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ANALYSIS OF THE DEVELOPMENT AND SPATIAL DISTRIBUTION OF SIKA DEER (*CERVUS NIPPON*) POPULATIONS ON THE TERRITORY OF THE CZECH REPUBLIC

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Abstract

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This paper gives an analysis of the size of populations of sika deer (*Cervus nippon*) that were introduced to the Czech Republic at the end of the 19th century. Control methods are applied to underlying data taken from the official statistics of the Czech Statistical Office with the aim to check retrospectively their accuracy. Based on statistical data of third-level territorial administrative units available, the recent population expansion of sika deer in the Czech Republic is evaluated as well as the manner and intensity of their spread into new, previously unpopulated areas. Results of applied control methods indicate errors in population management due to underestimation of overall population size data, in particular in the category of female deer.

Keywords: sika deer, population management, population size

INTRODUCTION

Breeding of game as an integral part of landscape ecosystems is a historical tradition in the Czech Republic. the development of own concept of game breeding has undergone many changes conditional upon the level of science and knowledge as well as a number of socio-political changes. Besides thus caused fluctuations, the history of game breeding on our territory is characterized by occasional targeted interventions into the game species spectrum by form of intentional introduction of some animal species, as was the case of pheasant, mouflon, and fallow deer during the history. At the opposite end of the time series of these introductions are muskrat or sika deer.

Sika deer (*Cervus nippon nippon*) is a species of deer native to East Asian region. They occur naturally on the Japanese islands, Korea, Manchuria, East China, and southeastern part of Siberia. In the second half of the 19th century, due to their remarkable ability to adapt to different environmental conditions, they have started to be bred also outside their homeland. In 1860, sika deer was brought to England, initially for the needs of a zoological garden (Whitehead 1984). Also the import of sika deer to deer parks in Ireland dates back to the same year (Powerscout 1884). This herd was then the main source of animals for other deer parks in Scotland and England (Whitehead, 1984). Sika deer have been gradually introduced into a number of other European countries as well as areas outside the European continent, e.g. Australia in 1868, New Zealand in 1885, France in 1890 (Legrand 1988; Cailmail 1988), countries of Austria-Hungary in 1891, Germany in 1893 (Niethammer 1963; hake 1988; Ueckermann 1972, 1988; Rumohr-Rundhof 1969), Denmark in 1900 (Bennetsen 1977), Poland (Pavlov *et al.* 1974; Matuszewski & Sumiński 1984), Hungary in 1910 (Markovic 1988), and Switzerland in 1917 (Schoenberger *et al.* 1988).

Sika deer were first introduced to the territory of present-day Czech Republic in the deer park Kluky near Poděbrady in 1891 (Kokeš 1970). At the same time they were also bred in deer parks of Nymburk district. Other places where sika deer were naturalized include the deer parks of Lipí

near Manětín and Čeminy in Pilsen-North district (1897). Animals that later escaped from these parks during the Second World War became the basis for developing sika deer populations in West Bohemia, from where they subsequently spread into new areas (Wolf & Vavruněk 1975, 1976).

The oldest sika populations in Moravia were the herds kept in **deer park** adjoining a castle of Žádlovice in Šumperk district from 1902 (Hosek 1983), and at Holešov country estate and Pernštejn country estate (Žďár nad Sázavou), of which there are records from 1912 (Babička *et al.* 1977; Wolf 1999). Most imports of this species into Bohemia and Moravia originated in Japan and Russia, East China, and Korea (Wolf & Vavruněk 1975, 1976), but also estates in England and Austria (Kokeš 1970).

These sika escaped from parks into the wild were doing very well in our natural environment, and their populations began to increase gradually. In 1979, the official state statistical data showed a total of 1,599 sika deer, while their numbers were only 464 in 1967. the largest populations of sika deer at that time were reported from West Bohemia (more than 50 percent), Central Bohemia (about 20 percent), East Bohemia (about 13 percent), and North Moravia (about 12 percent). In 1978, a total of 1,167 sika deer were hunted, while only 276 in 1966. In each region, the intensity of hunting was directly proportional to the counted numbers of deer, but neither the increased hunting obviously affected the actual annual population growth since the sika deer population size has nevertheless continued to increase (Švarc 1982).

Sika deer populations in the Czech Republic have been subject of a large number of studies in the past. Wolf and Vavruněk (1975, 1976) dealt with the then most important population of sika deer inhabiting the territory of West Bohemia. Already at that time they pointed to the penetration of sika to areas where it is not desirable, specifically the areas of Bohemian Forest and Slavkov Forest, and called for addressing this issue. Indications of the unbearability of any further increase in the size of sika deer populations and the need to provide a solution were published also by Švarc & Hromas (1975), Švarc (1982), or later by Baruš *et al.* (1982).

Contrary to the declaration concerning the aims of sika deer breeding in the matter of population size control and warning signals in terms of unwanted increase in population size and errors in population management (e.g. Švarc 1979; Mikeš 1983), the 80th of the last century were characterized by a primary inclination towards the quality of animals (Vajner 1983) regardless the necessity of population size control and regulation. This is evidenced e.g. by Hromas (1984), who published a draft classification of hoofed game hunting grounds, in which he addressed the need to balance the relationship between the population size of herbivorous animals and quality of the environment. But despite the growing size of population, neither this author deals with sika deer.

The aim of this paper is to analyse the recent development in population size of non-native species of sika deer on the territory of the Czech Republic, evaluate the results and accuracy of population management, and their impact on changes in the spatial distribution of species in colonization of new territories.

MATERIALS AND METHODS

Official statistical data of the Ministry of Agriculture (MoA) of the Czech Republic for 2003–2014 were used as a source data for the analysis of sika deer numbers on the territory of the Czech Republic and documentation of their trend. In order to process the development of sika deer populations in the Czech Republic, data from the official statistics were used since the beginning of period after introduction of legal obligations for hunting ground users to submit these data for statistical processing, that is since 1966. These statistics do not distinguish between subspecies of Japanese sika deer (*Cervus nippon nippon*) and Dybowski's sika deer (*Cervus nippon hortulorum*). Given the low numbers of Dybowski's sika deer in relation to the Japanese sika deer population, this error does not substantially influence the explanatory power of the study results. Data on the population size (registered as of 31 March) and number of harvested animals were subjected to a data analysis using reverse calculation methods published in the past by Nečas (1959) and used for example for establishing the concept of sika deer breeding in the Pilsen region (Dvořák, Kamler 2009). These methods are useful in identifying differences between the predicted size of population and its actual numbers. Even if these methods are retrospective, they may play an important role in the system of monitoring the meaningfulness of population management. For the analysis of a population size, the method of calculating the number of females or hinds not-specified in the population according to the population increment was used. This method is based on detecting the number of hinds needed to produce the reported increment based on the so-called coefficient of estimated production (CEP), which is to express the number of fawns per doe a year, and on finding the difference between the numbers thus observed and numbers reported on the basis of annual deer count made in the previous year.

For analysing the size of the entire population of sika deer living in the Czech Republic, results of annual deer counts and deer harvest data can be used again to compile a population management model (i.e. the plan of breeding and hunting) for sika deer, and subsequent confrontation between the numbers expected after the end of hunting season and numbers based on the annual deer count in the following year.

The basis for analysis of the spatial distribution of sika deer in the Czech Republic were data of bodies

I:

2003	1. Young animal (juv.) count as of 31 March 2004	1,711
	2. harvest and natural mortality in young animals (juv.) in 2003	2,426
	3. Total increment	4,137
	4. Number of females needed to produce the increment if CEP = 0.8	5,171
	CEP = 0.9	4,593
	5. Female count in 2003	1,953
	6. Difference between calculated and counted females if CEP = 0.8	3,218
	CEP = 0.9	2,644
	7. Not included females in % of the total count if CEP = 0.8	165
	CEP = 0.9	135

The calculation procedure is as follows: Lines 1, 2 & 5: statistical data of the Ministry of Agriculture; Line 3: sum of lines 1 & 2; Line 4 = line 3/CEP; Line 6: the difference of lines 5 & 4 indicates how many hinds are missing in the previous year count result to produce the increment (Line 3); Line 7: (6/5*100) in %.

II:

	♂	♀	**Juv.**	**Σ**
Sika deer count as of 31 March 2003	1,504	1,953	1,497	4,954
Increment (CEP = 0.9)			1,758	
Deer numbers before harvest	2,253	2,702	1,758	6,712
Harvest and natural mortality in 2003	1,633	3,073	2,426	7,132
Estimated numbers as of 31 March 2004	620	–372 (0)	–668 (0)	–420
Sika deer count as of 31 March 2004	1,884	2,491	1,711	6,086
The difference	1,264	2,491	1,711	6,506

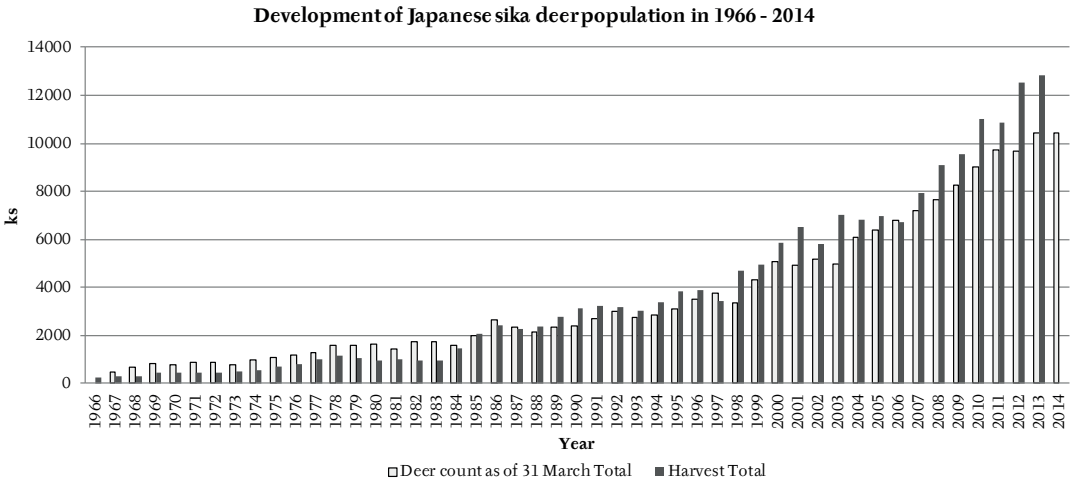
The calculation procedure is as follows: the starting point is the deer count figure (as of 31th March). the figure in the category of young deer as of this date is broken down into halves; they are added to the reported number of stags and hinds before the hunting season or harvest. the increment is calculated by multiplying the number of hinds by a coefficient of estimated production (CEP) = 0.9. the estimate for the next year is calculated by subtracting the deer harvest, including natural mortality, from the figure before the hunting season.

of the State Hunting Authority and the Czech Statistical Office broken down by administrative districts of municipalities with extended powers (MEPs) for the period since 2003, when the territorial administrative system of the Czech Republic was modified.

RESULTS AND DISCUSSION

Data on the sika deer population and harvest are systematically processed since 1966. In that year the sika deer head count was 460. In 2014, this figure was 10,437 which is nearly a twenty-three-fold increase in 48 years. However, this trend in the numbers over the given period does not comply with the trend in deer harvest, which has gone up forty-six-fold without stopping or even declining the population growth. While until 1985 the annual harvest was always lower than the deer count registered in the corresponding year, which corresponds theoretically to a sustainable way of population management; after 1985 this proportion was broken and with the exception of 1997 and 2006, the number of harvested sika deer was always higher than the registered head count of that year.

One of the commonly used population characteristics is its structure in terms of age distribution and the ratio of males to females in a population. the recommended optimum representation of animal categories in the sika deer population (Decree of MoA No. 491/2002 Coll.), with the coefficient of estimated production (CEP) equalling to 0.8 (annual increment from one female), amounts to 39 percent of males, 39 percent of females, and 22 percent of young animals under 1 year of age. If the value of CEP is 0.9, the optimum population consists of 38 percent of males, 38 percent of females, and 24 percent of young animals under 1 year of age. the observed average representation of animal categories in the populations in the Czech Republic is 31 percent of males, 42 percent of females, and 27 percent of young animals under 1 year of age. the average structure of animals harvested is 22 percent of males, 42 percent of females, and 36 percent of young animals. It appears from these results that females and young animals significantly outweigh in the population despite the fact that animal harvest in the female and juvenile categories in relation to the category of male animals gradually increases (female deer harvest 41.6 percent in 2002 and 44.4 percent in 2013; young deer harvest 35.9 percent in 2002 and 37.5 percent in 2013). Despite the implementation of this measure, trend

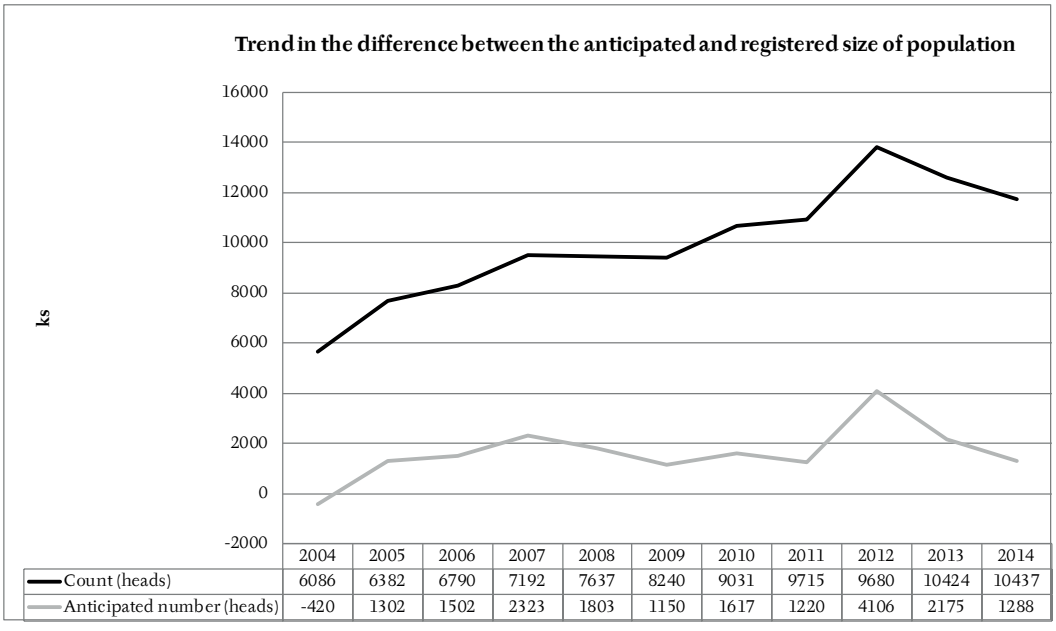


1: Development of sika deer population in the Czech Republic

of growing population size is not being reversed. the optimal sex ratio for sika deer population is defined as 1: 1. the established trend of gradual increase in the number of females being harvested at the expense of males seems to be logically correct and aims to stop the population growth. However, the number of harvested females within the Czech sika deer population is still insufficient as evidenced by only minor changes in the sex ratio of deer population.

The first method applied to check the correctness of population management, or more precisely the explanatory power of deer counting methods, is a reverse calculation method. This reverse calculation ascertains how many females needed to produce a real increment were not included in the deer counting results in the previous year. Over the analysed period, the annual percentage of females not recorded by deer counting methods ranges from 75 to 165 percent depending on the considered range of CEP values = 0.8 to 0.9. This means that every other female is not included in the register of deer counting results in the long term. So the population management system deals neither with this share of female deer nor their future offspring (Dvořák, Kamler 2009; Husák *et al.* 1986).

The results of analysis of model plans of population development drawn up on the basis of deer counting and harvest results show an ever growing mismatch between the deer population size as expected after the harvest and numbers which are subsequently found during the annual spring deer count in the following year. These results show the recurring significant underestimation of population size, whether due to inaccuracy of



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Count (heads)	6086	6382	6790	7192	7637	8240	9031	9715	9680	10424	10437
Anticipated number (heads)	-420	1302	1502	2323	1803	1150	1617	1220	4106	2175	1288

2: Graphical representation of the trend in the difference in population size

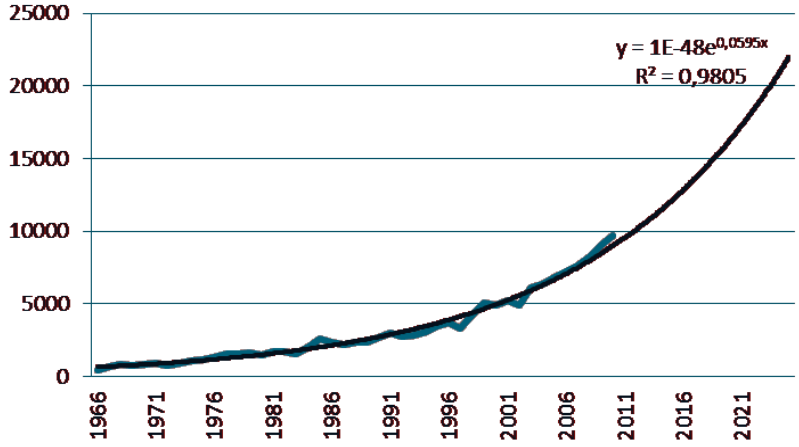
III: *Statistical data on the sika deer population between 2003 and 2014*

Statistical data on the sika deer count and harvest on the territory of the Czech Republic in 2003–2014

Year	Deer count as of 31 March							Harvest							Natural mortality				Population decrease in total (harvest + mortality)				Sex ration	
	Total	♂	%	♀	%	juv.	%	Total	♂	%	♀	%	juv.	%	Total	♂	♀	juv.	Total	♂	♀	juv.	Count	Harvest
2003	4,954	1,504	30.36	1,953	39.42	1,497	30.22	7,010	1,595	22.8	3,025	43.2	2,390	34.09	121	37	48	36	7,131	1,632	3,073	2,426	1 : 1.29	1 : 1.90
2004	6,086	1,884	30.96	2,491	40.93	1,711	28.11	6,818	1,612	23.6	2,806	41.2	2,400	35.2	208	51	67	90	7,026	1,663	2,873	2,490	1 : 1.32	1 : 1.74
2005	6,382	2,079	32.58	2,541	39.82	1,762	27.61	6,976	1,774	26.1	2,761	40.7	2,441	35.95	191	56	62	73	7,167	1,830	2,823	2,514	1 : 1.22	1 : 1.56
2006	6,790	2,177	32.06	2,777	40.90	1,836	27.04	6,704	1,588	23.7	2,732	40.8	2,384	35.56	261	45	108	108	6,965	1,633	2,840	2,492	1 : 1.27	1 : 1.72
2007	7,192	2,285	31.77	3,022	42.02	1,885	26.21	7,939	1,829	23	3,288	41.4	2,822	35.55	170	43	67	60	8,109	1,872	3,355	2,882	1 : 1.32	1 : 1.80
2008	7,637	2,489	32.60	3,123	40.89	2,025	26.51	9,081	2,047	22.5	3,824	42.1	3,210	35.35	217	48	87	82	9,298	2,095	3,911	3,292	1 : 1.25	1 : 1.87
2009	8,240	2,570	31.19	3,458	41.97	2,212	26.84	9,526	2,081	21.9	4,114	43.2	3,331	34.97	203	48	81	74	9,729	2,129	4,195	3,405	1 : 1.34	1 : 1.97
2010	9,031	2,831	31.35	3,881	42.97	2,319	25.68	11,019	2,115	19.2	4,826	43.8	4,078	37.01	285	77	101	107	11,304	2,192	4,927	4,185	1 : 1.37	1 : 2.28
2011	9,715	2,992	30.80	4,283	44.09	2,440	25.12	10,878	2,088	19.2	4,785	44	4,005	36.82	349	90	147	112	11,227	2,178	4,932	4,117	1 : 1.43	1 : 2.30
2012	9,680	3,007	31.06	4,176	43.14	2,497	25.8	12,587	2,415	19.3	5,531	44.2	4,578	36.55	257	64	101	92	12,781	2,479	5,632	4,670	1 : 1.39	1 : 2.30
2013	10,498	3,216	30.85	4,541	43.56	2,667	25.59	12,839	2,321	18.1	5,698	44.4	4,820	37.54	384	99	157	128	13,223	2,420	5,855	4,948	1 : 1.41	1 : 2.45
2014	10,437	3,299	31.61	4,452	42.66	2,686	25.74																1 : 1.35	

IV: *The share of female population not included in the records of population size in 2003–2013*

	CEP	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
6. the difference between the number of females registered and females calculated (heads)	0.8	3,218	2,824	2,897	2,694	3,112	3,757	3,697	4,400	3,844	4,880	5,001
	0.9	2,644	2,233	2,292	2,086	2,430	2,993	2,902	3,480	2,939	3,874	3,941
7. Not included females from the overall number of registered females in %	0.8	165	113	114	97	103	120	107	113	90	117	110
	0.9	135	90	90	75	80	96	84	90	68	93	87



3: Prognosis of sika deer population size development while maintaining the current system of population management (JKS = registered deer numbers as of 31 March)

methods used for determining the deer numbers or incorrect or misrepresented data provided for the needs of records.

In 2004, the gap between the expected and counted numbers amounted to 6,506 heads, while in 2014 this difference was 9,149 heads. These results support the conclusions of studies by Kamler, Plhal (2012) and Dvořák, Kamler (2009) dealing with the game population management in terms of hunting and assessment of the management system on the basis of the game counting results.

Trend in sika deer population size development on the territory of the Czech Republic shows a long-term growth. Analyses carried out above reveal that this tendency is due to unsatisfactory composition of population with a prevalence of representation in the female category as well as underestimation of deer count results, probably caused by the error rate of methods used to determine the deer population size (Kamler, Plhal 2012, Mayleova *et al.* 2011). Subsequent adjustment of sika deer population management based on such inaccurate data is not able to achieve the targeted reduction in sika deer numbers and stabilization of population size. With no change in the system of game population management, whether conditional upon changes in legislation or method for determining the population size, we can expect further steep increase in sika deer population size expressed using the mathematical model in Fig. 3.

Sika deer occurrence is reported in almost all regions of the Czech Republic, with the exception of the eastern part of the republic and South Bohemia. the largest area with the sika deer occurrence is West Bohemia. Area of occurrence, where sika is regularly counted and hunted, is located on the borders of Pilsen, Karlovy Vary, Central Bohemia and Ústí regions. This deer population substantially expands in all directions to the territories of other MEPs, namely Ostrov, Slaný, Klatovy, Přeštice, and Říčany. the intensity of deer spreading into new territories varies considerably. While on the territory of Slaný, Klatovy and Přeštice the deer density according to the annual spring deer count did not exceed 2 heads per 10,000 ha of hunting area, on the territory of Říčany and Ostrov the population density increased to 15 and 11 heads respectively per 10,000 ha in 6 years. the centre of sika deer occurrence is MEP Nýřany, on the territory of which the density increased from 203 to 295 heads per 10,000 ha as well as MEP Kralovice (an increase from 126 to 183 heads per 10,000 ha) and MEP Karlovy Vary (an increase from 162 to 220 heads per 10,000 ha) in the last 10 years. High density of animals according to the annual spring deer count is reported also in the neighbouring municipalities with extended powers (MEPs); towards the edge of the occurrence range the density decreases. Interesting data on the occurrence of sika deer are reported from MEP Pilsen, adjoining MEP Nýřany. In 2004 and 2011 no sika deer was counted here, although in other years sika were registered on this territory; however, deer density did not exceed 19 heads per 10,000 ha. Deer numbers in this area are growing every year despite the increasing number of animals harvested. In almost all MEPs of this area the harvest is reported higher than the counted numbers, with an increasing tendency during 2003–2010. the most intensive increase in hunting shows MEP Nýřany, where 206 heads per 10,000 ha were harvested in 2003 and as much as 342 heads per 10,000 ha in 2010.

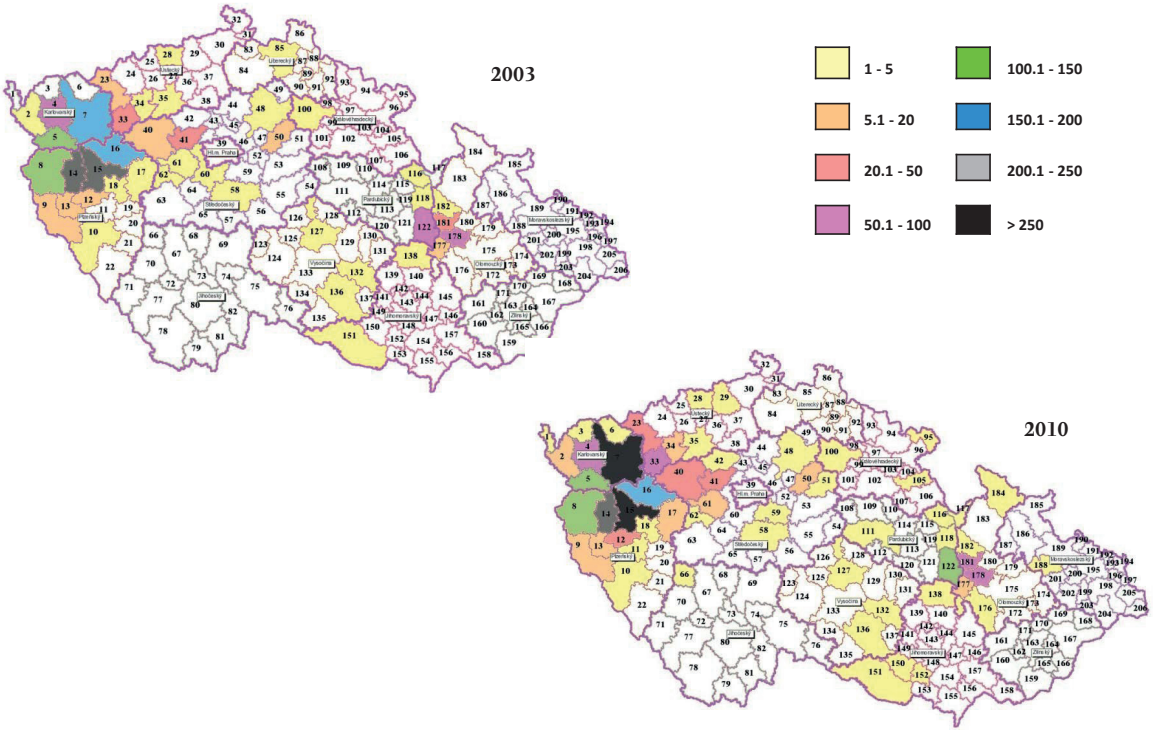
The second important site of sika deer occurrence is the border area between North Moravia and East Bohemia. Here, sika deer have been historically found throughout MEPs of Moravská Třebová, Svitavy, Mohelnice, Litovel, Konice, Boskovice, and Zábřeh; however, they subsequently extended their presence into the territory of MEPs of Prostějov, Lanškroun, and Králíky. the rate of sika deer expansion into the above MEPs varies as in the case of West Bohemia. While the numbers on

the territory of MEP Prostějov become gradually higher, on the territory of MEP Králíky they are maintained at constant, relatively low level. During the monitored period, MEP Lanškroun reports a significant increase in numbers in 2006, with a subsequent decline. In this region, the sika deer density is much lower compared to West Bohemia – most animals occur in MEPs of Moravská Třebové and Litovel, where the density of sika deer does not exceed 110 heads per 10,000 ha. But also in this region the population density shows an increasing trend, albeit with occasional fluctuations. Like in West Bohemia, the reported data on hunted animals are higher than the counted numbers. Over the past decade, the level of sika deer cull has increased from 70 to 117 heads per 10,000 ha on the territory of MEP Moravská Třebová and from 54 to 93 heads per 10,000 ha on the territory of MEP Litovel.

Smaller populations of sika are registered on the territories of MEPs of Nymburk, Benešov, and Znojmo, as well as Chrudim, havlíčkův Brod, Dobruška, Vítkov, and Brno. Here, however, the density of animals does not exceed 20 heads per 10,000 ha, and in some cases these animals are kept in deer parks (Havlíčkův Brod, Vítkov, and Brno). Furthermore, the occurrence of sika deer is also reported from territorial units along the borders with Germany and Poland – MEPs of Teplice, Broumov, and Jeseník, though sika deer herds are not present in adjoining MEPs.

In most MEPs, where sika deer are reported on the basis of the annual spring census, they are also hunted. However, in some MEPs sika deer are either only counted or only hunted, which is an indicator of seasonal migration of these animals. These are mainly MEPs near places of sika deer permanent occurrence, but in some cases animals also travel over great distances. Example is the registered cull of sika deer in MEP Jindřichův Hradec in 2005, when sika deer neither occurred on the territory of adjoining MEPs over the last ten years, nor were hunted there.

In terms of speed of sika deer spreading into new territories, deer registration data show following results: in 2003, either sika deer occurrence or hunting was reported in 46 territorial units (MEPs), whose total area was 1.973 thousand ha, while in 2010 sika deer occurred in 61 units with area of 2.361 thousand ha. So in the period 2003 – 2010, the sika deer population locally living on the territory of the Czech Republic occupied 55 thousand ha of new territories every year, on average. These results correlate with the findings of studies by Dvořák *et al.* (2014) dealing with the size of the home range of sika deer in Doupov Mountains based on telemetry monitoring.



4: Occurrence of sika deer in the administrative-territorial units of the Czech Republic in 2003 and 2010, according to his hunt in pieces on 10,000 hectares

CONCLUSION

The purpose of this paper was to analyse the trends in population size of sika deer occurring on the territory of the Czech Republic, and evaluate the accuracy of underlying registration data used for decision making processes concerning the management of populations of this species so important in terms of forest management, which in many cases limits the success of forest cultivation due to its impact on the environment

Another risk is its spreading into the previously unpopulated locations and the associated interaction with the native red deer (*Cervus elaphus*), particularly the hybridization demonstrated in the conditions of the Czech Republic (Bartoš *et al.* 1981, Bartoš, Žirovnický 1981, 1982). the result of analysis using retrospective methods of reverse calculations reveal fundamental differences between the number of animals anticipated in the population management system and number of animals being registered. On average, this difference reaches nearly 100 percent in the case of female populations. As far as spreading of species to new habitats for the period 2003 – 2010 is concerned, the intensity of sika deer expansion was around 55 thousand ha of newly populated territories per year.

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