits were manually distributed, with an average bait density of 3,24 baits/km^2, only in regions with the highest rabies incidence. At the time chicken heads were used as baits for the vaccine. The vaccine was produced in the Russian Federation and did not contain a biomarker. ORV campaigns were organized in collaboration with the Hunters association. During the vaccination campaigns vaccine baits were placed near the fox dens. ORV campaigns during this period were not carried out regularly and due to the vaccine type used, it was impossible to monitor bait uptake in target animals.

Strategy 2 – small-scale vaccination (1998-2004). Manufactured vaccine baits containing tetracycline as a biomarker were manually distributed, with an average bait density of 9,76 baits/km^2 in discrete regions of the country. Distribution of vaccine baits was organized in a similar way as in strategy one, however, the amount of vaccine baits and the size of the vaccination area was considerably increased. Monitoring of the ORV campaigns focussed on determination of bait uptake only, as serological methods were not implemented at that time.

Strategy 3 – large-scale vaccination (2005-2011). During this observation period the entire territory of Latvia was covered with manufactured baits using aerial distribution, with an average bait density of 24,18 baits/km^2. Monitoring of the ORV campaigns included determination of bait uptake and herd immunity in hunted target animals.

To perform analysis of cost efficacy of three ORV strategies implemented in Latvia, it was planned to collect data from Food and Veterinary Service of Latvia on costs directly related to implementation of ORV campaigns (costs of purchase and storage of vaccine baits, costs of distribution (manual and aerial) of vaccine baits, costs of laboratory testing between 1991 and 2011. Data on costs of strategy 3 were collected, converted from Lats (LVL) to Euro (at the rate 1 EUR= 0,702804 LVL) and cost efficacy analysed using model *f(x)=a exp(-n x)* in order to describe the decrease *f(x)* in rabies cases in relation to accumulated costs per year *(x)*, as described by Selhorst et al., 1997. However, due to request of data for a long period of time and involvement of different institutions (e.g. State Forest Service, Hunters Association) in an implementation of ORV it was not possible to collect data on costs of ORV campaigns from 1991 to 2003.

The fact that costs of vaccine purchase and distribution comprise more than 90% of all costs related to implementation of ORV strategy is well known (Selhorst et al., 1997). Both - vaccine purchase and distribution costs correlated with size of vaccinated area (km^2) (Aubert,1999). In order to estimate cost efficacy of strategy 1-2 and compare cost efficacy of three ORV strategies implemented in Latvia, model described by Selhorst et al., 1997 was adapted to this study using cumulative size of vaccination area per year instead of accumulated costs per year.

Statistical analysis was done using MS Excel 2007.

RESULTS AND DISCUSSION

Costs of rabies elimination including ORV between 1991 and 2003 were covered by national budget. Data on amounts spent for implementation of ORV strategies in this period were not available. In 2005 finances from PHARE Twinning Light project "Eradication of rabies among wildlife animals in Latvia" were able and for the first time ORV in Latvia was carried out using aerial distribution. Since 2006 costs of ORV campaigns were co-financed by the European Union. The costs directly related to implementation of ORV in Latvia from 2005 to 2011 are given in Table 1. During the period 90,37% of costs were spent for purchase and distribution of vaccine (67,85% and 22.52% respectively). From 2005 to 2011, average costs for implementation of ORV for one square kilometre of vaccinated area were 26,9 Euro per year.

Very few articles dealing with economical aspects of rabies elimination have been published. The results of study performed in France for period of 1988 to 1993 revealed that costs of implementation of two ORV campaigns (one year) are 56 USD/km^2 (vaccine purchase and distribution costs presented 92,9% of total costs) (Aubert, 1999). In comparison, annual total costs for implementation of protective belt for keeping EU territory free from rabies (vaccine purchase, distribution and rabies surveillance after campaigns), depending on a country were estimated from 37–69 Euro/km^2 (Freuling et al., 2008).

Table 1

Main costs of ORV strategy 3 in Latvia (2005-2011)

Year	**Costs of vaccine purchase (EUR)**	**Costs of vaccine distribution (EUR)**	**Laboratory costs for monitoring of ORV efficacy (EUR)**	**Costs for vaccine storage (EUR)**	**Prize for hunters for animals submitted (EUR)**	**Total costs per year (EUR)**
2005	568124,3	141942,0	81539,9	2871,4	18844,5	813322,0
2006	1362143,6	192300,6	138892,3	5541,5	39422,1	1738300,1
2007	1092044,9	372735,5	162062,5	5747,0	45099,3	1677689,2
2008	335989,1	140369,1	88878,9	5581,2	31085,5	601903,9
2009	1082623,3	288188,5	66890,6	0,0	23037,7	1460740,1
2010	1316156,4	455319,0	92914,5	0,0	19412,2	1883802,2
2011	895928,3	617712,4	102374,4	0,0	13595,5	1629610,6
Total	6653009,9	2208567,1	733553,0	19741,1	190496,9	9805368,1

In order to assess the cost efficiency of strategy 3 we analyzed the dependency between yearly rabies incidence and the accumulated amount of money spent from 2005 to 2011 (Figure 1).

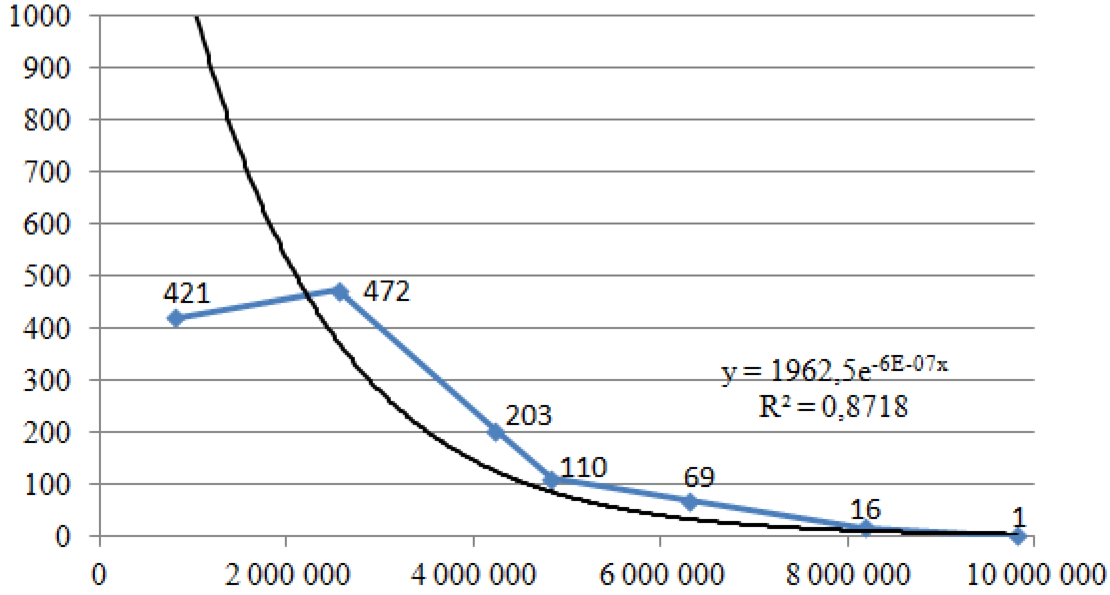

Figure 1. **Rabies incidence in relation to accumulated costs (EUR) in Latvia during ORV strategy 3 (2005-2011). Fitted exponential function *f(x)=a exp(-n x)* (trendline)**

Taking into account that in our study vaccine purchase and distribution costs represents 90,37% of all costs related to implementation of ORV strategy 3 and both are directly related to size of vaccination area, we replaced accumulated costs in Figure 1 with the size of cumulated vaccination area (Figure 2).

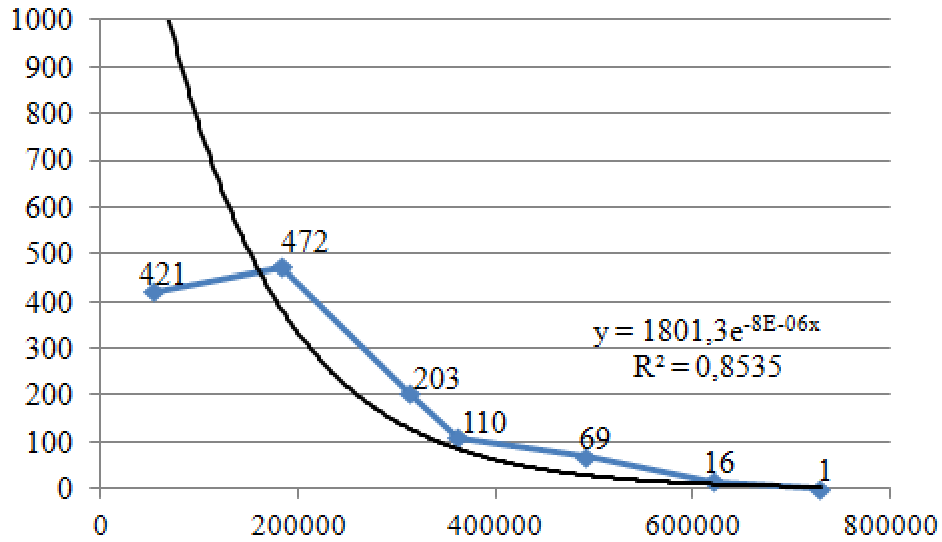

Figure 2. **Rabies incidence in relation to cumulated vaccination area (km^2) in Latvia during ORV strategy 3 (2005-2011)**

As a result, data on cumulated vaccination area fits well in the model (there is no significant difference between coefficients of determination in Figure 1 and Figure 2 (R^2=0,87 and R^2=0,85 respectively)) that allows us to use this method to estimate the cost efficacy of ORV strategies 1 and 2.

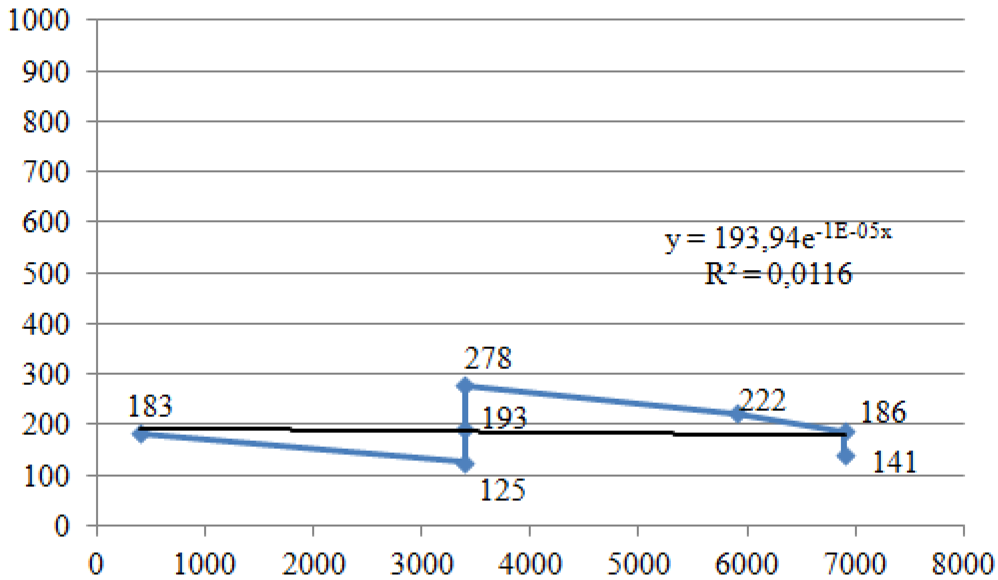

Figure 3. **Rabies incidence in relation to cumulative vaccination area in Latvia during ORV strategy 1 (1991-1997)**

The estimations of the cost efficiency of ORV strategies 1 and 2 are illustrated in Figures 3 and 4.

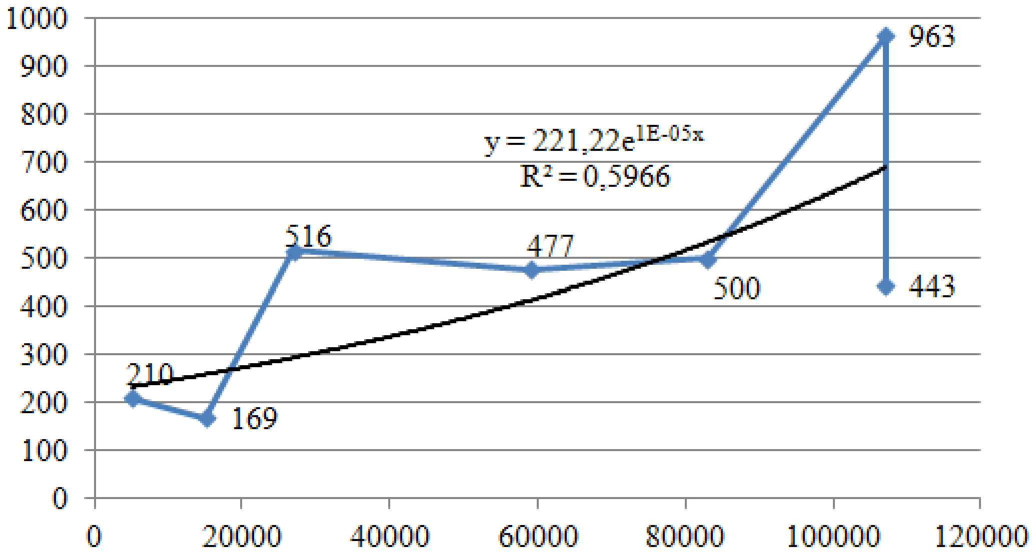

Figure 4. **Rabies incidence in relation to cumulative vaccination area in Latvia during ORV strategy 1 (1998-2004)**

Estimations of cost efficiency (Figures 3 and 4) shows that during ORV strategies 1 and 2 despite of money spent for ORV campaigns, significant decrease in rabies incidence were not observed.

CONCLUSIONS

The results of this study reveal that only during the large-scale ORV (strategy 3) decrease of rabies cases was continuously comparing to other strategies and is considered as cost-effective.

This study is good example for countries where rabies is endemic in wildlife and only large-scale ORV strategy is recommended as cost-effective tool for rabies elimination, despite high implementation costs.

ACKNOWLEDGEMENTS

Academic study and publication is financed by the Project 'Support for doctoral studies in LUA' Contract No. 2009/0180/1DP/1.1.2.1.2/09/IPIA/VIAA/017/, agreement No. 04.4-08/EF2.D1.23.

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