THE DYNAMICS OF FOX *(VULPES VULPES L.)* POPULATIONS IN SELECTED HUNTING REGIONS OF THE CENTRAL-EASTERN POLAND IN RELATION TO EFFECTIVENESS OF RABIES VACCINATION

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Abstract. The objective of the study was to analyse changes in the red fox population abundance and hunting bag statistics from the Polish Hunting Association's (PHA) hunting regions in central-eastern Poland, and to examine data from monitoring and routine red fox studies on the effectiveness of rabies vaccination. Studies on changes in the number and level of fox population exploitation were conducted in 8 hunting regions of central-eastern Poland over 9 hunting seasons; that is from 1998–1999 to 2006–2007. The number and density of fox population as well as the numbers of foxes harvested in each region were estimated in the study. An intensive control of fox numbers in the study period (5-fold increase in the red fox harvest) was associated with an almost 3-fold increase in red fox numbers. Our study demonstrated that the program of reducing fox numbers in the examined regions of central-eastern Poland has not produced the anticipated results so far. A seasonal application of rabies vaccination can be one of possible reasons for the phenomenon observed. Prior to immunization there was observed an increase in fox numbers in the examined regions. It was not so great, however, as after the hunting season 2001–2002. Foxes developed resistance to rabies as no case of sick foxes was found in the Mazovia Province in 2007–2009. The program of fox vaccination against rabies is necessary because it effectively reduces the occurrence of the disease in domestic animals and other species living in the wild. At present it is assumed that an application of oral vaccines should be continued till rabies in terrestrial animals is eradicated from the environment.

Keywords: red fox, density, rabies

Introduction. The red fox *(Vulpes vulpes L.)* is characterised by the greatest geographical range of all the predators living in the wild (Hersteinsson and MacDonald, 1992; www. iucnredlist.org.). The red fox population is very flexible and has special abilities to adapt to all types of environments (Korytin, 2002; Gołdyn et al., 2003). Red foxes feed on rodents, birds, carrion and human refuse. They also hunt small game animals, in particular hares *(Lepus europaeus)*, partridges *(Perdix perdix)* and pheasants *(Phasianus colchicus)* (Pińkowski, 1995; Bombik et al., 2005; Bombik et al., 2009; Panek, 2005; Jabłoński, 2007). Fox predation is one of the reasons behind the reduced abundance of juvenile roe deer. (Jarnemo, 2004; Kamieniarz, 2008).

An increase in fox population abundance, which has been observed in recent years in Poland, may result from seasonal applications of vaccines against rabies because the disease is the main factor limiting the fox population size (Smreczak et al., 2007; Kamieniarz et al., 2008). The decision to apply oral vaccination of foxes against rabies was made because the fox is the major rabies vector species and a source of the distribution of this disease in domestic and wild animals both in Poland and other European countries (Vos, 1995; Smreczak and Żmudziński, 2005; Smreczak and Żmudziński, 2009; Vos et al., 2008; Smreczak et al., 2009; Mól, 2010). In 1989, the European Union introduced the program of rabies elimination by means of oral vaccination of wild animals. In Poland the vaccine started to be distributed in provinces bordering Germany in 1993. In the following years, the program was gradually introduced in provinces to the east and in 2002 the whole area of Poland was included (Smreczak et al., 2009).

Other factors contributing to increased numbers of red foxes include lack of natural enemies in many habitats and a decreasing interest in fox hunting (Tryjanowski et al., 2002; König, 2008). For this reason, action was taken in hunting regions to reintroduce and improve the situation of small game species and a program was initiated to reduce red fox numbers (Kamieniarz, 2008; Kamieniarz, 2010). The efficiency of the actions depends to a great extent on the information on the dynamics in fox population numbers.

The objective of the present study was to analyse data on red fox population numbers and hunting bag statistics from the Polish Hunting Association's hunting regions in central-eastern Poland, and to examine the results of red fox monitoring and routine studies to evaluate effectiveness of vaccination against rabies.

Materials and methods. Studies were conducted in 8 hunting regions in central-eastern Poland (Map 1) over the period of 9 hunting seasons; that is from 1998–1999 to 2006–2007. The following regions, located in central-eastern Poland, were analysed: Warszawa, Biała Podlaska, Ciechanów, Ostrołęka, Płock, Radom, Siedlce and Skierniewice. The total area of the regions in the hunting season 2006-2007 amounted to 3,896,435 ha of which the woodland area was 897,698 ha, that is 23.04% of the study area. Calculations included data from 604 districts, including: 46 districts within the Warszawa region, 15 districts within the Biała Podlaska region, 102

districts within the Ciechanów region, 113 districts within the Ostrołęka region, 60 districts within the Płock region, 125 districts within the Radom region, 124 districts located within the Siedlce region and 19 districts within the Skierniewice region. The average district area in the individual region ranged between 4805.63 ha (Ciechanów region) and 5343.56 ha (Ostrołęka region). The regions examined had a varied share of forested area in the total area (from 15.8% in the Płock region to 31.2% in the Ostrołęka region).

Map 1. **Location of hunting districts examined in Poland for numbers, densities and harvest rates of red fox**

The work was based on materials and information from records kept by the Polish Hunting Association Research Station in Czempiń. Red fox numbers and densities, as well as harvests, were assessed for each region studied. Fox numbers in individual regions were determined during counts of flushed foxes by means of the strip-transect method and year-round observation. The strip transect method is based on determining (on a district map) the transect strip whose length depends on the area of the district. Transects are annually conducted on fixed routes, which should include all environmental variations and characteristic of a particular hunting area. Transect routes were marked out through bridges, or through ditches and gaps between buildings, in order to eliminate possible obstacles. The strip transect method included ≥5% of the hunting area. When the district area is 3,000 ha and the strip transect method is 100 m wide, the length of strip transect method route will be 15 km (10 km of route = 100 ha). Seven people walk at equal distances from each other along the strip transect method route and count foxes flushed out of the strip. When the number of foxes/1,000 ha is counted, the number of foxes in the district can be estimated (Fruziński, 2002).

Red fox harvest was expressed as the total number of the animals shot in a region during a given hunting season, i.e. from the 1st of April to the 31st of March the next year. According to the Polish hunting code, foxes can be hunted from the 1st of June to 31st of March in districts where the capercaillie and black grouse occur, or all year round in districts where hares, pheasants and partridges are being introduced. (Directive of the Minister of the Environment of September 22, 2009). Moreover, fox densities were determined per 1,000 ha total area, and fox population exploitation levels were calculated for individual regions and hunting seasons. An index of the level of fox population exploitation in a given hunting region or season was computed following the equation:

$$\text{Fox population exploitation level (\%)} = \frac{\text{average number of red foxes harvested}}{\text{average red fox number in the population as of the 31st of March}} \times 100$$

The results of fox population exploitation levels were analysed using STATISTICA (2012) statistical program. Significance of the differences between groups was checked by Tukey's test.

Distribution of vaccines against rabies in the examined hunting districts in the Mazovia Province was initiated in 2000. Since then, aerial distribution of oral vaccines has been conducted twice a year: in spring and autumn. The density of bait distribution depends on fox population density in a given area, social structure of the population, food availability and the presence of other animals competing for baits. During vaccine distribution, many species were identified as rivals. They included: wild boars, rodents, the weasel family, stray dogs and cats, and birds, particularly the crow family *(Corvidae)*. In the investigated hunting districts baits are distributed by aeroplane over 50 km strips and 40 baits are dropped per km^2. The strips are 1 mile apart. In order to test the effectiveness of rabies vaccines, analyses were performed on dead foxes collected by the Hygiene Inspection Services and tested epidemiologicaly at the Mazovian Voivodeship Veterinary Inspectorate.

Analyses were performed on red foxes examined in monitoring and routine studies conducted to control the effectiveness of rabies vaccines, numbers of vaccines administered and effectiveness of vaccine consumption by foxes in the years 2007–2009. Samples for monitoring studies to diagnose rabies were taken from foxes shot in order to check effects of oral immunization against rabies. Routine studies were carried out on samples of dead animals, foxes suspected of contracting infection, with rabies symptoms, animals which had bitten people and road kills. All the samples taken were analysed applying the same procedure. The samples were analysed in an authorized laboratory to detect rabies by means of immunofluorescence reaction (IF) to exclude from further analysis the samples taken from rabies-infected foxes. Next, we determined the level of the marker tetracycline accumulated in the fox mandibular bone, taken with bait containing the vaccine, following an assumption that the foxes positive for tetracycline had consumed the vaccine.

Results. The average fox population numbers varied in the years 1998–1999 to 2006–2007 and ranged from 1056 individuals in the Skierniewice region to an over 3-fold higher number in the Radom region (on average, 3834 foxes per season) (Table 1). The average number of foxes shot varied between the eight regions and ranged from 699 animals killed in the Skierniewice region to a 3-fold higher number in the Radom region. But the 699 represents a significantly higher exploitation level than the 2268 shot in Radom. Over the study years, there were observed large differences in the average fox densities between individual hunting regions ranging between 4.11 animals per 1,000 ha total area in the Siedlce region and 7.36 foxes per 1000 ha total area in the Biała Podlaska region. There were found significant differences between indices of fox population exploitation levels in individual hunting regions (Table 1). The exploitation levels of red fox population found in the regions Płock and Siedlce were more than 25% higher compared with the Ostrołęka region. It was demonstrated that, in the regions with high red fox numbers, the population exploitation level was lower as compared to the regions with smaller numbers of foxes.

Table 1. **Exploitation intensity of red fox population in selected regions of central-eastern Poland** (means for the hunting seasons 1998–1999 to 2006–2007)

Hunting region	Fox numbers	Fox harvest (heads)	Fox density per 1000 ha	Exploitation level of population (%) (means±SD)
Radomski	3834	2268	6.32	$59,15^{A}$±54.65
Ciechanowski	2784	1354	5.39	$48,64^{C}$±45.37
Ostrołęcki	2658	1053	4.44	$39,62^{D}$±37.07
Siedlecki	2643	1760	4.11	$66,59^{B}$±57.96
Płocki	1874	1278	5.66	$68,20^{B}$±60.31
Warszawski	1378	846	6.09	$61,39^{E}$±50.65
Bialskopodlaski	1550	745	7.36	$48,06^{C}$±33.76
Skierniewicki	1056	699	6.20	$66,19^{B}$±46.14
* Values in columns marked with different letters differ significantly at P≤0.01				

A consistent increase in fox numbers was found in successive hunting seasons (Table 2). In 2006–2007, fox numbers increased more than 3-fold compared with 1998–1999. The fox harvest showed an almost 5-fold increase; from an average of 424 animals shot in 1998–1999 to 2297 individuals killed in 2005–2006. Moreover, there was estimated an increase in fox density from 2.91 foxes per 1,000 ha total area in the hunting season 1998–1999 to 7.65 animals per 1,000 ha total area in the hunting season 2006–2007. The level of red fox population exploitation in the hunting seasons examined tended to increase. Over the study years, it increased by about 55.4 percent value, from 41.05% in 1998–1999 to 63.79% in 2005–2006. However, an increased harvest of red foxes did not result in a decline of the fox population.

Table 2. **Exploitation intensity of red fox population during particular hunting seasons** (means for 8 districts in east-central Poland) **before and after aerial rabies vaccinations conducted 1989–2007**

Vaccination timing	Season	Fox numbers	Fox harvest (heads)	Fox density per 1000 ha	Exploitation level of population (%) (means±SD)
Before the vaccines	1998-1999	1033	424	2.91	$41,05^{A}$±39.83
	1999-2000	1255	550	3.33	$43,82^{B}$±41.34
	2000-2001	1589	679	4.21	$42,73^{AB}$±38.14
After the vaccines	2001-2002	1535	776	4.06	$50,55^{C}$±45.02
	2002-2003	1960	1154	5.21	$58,88^{D}$±51.04
	2003-2004	2155	1214	5.68	$56,33^{E}$±47.03
	2004-2005	3145	1879	6.39	$59,75^{D}$±54.52
	2005-2006	3601	2297	7.29	$63,79^{F}$±54.92
	2006-2007	3726	2281	7.65	$61,22^{G}$±51.63
* Values in columns marked with different letters differ significantly at P≤0.01					

The data in this work show that an increase in fox density per 1,000 ha (Fig. 1) in all the examined hunting districts was observed in 1998–1999 to 2006–2007. Over the study period, the greatest increase in fox density was found in the Płock District whereas the lowest density per 1,000 ha was in the Siedlce region. A rapid increase in fox population density was observed since the hunting season 2001–2002.

There was observed a tendency towards increased fox hunting per 1,000 ha of the total area in all the examined hunting districts over the hunting seasons analysed (Fig. 2). The greatest and the smallest fox harvests were obtained in the Płock and Siedlce districts, respectively. A rapid increase in fox harvest was observed in the districts examined since the hunting season 2001–2002.

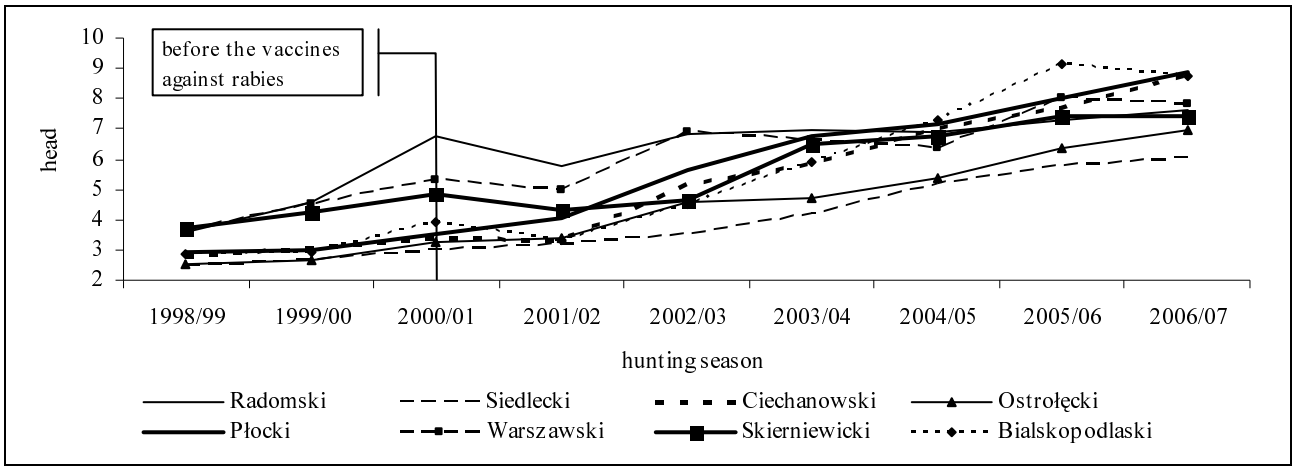

Figure 1. **Red fox density per 1000 ha in selected regions of central-eastern Poland in the hunting seasons 1998/99–2006/07**

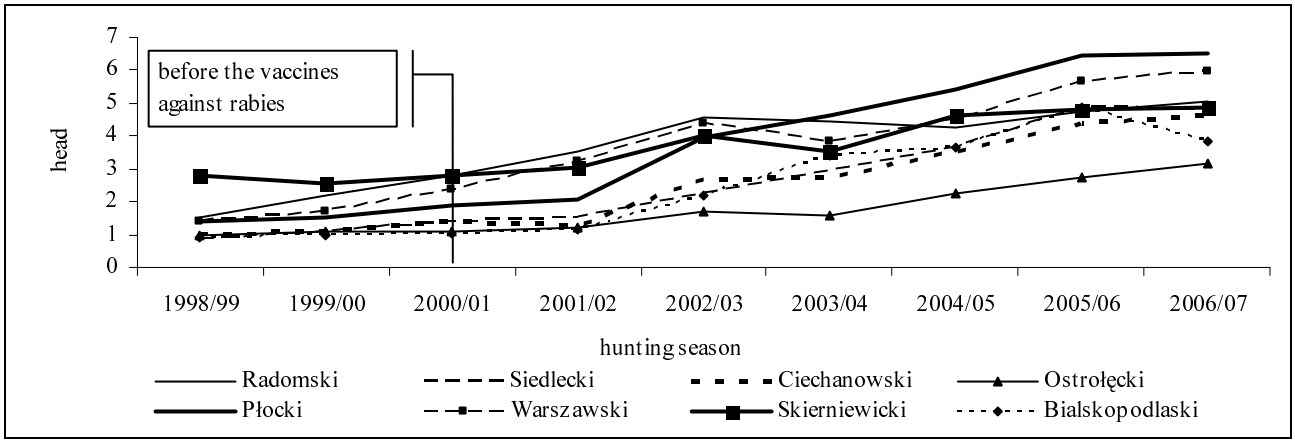

Figure 2. **Red fox harvest per 1000 ha in selected regions of central-eastern Poland in the hunting seasons 1998/99 – 2006/07**

Table 3. **Results of studies in the Mazovia Voivodeship, Poland, 2007–2009, on effectiveness of rabies vaccine consumption by red foxes**

Years	Numbers of foxes tested					Foxes positive for tetracycline		Numbers of foxes which contracted rabies
	monitoring study	%	routine study	%	total	number	%	
2007	2196	91.5	203	8.5	2399	2197	91.69	0
2008	2260	94.6	129	5.4	2389	2118	88.64	0
2009	2684	100	0	0	2684	2521	93.92	0

Table 3 shows the results on the effectiveness of rabies vaccine uptake by red foxes in the Mazovia Voivodeship (Province) in the years 2007–2009. The data were obtained from monitoring and routine studies of 7472 foxes altogether. The studies to diagnose rabies were conducted in foxes shot for monitoring purposes (from 91.5 % in 2007 to 100 % in 2009) whereas routine studies included 8.5 % foxes in 2007 and 5.4 % foxes in 2008. In the year 2009, no foxes were obtained for routine studies. No single case of rabies in foxes was recorded in the Mazovia Voivodeship in the years 2007–2009. A very high uptake of the vaccine by the foxes examined was recorded, as indicated by the presence of the marker tetracycline in the mandibular bone (range: 88.64–93.92 %).

Discussion and conclusion. Fluctuating dynamics of red fox populations were observed in the Polish Hunting Association hunting regions, including changes in fox numbers, densities and harvests. Varied fox densities found in the present work showed inverse proportionality to the size of the hunting region. The greatest fox density was recorded in the Biała Podlaska region which was one of the smallest of the examined regions. By contrast, the

lowest density was determined in the Siedlce region which has the greatest area of all the examined regions. The districts had a similar share of forested area in the total area, i.e. 24%. Despite a 5-fold increase in the number of foxes shot over the study period the estimated fox density showed an almost 3-fold increase. In the 80s and early 90s of the previous century, the number of foxes remained at a stable level despite the yearly cycles' fluctuations. In this period, there were approximately 60 thousand of foxes living in Poland, with a yearly harvest of approximately 25 thousand. Taken Poland as a whole, the data shows an almost 2-fold increase in fox numbers from 106.8 thousand foxes in 1998 to over 219 thousand foxes in 2007 (Main Statistical Office, 1999; Main Statistical Office, 2008). The Mazovia Voivodeship was one of the regions with the greatest red fox abundance in 2007, followed by the Wielkopolska and Lubuskie Voivodeships. By contrast, the lowest numbers of red foxes were determined in the Opole Voivodeship (Main Statistical Office, 2008). An increase in fox number leads to an increase in fox harvest. At the same time, there was observed an almost 2-fold increase in the numbers of foxes harvested in Poland (from 85 thousand animals in the hunting season 1998/99 to 147 thousand foxes in 2007/08). In 2007, the Mazovia Voivodeship had the second greatest red fox harvest, compared with the rest of Poland (Main Statistical Office, 2008).

Since the implementation of the oral vaccination (ORV) of foxes against rabies, Europe has recorded a consistent decrease in the amount of rabies among red foxes and other animals living at large. The ORV method causes a significant statistical reduction in a number of rabies cases on the territories subjected to vaccination (Smreczek, 2003). Seasonal applications of vaccines to control rabies since 2000, which limited the incidence of the disease and reduced fox mortality, were a factor which contributed to increased numbers of foxes in the districts examined. Prior to immunization in the districts studied there was observed an increase in fox number which, however, was not as intensive as in the hunting season 2001–2002. A rapid growth of fox population following an application of protective vaccinations against rabies has been reported by other authors (Bresiński and Panek, 2000; Panek et. al., 2002; Skoczylas et al., 2007; Flis 2009; Smreczak et al., 2009; Mól, 2010). A seasonal rabies vaccination, to curb the disease and, in consequence, reduce fox mortality, was the second most important factor contributing to increased red fox numbers in the whole of Poland (Bresiński and Panek, 2000; Panek et al., 2002; Flis, 2009; Smreczak et al., 2009; Mól, 2010). As indicated by records of the Mazovian Voivodeship Veterinary Inspectorate, the numbers of rabies vaccine doses distributed in the Mazovia Province in 2007–2009 were summed up to 1,308,680 baits annually, which gave about 40 doses per 1 km^2. The index of vaccine distribution per 100 km^2 in the Mazovia Province is lower than the average for the whole of Poland and the western voivodeships (Mól, 2010). In our study foxes consumed over 90% vaccines. According to the data from 2008, the average index of vaccine consumption by foxes in Poland reached the level of 86.9% (www.piwet.pulawy.pl). Kamieniarz et al. (2008) reported a slightly lower percentage (77%) of foxes positive for the marker in Wielkopolska. No cases of rabies were detected in foxes in the Mazovia Province in 2007–2009, which indicates that foxes developed resistance against rabies. So far, the results have demonstrated that oral application of immunization in wild foxes has been successful in Poland. The highest number of rabies cases (3084) discovered in the years of 1983–2000 was reported in 1992. Since the implementation of the oral vaccinations against rabies, the amount of cases detected in Poland has decreased from 2,555 in 2001 to 43 in 2006. In 2009, there were only 6 such cases recorded (www.piwet.pulawy.pl). In the Mazovia Voivodeship, the number of rabies cases discovered in red foxes has decreased from 230 in 2001 to 2 in 2004. In 2007, there was not a single case of rabies detected in red foxes living on this area (Smreczek and Żmudziński 2007).

The highest increase in fox numbers was found in the west of Poland resulting from less hunting pressure due to a decline in demand for fox skins (Skoczylas et al., 2007). Low effectiveness of red fox control may result from underestimated numbers of foxes. Lack of knowledge about the actual increase in fox numbers means that both annual planned and actual numbers of foxes shot are too low to effectively control red fox populations (Jabłoński et al., 2007). Only in few areas were the numbers of foxes killed high enough to effectively control the population size. According to Kamieniarz (2010), fox numbers have ceased to increase in recent years with fox population densities declining in the west of Poland. It indicates that the possibility exists to reduce fox numbers and, in consequence, recover small game populations. As Kamieniarz (2008) put it, to improve the conditions of small game, it would be enough for every hunter to shoot an excess of two foxes per season, on average. Intensive fox hunting is necessary to protect small game animals, in particular hares, partridges and pheasants (Bombik et al., 2005, Bombik et al., 2009). The fox population size is also influenced by other factors. Road kills are most frequent in the summer and autumn (Snow et al., 2011; zwolnij.wwf.pl/dokumenty/raport.pdf). There is lack of information in Poland on road kills.

The level of population exploitation in the analysed hunting seasons increased from 41.05% in 1998/1999 to 63.79% in 2005/2006 but it was not enough to contribute to reduced numbers of foxes in the area. To effectively control a fox population, the numbers of foxes shot and those killed due to the remaining mortality causes should outnumber the birth rate (Jabłoński et al., 2007). It is assumed that harvest at the level of 100–150% of spring fox numbers results in stable fox populations. When reduction of fox numbers per one district is attempted, hunting intensity should be even higher and amount to 200–300% of fox numbers is spring. At present it is recommended to shoot at least 8–10 foxes per 1,000 ha of a district's total area (Kamieniarz, 2008). Shooting intensity in this study and in works by other authors was

at the level of 3–6 foxes per 1,000 ha. (Bresiński and Panek, 2000; Kamieniarz and Panek, 2003, Kamieniarz, 2008). According to the Polish hunting code, foxes can be hunted from the 1st of June to 31st of March in districts where the capercaillie and black grouse occur, or all year round in districts where hares, pheasants and partridges are being introduced (Directive of the Minister of the Environment of 22 September 2009). There are no limits to fox hunting but hunting associations do not exploit this species in practice because hunters are not interested in shooting foxes.

In the present study, red fox density in the hunting season 1998/99 averaged 2.91 animals per 1,000 ha total area, while the average fox density in Poland in 1999 was 5.1 animals per 1,000 ha (Bresiński and Panek, 2000). As reported by Panek (2007), around 10 foxes per 1,000 ha was observed in the proximity of Czempiń in the spring of 1999. During the study period there was recorded an over 2.5-fold increase in fox density in the hunting regions of central-eastern Poland from 2.91 foxes per 1,000 ha in the hunting season 1998/1999 to 7.65 foxes per 1,000 ha total area in the hunting season 2006/2007. A similar increase in the average number of foxes per 1,000 ha total area was reported by Skoczylas et al. (2007) for the Szczecin region, as well as Kamieniarz et al. (2008) in the Czempiń region. Red fox density in Poland in the spring of 2008 ranged from 2 to 14 animals per 1,000 ha and was 3 times as high as 15 years ago (Kamieniarz, 2008). The issue of too high red fox densities pertains to most hunting areas in Poland. It would be an unquestionable success of appropriate fox population management if fox densities were reduced to 2–3 animals per 1,000 ha total area of a hunting region (Panek, 2007; Kamieniarz, 2010).

Our study revealed that, despite increased red fox harvest, there was observed an increase in fox densities in the area studied. Perhaps it was due to the fact that the winters in the study period were relatively mild, which was supported in the study by Kamieniarz (2008). Fox hunting is not that successful when there is no snow in winter as the predator needs less energy and food availability is higher. During freezing cold and snowy winters it is possible to hunt at night. At dawn and dusk foxes' activity increases because the animals need more energy. Intensive fox hunting cannot be limited because in the next year the density may be the same as the previous year. Hunters should make use of achievements in other countries, like Germany and Austria, where the approach towards predator reduction is different and hunters prefer to shot foxes rather than boars or stags (Kamieniarz, 2008). According to Kamieniarz (2010), due to longer fox hunting seasons (Directive of the Minister of the Environment of September 22, 2009), hunters are not interested in shooting foxes in the summer or at the end of the hunting season. Fox numbers can be limited by more intensive shooting in the autumn, particularly at the end of the hunting season. Hunting foxes, particularly vixen in heat or immediately after heat, using working terriers, can yield the greatest number of females killed, what reduces fox breeding effectiveness in the next season (Wiśniewski, 2006; Kamieniarz, 2008).

In the past, Polish hunters hunted foxes to harvest fur. In 1990s, red fox furs ceased to be fashionable. At present, hunters are obliged to reduce fox populations because the species hunts small game, in particular hares and partridges. One of the ways to encourage hunters to control fox numbers is to pay them for the foxes shot (Przybylski, 2000). It should also be highly effective to suggest less popular yet efficient red fox hunting methods, including hunting with working terriers, meat bait hunting, hunting using fox calls, hunting young foxes just after the beginning of the hunting season, nocturnal hunting, hunting at artificial dens.

In order to limit fox populations, it is also necessary to maintain constant cooperation between tenants or managers of the neighbouring hunting regions (Kamieniarz, 2010).

The present study demonstrated that the program of controlling red fox numbers in the examined regions of central-eastern Poland has not yielded the assumed results. Although foxes were intensely hunted over the study period, there was observed an increase in their numbers. Fox densities increased because foxes had become resistant to rabies as a result of an application of seasonal oral vaccines in the examined area. Prior to immunization in the districts under study, there was observed an increase in fox densities per 1,000 ha which, however, was not as intensive as after the hunting season 2002/03. The 90 % vaccine uptake of baits by foxes in the Mazovia Province indicates that foxes developed resistance to rabies. The program of fox vaccination against rabies is necessary as it successfully limits the incidence of rabies in domestic and wild animals. Field application of oral vaccines should be continued until rabies in terrestrial animals is eradicated from the environment. It can be concluded that hunting foxes in the areas examined is not enough to reduce the size of fox population. In order to successfully control the size of fox populations and maintain the equilibrium between species inhabiting the habitats studied, more foxes will have to be killed.

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