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The influence of sex mature of wild boar to reproduction in the Czech republic

Vliv pohlavního dospívání na reprodukci prasete divokého v České republice

Doctoral thesis

Disertační práce

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Declaration

I declare that I wrote the dissertation “Influence of Sexual Maturation on the Reproduction of Wild Boar in the Czech Republic” independently under the expert advisory of doc. Ing. Jaroslav Červený, CSc. I also declare that I have listed all literary sources and publications that I used.

Prague, 23.5.2012

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Ing. Miloš Ježek

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Abstract

Problems of growth in the wild boar population are today a subject of interest for numerous researchers throughout Europe. In all countries where wild boar is found, there has been a population explosion in the last 30 years and the species has expanded its territory into areas where it did not previously exist (Nordic countries and Portugal). In most European countries, the wild boar's population growth has been of an exponential character. This situation has been associated with high fertility of adult females, environmental changes and, in recent years, also involvement of physically immature individuals in reproduction. A very important factor causing an increase in the numbers of wild boars is the quality of their environment, which influences the growth of juvenile individuals, or, more precisely, their sexual maturation. Our study aimed to determine morphometric data for wild boar (*Sus scrofa*) in various areas of the Czech Republic and the potential influence of environment on its body measurements and reproduction potential by juveniles females. During 2003–2010, a total 1290 boars were examined in various age categories. Body development was similar in all areas and without statistically significant differences until the age of 6–7 months. From 8 months, statistically significant differences in body proportions occur across all localities. It is just at that time that carrying capacities change in the selected localities. The results show that morphometric differences among boars of the same age are influenced by external environmental conditions in which the boars live. The farrowing and rut times show a similar trend in all three localities. The reason for greater dispersal of farrowing during the year in the individuals from Šumava might be due to harsher weather conditions, which cause an early spring litter to die owing to low temperatures and the sows then rut again in the course of several following weeks and become pregnant. Environmental conditions influence the physical development of wild boar. The results suggest that the differences between areas vary considerably, and these increase with age. This may result in an earlier (Kostelec area) or later (Šumava) involvement of juvenile individuals in reproduction. Thus, the areas may significantly differ in their population dynamics. This finding is important for determining the appropriate management of a game population that is now a major issue in professional circles.

Abstrakt

Problém populačního růstu je v současné době řešen na mnoha úrovních v téměř celé Evropě. Prase divoké vykazuje v posledních letech téměř ve všech oblastech svého výskytu výrazný nárůst početnosti a také dochází k jeho šíření do nových oblastí (Severní Evropa) a nových habitatů (městská a příměstská prostředí). Tato situace je zapříčiněna vysokou reprodukční schopností samic a změnami prostředí, které směřují k vyšší potravní nabídce pro tento druh. Právě to může ovlivňovat růst juvenilních jedinců, resp. jejich zapojení do reprodukce. Tato práce je zaměřena na zhodnocení tělesného vývoje jedinců prasete divokého v různých regionech České republiky, a určení reprodukčních charakteristik samic vyvíjejících se v odlišných typech prostředí. Během roku 2003-2010 bylo vyšetřeno 1290 kusů ulovených prasat divokých. Tělesný vývoj byl podobný a bez signifikantních rozdílů do věkové kategorie 6-7 měsíců. Od 8 měsíce jsme zaznamenali signifikantní rozdíly ve všech věkových kategorií u většiny tělesných rozměrů. To potvrzuje hypotézu, že environmentální podmínky mají významný dopad na rychlost růstu juvenilních jedinců prasete divokého a tak nepřímo ovlivňují začátek reprodukce samic. Zastoupení reprodukčně aktivních juvenilních jedinců bylo nejčastější v oblasti s vysokou nabídkou potravy. Rozdíly v počtech zárodků v dělohách samic mezi oblastmi nebyly prokázány. Říje a narození mláďat vykazovalo podobný trend ve všech třech oblastech. V oblasti s vysokou potravní nabídkou bylo ovšem kladení mláďat vysoce synchronizované v 3 měsících. V chudších oblastech se vyskytoval poměrně významný druhý vrchol kladení mláďat v pozdním létě. Ten mohl být způsoben právě zabřeznutím samic, které dosáhli prahové hmotnosti pro první zabřeznutí až v jarních měsíc a jejich tělesný vývoj nebyl tak intenzivní. Výsledky podporují velký vliv vnějších podmínek na reprodukční výkon, kdy vyšší nabídka potravy může indukovat rychlejší reakce populace na aktuální podmínky a jejich výrazný početní nárůst. S těmito předpoklady je nutné počítat v udržitelném managementu populace prasete divokého, kdy zejména v zemědělských oblastech je nutná rychlá reakce a úprava lovu v závislosti na aktuálních zdrojích potravy. V rámci udržitelného managementu populace prasete divokého je v návaznosti na uvedené předpoklady nutné zintenzivnit lovecký tlak, zejména v zemědělských oblastech.

Contents

List of papers (Appendix)

I based my thesis on the following papers, which will be referd to in the text by their corresponding Roman numerals.

I. Ježek, M., Štípek, K., Kušta, T., Červený, J., Vícha, J. (2011): Reproductiv and morphometric characteristics of wild boar (Sus scrofa) in the Czech republic. Journal of forest sciences, 57 (7): 285-292.

II. Nováková, P., Štípek, K., Ježek, M., Červený, J., Ešner, V. (2011): Effect of diet supply and climatic conditions on population dynamics of the wild boar (Sus scrofa) in the Křivoklát region (Central Bohemia, Czech republic).Scientia agriculturae bohemica, 42 (1): 24-30.

III. Hanzal, V., Ježek, M., Janiszewski, P., Kušta, T. (2012): A contribution to determining craniometric values for wild boar (Sus scrofa) in the Czech republic. Sylwan, in Press

IV. Kušta, T., Ježek, M., Keken, Z. (2011): Mortality of large mammals on railway tracks. Scientia agriculturae bohemica, 42 (1): 12-18.

V. Suk, M., Kušta, T., Ježek, M., Keken, Z. (2011): Methodological aspects of monitoring of large mammals along traffic corridors: A case study (Lagomorpha, Carnivora, Artiodactyla). Lynx, n.s., 42: 177-188.

Introduction

Wild boar (*Sus scrofa*) is distributed across much of Europe, with the exception of northern regions (ČERVENÝ 2004). The species is today beginning to spread rapidly also across Fennoscandia (MASEI et al. 2004). At the same time, the abundance of wild boar is rapidly increasing throughout Europe (e.g. Poland: GENOV 1981, Scandinavia: ERKINARO et al. 1982, Germany: FEICHTNER 1998, France: KLEIN et al. 2007, Czech Republic: HLADÍKOVÁ et al. 2008).

Wild boar populations can prosper very well even in regions greatly impacted by human activity (GEISSLER and BURGIN 1998). The diet of this omnivorous species is comprised predominantly of plants (SCHLEY and ROPER 2003). Localities with high-quality food resources are intensively exploited by wild boar, resulting in conflicts with the agricultural economy (GERARD et al. 1991, HERRE 1993). High abundance of wild boar not only leads to generally large-scale material damages in agriculture (PIMENTEL et al. 2001, THURFJELL et al. 2009), it also can have a negative influence from a veterinary perspective through transmission of diseases to domestic and farm animals as well as humans (KLEIN et al. 2007). Damages caused by wild boar to field crops are reported in numerous studies (MACKIN 1970, KRISTIANSSON 1985, GROOT BRUINDERINK et al. 1994, SCHLEY and ROPER 2003, BAUBET et al. 2004, HERRERO et al. 2006, SCHLEY et al. 2008). While it is evident that this problem extends far back into history, its importance has become significant only with rapid rise in the wild boar population throughout Europe during the past 30 years.

One of the reasons for such extreme population growth may be the global rise in average temperature (ROOT et al. 2003), as it, along with reduced snow cover, positively impacts population growth (JEDRZEJEWSKA et al. 2007). Some authors offer as an explanation the increasing frequency of mast seeding of beech (e.g. HOFMAN et al. 1997) and the inability of humans to reduce the population and thus to fill the role of predators (CHOQUENOT 1998). Most authors agree, however, that the growth is related to an increase in food supply and higher survival rates of young in winter (e.g. AHRENs 1984, FONSECA et al. 2004, BIEBER and ROOF 2005, GEISSER and REYER 2005, SANTOS et al. 2006, GETHOEFFER et al. 2007, CELLINA 2008, SERVANTY et al. 2010).

It is therefore apparent that conflicts with human activities are on the rise (ANDRZEWSKIJ and JEZIERSKI 1978, GEISSER and BURGIN 1989, BOUTIN 1990, AHMAD et al. 1995, MASSEI et al. 1997, SAETHER 1997, BIEBER and RUF 2005, GEISSER and REYER 2005, GETHOEFFER et al. 2007, KLEIN et al. 2007, CELLINA 2008) and that human society’s active involvement in their population control and reduction has become necessary.

Summarising chapter

Reproduction ability

Reproduction parameters are one of the most important aspects in the management of wild boar (FONSECA 2004). The reproductive biology of wild boar is a very complicated process involving a broad range of factors. The basic requirement for reproduction is normally developed sex organs. Their function is subject to a number of biological factors. These factors are genetically fixed but are considerably influenced by external environmental conditions (HEBEISEN 2007). The rut usually takes place between November and January, though it sometimes occurs also during other periods (ČERVENÝ et al. 2004). According to HAPP (2005), large variations may appear. Female fertility is markedly affected by age and conditio. Early spring (March, April) is usually considered the peak farrowing period (AHRENS 1984, APPELIUS 1995, GEISSER 2000, FONSECA et al. 2004, MAILLARD et al. 2004, GOETHOEFER et al. 2007, HEBEISEN 2007, JEŽEK et al. 2011). A part of the population gives birth throughout the year, however, and the lowest percentage gives birth in November and December (MAILLARD et al. 1995, SANTOS 2006).

Locality		Number of fetus			
		juv	sub	adult	
Germany	Brandenburg	4,1	5,8	6,3	Briedermann 1971
	Brandenburg	4,4	5,7	6,5	Stubbe 1977
	Brandenburg	3,7	5,6	6,8	Ahrens 1984
	Lower Saxony	4,4			Appelius 1995
	Lower Saxony	5,2	6,7	7,6	Gethoffer 2007
	Rhineland	4,6	5	6,7	Gethoffer 2007
France		4		4	Aumaitre et al. 1984
Italy	Toscany	3,8	5,4	5,7	Boitani et al. 1984
Šchweiz	Malcantone			4,9	Moretti 1995
Spain	Almeria			4,1	Abaigar 1992
	Andalusia			3	Fernandez-Llario et al. 2000
	Katalunia			3,8	Rossel 1998
Hungary		5,14		6,7	Nahlik a Sandor 2003

Tab. 1 Number of fetus in different countrie

The onset of puberty is connected with age and body weight. GETHOEFER (2006) states that in Germany 80% of 8-month-old piglets weighing at least 20 kg had reached sexual maturity. He states that depending on the area 60–70% of piglets will become pregnant during the main reproduction period (November, December), while two-thirds of the remaining individuals give birth in summer. The rut is delayed in up to 15% of piglets and yearlings on average, which can lead to a second peak in births during July and August. In one of the monitored areas where forest cover is 50%, and 40% of that is comprised of production stands of beech and oak, GETHOEFER even states that in January 2005 100% of those females of all age categories examined were pregnant. This had been preceded by a massive crop of beechnuts and acorns in autumn 2004. MAILLARD et al. (2004) also obtained similar results in their monitoring of wild boar populations in southern France in areas with an abundance of scrub oak. Their results indicate that when the crop of acorns was large, the birth rate of piglets was highly synchronized with the peak in February and March. In the case of a small crop, on the other hand, the peak was less intensive and occurred later (April, May, June). The authors did not, however, record a bimodal distribution of births. They explain this model through possible shortening of the oestrous cycle caused by extraordinary food abundance in September and October.

Average fecundity ranges between 3 and 7.6 embryos (Table 1). The number of embryos depends on age, which, in addition to weight, is a highly significant factor. The number of embryos increases with age (FONSECA 2004). From a seasonal perspective, the wild boar is classified as a seasonally polyoestrous species due to its ability to go through oestrus several times per season (OLOFF 1951, AUMAITRE et al. 1982, MAUGET 1982, DELCROIX et al. 1990, ABAIGAR 1992). The cycle is reported to be 21–23 days long (HENRY 1968) or 23 days (HOFACKER 1992), essentially conforming to that of the domestic pig at 18–24 days (DZUIK 1997) or 21 days (EVANS 2003).

Synchronization of reproduction

Wild boar reproduction is usually seasonal, with oestrous cycles during summer and early autumn (MAUGET 1982). Farrowing ranges from late winter to early summer. As in most wild species (MAUGET et al. 1981), photoperiodism plays a crucial role in reproduction, but availability of food may be responsible for major year-on-year variations. Oestrus synchronization in females has been observed in many species of domestic and wild animals due to socio-sexual interactions (DELCROIX et al. 1990). Olfactory stimuli produced by males seem to be especially important for stimulating females' oestrus (KEVERNE 1983, VANDEBERGH 1988). Field observation of wild boar indicates that even if the farrowing interval is prolonged to several months in the entire population, synchronization within the social group can still occur represented by stable association of a small number of females (MEYNHARDT 1978). To verify these observations, DELCROIX et al. (1990) performed an experiment monitoring the timing of oestrous cycles in groups of female boars kept in large forest enclosures in the presence and non-presence of a male. In the group with the male, 6 of the adult females present gave birth to piglets during 7–11 July (i.e. over the course of 5 days). Only one juvenile female reached puberty in the first year (in March, 11 months) and gave birth to piglets in late July. During the second year, the farrowing of 6 adult females and 2 sub-adult females was limited to a period of several days (during 21–27 May). Only one of the sub-adult females gave birth a month later. Even in the group without females, strong synchronization of oestrous cycles and ovulation among group members was apparent.

The results of DELCROIX et al. (1990) show that precise synchronization within a social group of female wild boar is independent of the time of reproduction. This is only an observation, however, and not a summary of mechanisms. In most cases describing synchronization of oestrous cycles, this phenomenon is caused by the male effect. This was first described in laboratory rodents (WHITTEN 1956) and also has been observed in several other species. In a group of female goats and sheep isolated from males, the subsequent presence of males caused synchronization of oestrous cycles (UNDERWOOD et al. 1944, SHELTON 1960). In domestic livestock, the presence of males may even cause earlier onset of puberty (ZALESKY et al. 1984). Reproduction of domestic female pigs is affected by socio-environmental factors (HEMSWORTH 1982). Puberty is accelerated in the presence of a male (BROOKS and COLE 1970, HUGHES 1982), as is the incidence of postnatal ovulation (WALTON 1986). Presence of a male as the sole stimulus of oestrus in pre-pubertal females has not been demonstrated, however, and changes in the environment can have the same effects, thereby replacing the absence of males (DU MESNIL et al. 1962, WODZICKA-TAMASZEWSKA et al. 1985). The findings of DELCROIX et al. (1990) indicate that ovulation is synchronized both in the absence and presence of males. Consequently, synchronization seems to be the result of mutual interactions among females. Similar observations have been made for dogs (NAAKTGEBOREN and STRAALEN 1983) and red deer (IASON and GUINESS 1985). Timing and synchronization at the social unit level is probably related to the positive influence resulting from group homogeneity and, for example, more effective protection of newborns (DELCROIX et al. 1990).

Sexual maturity

Identifying those factors influencing age and size at which an individual reaches maturity is important especially for understanding evolution and life strategies (COLE 1954). Populations intensively managed through hunting or fishing in particular often respond by a decrease in the age and weight at which they first reproduce (STEARNS 1992). In this context, it is expected that factors influencing these life strategies cause differences in individual fitness and should lead to divergences in population densities over time and to evolutionary changes (LANDE 1982). To date, an increasing number of studies have revealed that human activities influence evolutionary changes of wildlife populations (PALUMBI 2001) and affect aspects of life-history such as body dimensions and reproductive characteristics (e.g. ROOS and PERSSON 2006, PROAKTOR et al. 2007). This is especially visible in intensively managed populations (i.e. by fishing and hunting, MILNER et al. 2007, ALLENDORF et al. 2008, FENEBERG and ROY 2008, DARIMONT et al. 2009). Thus, the identification of factors influencing age of first reproduction and reproductive performance is decisive for understanding population dynamics and development under strong human pressure. In mammals, the age of reaching adulthood and, in some cases, also fecundity depends on fitness, i.e. the female must reach a threshold weight (not a certain minimum age) to be able to reproduce (GAILLARD et al. 2000). Climatic conditions, habitat quality and population density in general affect changes in productivity of females through their influence on food sources (LANGVATN et al. 2004). Species are divided into capital versus income breeders based on the difference in source of energy for reproduction. In the case of capital breeders, females use reserves accumulated before the reproduction period, while income breeders rely solely on short-term acquisition of resources during the reproduction period (DRENT and DAAN 1980, JONSSON 1997). Most mammals use body reserves, and current resources cover the active requirements of late pregnancy and early lactation (OFTEDAL 1985). In most large ungulates, females rely mainly on reserves accumulated during the previous summer, i.e. they are capital breeders (FESTA-BIANCHET et al. 1998). Wild boar represent an exception, as they are expected rather to be income breeders, although they have a tendency, as do most other ungulates, for maximum accumulation of body reserves (e.g. DEMMENT and VAN SOEST 1985). They have a markedly higher reproduction effort than do other ungulate species, however, and are therefore more dependent on current sources of food. Moreover, relative to other ungulates wild boar are characterized by an unusual life history, which may increase the demographic impact of changes in age of first reproduction. Foremost, the female wild boar may first be impregnated at a younger age (1 year, MAUGET 1982) than other similar-sized ungulates (2–3 years, HAYSSEN et al. 1993). They also have high fertility, with an average litter size of up to 5 offspring (e.g. SERVANTY et al. 2007), while most other similar-sized ungulates only have 1–2 offspring (HAYSSEN et al. 1993). Studies show that the start of sexual maturity of the wild boar depends significantly on the availability of resources (PEPIN and MAUGET 1989, GEISSER 2000, GETHOEFFER et al. 2006), and they stress the importance of the peak of the seed crop (e.g. OSTFELD and KEESING 2000) which fluctuates year on year and may induce large changes in female reproduction and therefore also in population growth rate. This has been detected also in other types of animals (e.g. PERRINS 1979 in titmouse, HANNON et al. 1987 in woodpecker, OSTFELD et al. 1996 in white-footed mouse, etc.). SABRINA et al. (2011), however, focused on identifying factors forming annual and age-specific changes in the timing of oestrous cycles in the proportion of reproductively active females to the given period, with a focus on demonstrating the influence of large hunting pressure on change in life strategy. SABRINA et al. (2011) tested the relative influence of phenotypic attributes (age and weight) versus environmental factors (winter resources, climatic factors affecting phenology of plants in spring and summer) on the proportion of females in oestrus at a given time. They were expecting an age-specific response in reproductive characteristics to changes in environmental conditions (GAILLARD et al. 1998) and determined the age-specific proportions of female reproduction. The following hypotheses were established as part of this study: 1) Assuming a relatively early age of first female reproduction and a short generational period of this intensively hunted population, they expected the threshold body weight for first impregnation to be at least 80% of the asymptotic weight of adult females, i.e. the value generally observed in ungulates (GAILLARD et al. 2000). 2) Within a given age class, they expected higher representation of reproductively active individuals among heavier rather than lighter females.

Their results indicate that the threshold weight for first reproduction occurred at much lower body weights in this intensively hunted population than in similar populations of same-sized ungulates (1/3 weight in boars vs. 4/5 weight in other ungulates). Higher-weight females had higher reproductive ability than lower-weight females, and the proportion of female reproduction increased during the hunting season. The relationship between female reproduction and timing of oestrus changed depending on food sources and climate. According to SABRINA et al. (2011), 90–100% of yearlings and adult females were reproductively active each year regardless of weight, food sources and climatic conditions. While earlier studies only concerned high reproduction ability of wild boar (MAUGET 1982, GROOT BRUINDERINK et al. 1994, MASSEI et al. 1996), it has now been demonstrated that once females become sexually active almost every such female then tries to reproduce every year under any environmental conditions. It seems female wild boar follow a higher-risk life strategy than do other similar-sized ungulate species such as sheep (SHAW 1804, FESTA-BIANCHET et al. 2008), mountain goats (*Oreamnos americanus*, FESTA-BIANTECH 2008) and reindeer (CAMERON 1994), which tend towards reproduction surges, thereby maximizing their own survival in poor conditions (GAILLARD and YOCCOZ 2003). Moreover, while sexual maturity in similarly sized ungulates occurs in general between 2 (e.g. bighorn sheep) and 4 years (e.g. mountain goats), a large proportion of juvenile wild boar may reproduce already in their first year of age. It should be noted, however, that young wild boar are able to reproduce only once they have reached the threshold body weight. This threshold weight has generally been established at 20–25 kg of a field-dressed individual (e.g. 26–33 kg of a live individual) (GAILLARD et al. 1993) in yearling females, and up to 80% of these juveniles above this weight threshold actually show reproductive activity. This representation of juvenile females in reproduction may even be undervalued. A 2-year study showed that in various parts of Germany only 30% of juvenile females were not sexually active during the hunting season (October–January), and 60% of those were active in the following March and April (GETHOEFFER et al. 2007). The generally observed threshold weight above which juvenile females can reproduce is less than 40% of adult weight, which is very low in comparison with other ungulates. There are two possible explanations for such marked differences between wild boar and other similar-sized ungulates. The first points to a very unusual combination in the wild boar's life strategy (e.g. high weight and high fecundity [FOCARDI et al. 2008] but at the same time low threshold weight of first reproduction [GETHOEFFER 2006 et al.]). The low weight at early sexual maturity relative to the weight of adult females may be the result of selective pressure generated by hunting, as is commonly observed in fishing (e.g. CONOVER and MUNCH 2002). The second explanation is that the population has a relatively high population density and lives in a highly productive environment, i.e. the capacity of food sources is high and leads to high reproduction performance (BONENFANT et al. 2009).

Materials collected to date support the immense impact of hunting on wild boar populations as compared to other ungulate species. The low average life expectancy due to the high risk of being hunted accelerates the onset of reproduction effort in intensively hunted populations (FESTA-BIANCHET 2003, GATEL et al. 2007), assuming that food sources are not limited (e.g. high frequency of seed years, low density, etc.). The threshold body weight is higher in species less intensely managed through hunting (see Table 2). Moreover, the threshold weight in intensively hunted populations is much lower than in females captured as piglets and fed *ad libitum* (35 kg of live weight, PEPIN and MAUGET 1989). In the aforementioned study, the authors tested the influence of various nutrition plans on growth and sexual maturity and determined that females never reach sexual maturity before the 20th month of age (PEPIN and MAUGET 1989). These results clearly signal that early reproduction at low body weights is not a species-specific characteristic of wild boar and supports substantial prevalence of the occurrence of population changes relative to weight and reproduction (ALBON et al. 1993 in red deer, HEARD 1997 in moose).

The literature therefore provides strong support for the theory of species response to high hunting pressure. This pressure is largely responsible for the incidence of reproductively active juvenile females and low threshold weight which has occurred in these strongly hunted populations. It is interesting to note that a small monthly change in the ratio of reproductively active juvenile females and available food sources was observed, while a high monthly change in representation occurred in sub-adult and adult females (SERVANTY et al. 2011). The timing of oestrus and considerable impact of the availability of food on reproductive performance in the current and preceding years may indicate the occurrence of subsequent reproduction events. Yearlings include 2 groups of females: those which previously gave birth as sub-adults, thus causing high reproduction costs for themselves (OFTEDAL 1985), and females which have not previously reproduced and therefore had energy exclusively for growth and body reserves (SABRINA et al. 2011). Among adults, almost all females have given birth previously (i.e. all give birth several times) and most reproduced the previous year (i.e. no break in reproduction, CAMERON 1994). Such high representation of reproducing females each year indicates that females have sufficient energy and nutrients to fulfil the high energy demands for reproduction and they are easily able to replenish this high energy output before their next reproduction (GITTLEMAN and THOMSON 1988). Of course, reproduction and suckling of piglets may cause a negative energy balance in females, and energy reserves will not be fully replaced before the end of summer, at which time females stop lactating and are in anoestrus. Moreover, the observed changes in the proportion of active females correspond to past and current resources. For this reason, wild boar can be classified in a middle category (SERVANTY et al. 2009), among so-called capital–income breeders (e.g. JONSOON 1977).

Prediction of food conditions during the current and previous periods (e.g. MOUSSEAU and FOX 1998) is a very poor indicator of juvenile females' ability to reproduce (OSTFELD and KEESING 2000). Climatic conditions serve as a better indicator of the proportion of reproductively active females, as lower average temperatures and precipitation in spring and a rainy, warm summer will result in a longer vegetation season and better conditions for offspring (LANGVATH et al. 1996, FENNER 1998, BAUBET et al. 2003).

It is necessary to emphasise that juveniles comprise a large proportion of the population increase, perhaps due to the high hunting pressure on the wild boar population (SERVANTY et al. 2009). Most females do not live for longer than 2 or 3 reproductive periods, and therefore the selective pressure pushes them towards increased reproductive effort in early life. Juveniles thus invest more energy into reproduction, with the risk of adult size reduction and shorter expected lifespan (FESTA-BIANCHET 2003, GAREL et al. 2007).

Management consideration

Management, control and regulation of reproductively active wild boar are necessary today. Due to the high reproductive ability of females, wild boar populations need to be intensively managed, and this should be carried out especially through hunting (BIEBER and RUF 2005, SODEKEIT et al. 2005, GETHOEFFER et al. 2007, CELLINA 2008, SERVANTY 2008). Given that predation, natural mortality and mortality on roads are minimal, food conditions and predation in the form of hunting are decisive factors (OKARMA et al. 1995, NORES et al. 2008, TOIGO et al. 2008). Optimal nutrition conditions within artificially created agricultural environments improve reproductive condition (BOUTIN 1990, SAETHER 1997, GETHOEFFER et al. 2007). Supplemental feeding in winter also has a marked positive influence, as it enables females to survive the winter in very good condition (ANDRZEWSKIJ and JEZIERSKI 1978, MASSEI et al. 1997, BIEBER and RUF 2005, GEISSER and REYER 2005, CELLINA 2008). Population dynamics of wild boar reflect fluctuations in availability of food, and especially acorn abundance (CAHILL and LLIMONA 2004, MAILLARD and FOURNIER 2004, NOVÁKOVÁ et al. 2010). Reduction of the wild boar population in forests in winter is necessary for regulating and preventing damages in agricultural areas (MEYNHARDT 1989, LIEBL et al. 2005). In summer, most wild boar herds move to agricultural areas where they cause damages (GERARD et al. 1991, CAHILL et al. 2003, KEULLIG et al. 2010). Such animals migrating into the agricultural landscape should therefore be regulated. This should be achieved primarily by decreasing population abundance and by hunting adult females and piglets, thereby preventing them from learning to use these areas (KEULIG et al. 2010). Moreover, mothers of hunted piglets may learn from this and thus stay in the forest in future (MEYNHARDT 1990, KEULIG et al. 2010). Supplemental feeding and fencing have proven to be effective prevention tools only in the first phases (PASLAWSKI 1975, HONE and ATKINSON 1983, MAILLARD 1998, GEISSER and REYER 2004), as wild boar adapted to them after longer periods. Supplemental feeding, or possibly small fields for the animals, may also be a non-lethal instrument and means of mitigating the damages (e.g. ANDRZEJEWSKIJ and JEZIERSKI 1978, ZIEGELTRUM 2004, FATTEBERT et al. 2005). Most authors, however, consider supplemental feeding to be counter-productive as it supports the already high reproductive ability, especially of juveniles (BOUTIN 1990, GEISSER and REYER 2004, BIEBER and RUFF 2005, CELIINA 2008, KEULIG et al. 2010). Supplemental feeding should certainly be minimized and used with caution (BIEBER and RUFF 2005, GEISSER and REYER 2005). Hunting on baiting grounds with small amounts of food, however, is highly effective (BRIEDERMAN 1977, DOERR et al. 2001, ELLIGER et al. 2001, LIEBEL et al. 2001, KEULIG et al. 2010). Management by hunting is the most important tool for controlling diseases and damage (MAILLARD 1998, KADEN 1999, GEISSE and REYER 2004). The effectiveness of hunting is influenced by hunting traditions, landscape structure, terrain and food conditions (BRIEDERMAN 1990, CSANYI 1995, HERRERO et al. 1995, FERNANDEZ-LLARIO et al. 2003, ACEVEDO et al. 2005, UEDA and KANZAKI 2005, ACEVEDO et al. 2006, MASSOLO and MAZZONI DELLA STELLA 2006). Hunting can be a very effective tool for regulating population density and thus can reduce the risk of the spread of diseases. On the other hand, intensification of effective methods may also significantly affect spatial behavior (e.g. MAILLARD and FOURNIER 1995, BAUBET et al. 1998, CALAGNE et al. 2002). Higher numbers of juveniles may increase the risk of damages, as they cover larger areas than do adults (KEULIG et al. 2010). Hunting of piglets already at a young age is thus very important (GENOV et al. 1994, BIEBER and RUF 2005), as piglet mortality is much lower than is called for by regulation. Capturing and shooting from helicopters also appear to be very efficient (DEBERNADI et al. 1995, KEULIG et al.

2010). Effectiveness should now be preferred over the traditionalism which is ingrained especially in Central Europe.

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Appendix

List of papers

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I

Ježek, M., Štípek, K., Kušta, T., Červený, J., Vícha, J. (2011)

Reproductiv and morphometric characteristics of wild boar (*Sus scrofa*) in the Czech republic.

Journal of forest sciences, 57 (7): 285-292.

Reproductive and morphometric characteristics of wild boar (*Sus scrofa*) in the Czech Republic

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ABSTRACT: Our study aimed to determine morphometric data for wild boar (*Sus scrofa*) in various areas of the Czech Republic and the potential influence of environment on its body measurements. Three localities with varying agricultural systems and overall landscape structure were selected. Hunted boars were measured for height at the withers, body length, ear length, metatarsal length and weight (depending on the circumstances, either dressed with head, without head, or undressed). We also determined the age of the hunted boars according to teeth development. During 2003–2007, a total 654 boars were examined in various age categories. Body development was similar in all areas and without statistically significant differences until the age of 6–7 months. From 8 months, statistically significant differences in body proportions occur across all localities. It is just at that time that carrying capacities change in the selected localities. The results show that morphometric differences among boars of the same age are influenced by external environmental conditions in which the boars live.

Keywords: environmental factors; juvenile individuals; morphometry; *Sus scrofa*; wild boar

Problems of growth in the wild boar population are today a subject of interest for numerous researchers throughout Europe. In all countries where wild boar is found, there has been a population explosion in the last 30 years (Hladíková et al. 2007), and the species has expanded its territory into areas where it did not previously exist (Nordic countries and Portugal). In most European countries, the wild boar's population growth has been of an exponential character. This situation has been associated with high fertility of adult females, environmental changes and, in recent years, also involvement of physically immature individuals in reproduction (Gethoffer et al. 2007). A very important factor causing an increase in the numbers of wild boars is the quality of their environment, which influences the growth of juvenile individuals, or, more precisely, their sexual maturation (Santos et al. 2006).

The main objective of the study was morphometric evaluation of three wild boar populations and to determine in these areas the morphometric parameters in different age groups. Since statistics hunting show that juvenile and sub-adult individuals comprise the largest part of a wild boar population (Gethoffer et al. 2007), determination of physical development of this class is important for acquiring data about reproduction.

MATERIAL AND METHODS

Three localities with varying agricultural systems and different overall landscape structure were selected: Kostelec nad Černými lesy (280–350 m a.s.l., intensive agriculture, in the vicinity of Polabí lowland), Doupov area (350–800 m a.s.l., a specific area within military territory) and Šumava area (450–1,000 m a.s.l., low carrying capacity as extensive agriculture). In all areas, measurements of hunted wild boars were made during the years 2005–2007. Measurements were taken both from individually hunted boars as well as, in most cases, from individuals killed during common hunts. In total we measured 682 pieces of wild boars.

The morphometric data were measured according to Anděra and Horáček (2005). Body length (LC) was measured from the tip of the snout to the root of the tail, tail length (LCd) from the root of the tail to the tip where the tail vertebrae can still be found (without the ending and often extended hairs), metatarsal length (LTp) from the calcaneal joint to the tip of the hoof, ear length (LA) from the root of the ear to the tip, and height at the withers (AC) as the distance from the tip of the fore leg to the highest point at the withers. Weight was determined according to circumstances: (*i*) the whole undressed individual, (*ii*) the weight of a dressed individual including head and legs, or (*iii*) the weight of a dressed individual without head and legs.

Age was determined in all animals. In individuals up to the age of 2 years, age was determined according to Wolf's methodology (Wolf, Rakušan 1977) that is based on the development of permanent teeth and for the adults was age determined by tooth wear according to Briedermann (1986).

For statistical evaluation of the collected data, we used the programme STATISTICA for Windows, Vers. 7.0. To identify differences between the individual localities, one-factor ANOVA was used, with locality taken as a factor. The purpose of this method is to test significant differences between means by comparison of variances.

For all variables, tests for normal distribution (Kolmogorov-Smirnov and Lilliefors test for normality) and for homogeneity of variances (Cochran's, Hartley's and Barlett's tests) were performed. Tukey's test was used to determine differences between individual groups. For the analysis of variables that did not meet the requirement of homogeneity of variance, the Kruskal-Wallis nonparametric test was used.

When there was insufficient data to process for one group, we used Student's two-sample *t*-test for independent variables to compare the other two localities.

RESULTS AND DISCUSSION

Differences in morphometric parameters

The morphometric parameters observed in all age categories fall within their ranges for values found in the Czech Republic (Kratochvíl et al. 1986; Wolf 1987), as well as in Europe (Briedermann 1986; Niethammer, Krapp 1986; Babet et al. 1995; Gallo Orsi et al. 1995; Moretti 1995). Overall, wild boars in the Czech Republic are bigger than in central Italy (Mattioli, Pedone 1995) and their size is comparable for individuals from Central Europe (Gethoffer et al. 2007; Hebeisen 2007).

The influence of locality as a factor affecting the morphometric parameters is very important in individuals up to 1 year of life (Fig. 1). Inasmuch as there was sufficient data available in these categories, this result can be regarded as authoritative (statistically significant). Data obtained in this study can be compared with the results found in Switzerland (Moretti 1995; Hebeisen 2007). In those studies, similar age classes were chosen. In other studies, individuals are classified according to broad age scales, mostly in the categories of piglet (0–12 months), sub-adult (13–24) and adult (24+) (Wolf 1987; Pedone et al. 1991; Gallo Orsi et al. 1995; Mattioli, Pedone 1995), or the morphometric data was recorded in individual months of the year in the categories of piglet and

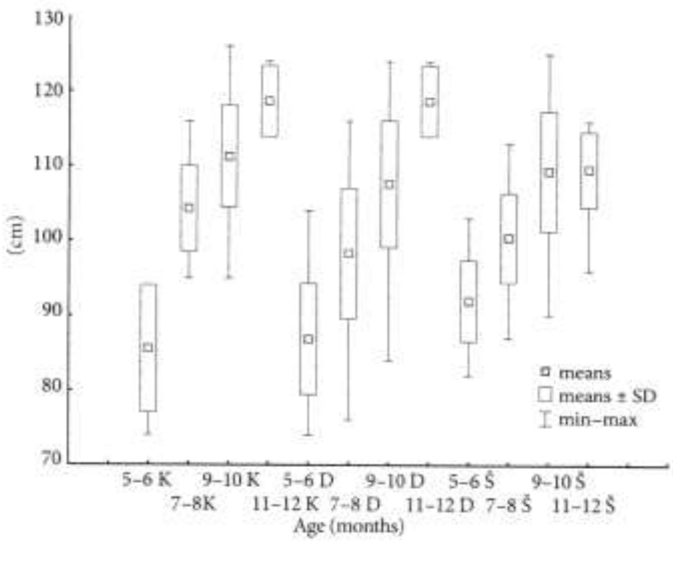

Fig. 1. Average body length in juvenile boars (K – Kostelec, D – Doupov, Š – Šumava)

Table 1. Average body length, dressed weight of individual with head, height at the withers, metatarsal length and ear length by area

Age (months)	Kostelec	*N*	Doupov	*N*	Šumava	*N*	*P*
Ø body length (cm)							
5–6	85.5 ± 8.5	7	86.9 ± 7	17	92.0 ± 5.4	17	0.080
7–8	104.3 ± 5.8	46	98.3 ± 8.7	79	100.4 ± 6.0	45	0.000
9–10	111.3 ± 6.8	82	107.6 ± 8.5	35	106.3 ± 8.0	23	0.095
11–12	118.7 ± 4.7	3	117.5 ± 3.5	4	109.6 ± 5.0	14	–
13–14	–	0	–	0	113.4 ± 4.5	10	
15–16	–	0	–	0	118.3 ± 3.5	22	
17–18	122.0	1	116.4 ± 5.6	7	122.2 ± 4.8	10	0.003
19–20	131.0 ± 1.0	1	126.9 ± 7.2	14	125.3 ± 6.2	21	0.000
21–22	136.0	1	135.3 ± 4.9	14	127.6 ± 5.7	21	0.000
Ø dressed weight of individual with head (kg)							
5–6	11.4 ± 1.5	7	1 2.0 ± 3.01	16	12.7 ± 26	17	0.410
7–8	24.4 ± 5.8	45	20.4 ± 6.6	71	19.9 ± 4.4	44	0.000
9–10	29.5 ± 6.9	82	28.7 ± 7.8	34	25.5 ± 6.8	23	0.090
11–12	38.0 ± 2.6	3	30.8 ± 1.8	4	27.2 ± 5.9	14	–
13–14	–	0	–	0	32.8 ± 5.5	10	–
15–16	–	0	–	0	35.7 ± 5.7	22	–
17–18	42.0	1	40.7 ± 8.1	7	44.5 ± 7.5	11	0.264
19–20	51.6 ± 2.1	3	46.5 ± 7.7	17	44.4 ± 5.3	17	0.342
21–22	60.0	1	56.0 ± 6.6	14	48.3 ± 6.6	21	0.002
Ø height at the withers (cm)							
5–6	54.7 ± 6.9	7	51.5 ± 6.3	17	50.5 ± 4.0	16	0.038
7–8	63.3 ± 5.3	46	58.9 ± 6.6	79	58.7 ± 5.6	45	0.000
9–10	67.3 ± 6.3	82	63.9 ± 7.7	35	64.2 ± 6.4	23	0.005
11–12	76.7 ± 2.3	3	65.5 ± 3.5	4	64.8 ± 4.9	14	–
13–14	–	0	–	0	71.0 ± 4.7	10	–
15–16	–	0	–	0	71.5 ± 5.2	22	–
17–18	82.0	1	67.3 ± 8.1	7	71.0 ± 4.7	10	0.009
19–20	78.7 ± 1.2	3	75.2 ± 4.6	17	74.7 ± 4.9	17	0.773
21–22	85.0	1	78.1 ± 2.9	14	76.4 ± 4.2	21	0198
Ø metatarsal length (cm)							
5–6	22.0 ± 2.4	6	20.9 ± 2.1	12	21.4 ± 1.2	17	0.765
7–8	24.6 ± 2.7	38	22.5 ± 2.3	72	23.3 ± 1.9	45	0.000
9–10	25.8 ± 1.2	53	24.6 ± 2.0	34	24.3 ± 1.3	23	0.000
11–12	27.3 ± 1.5	3	25.5 ± 0.7	4	25.7 ± 1.6	14	
13–14		0		0	27.0 ± 1.7	10	
15–16		0		0	26.7 ± 2.6	20	
17–18	27.0	1	26.5 ± 0.7	3	28.6 ± 1.7	11	
19–20	28.0 ± 1.0	3	26.4 ± 2.3	17	27.3 ± 1.5	17	0.207
21–22	28.0	1	28.5 ± 1.51	14	26.3 ± 5.2	21	0.134

Table 1 to be continued

Age (months)	Kostelec	N	Doupov	N	Šumava	N	P
Ø ear length (cm)							
5–6	8.2 ± 0.75	7	8.2 ± 0.67	17	9.7 ± 1.4	16	0.040
7–8	10.0 ± 1.3	46	9.2 ± 1.1	79	10.0 ± 1.5	45	0.220
9–10	10.6 ± 0.9	82	10.6 ± 0.9	35	11.3 ± 1.7	23	0.000
11–12	10.3 ± 0.4	3	8.5 ± 0.7	4	11.1 ± 0.9	14	–
13–14	–	0	–	0	11.8 ± 1.0	10	–
15–16	–	0	–	0	12.7 ± 0.8	22	–
17–18	14.5	1	11.3 ± 1.1	7	12.9 ± 1.2	10	–
19–20	11.7 ± 1.2	3	11.6 ± 0.6	17	12.2 ± 0.9	17	0.038
21–22	11.9 ± 1.2	2	11.7 ± 0.6	14	12.0 ± 0.9	21	0.028

sub-adult without determining the absolute age of an individual (Stubbe et al. 1980). Therefore, the comparison with these studies can only be considered as indicative.

Body length at the age of 5–6 and 7–8 months is slightly higher than the value given by Moretti (1995) in Switzerland. At the age of 9–10 and 11–12 months, the body length is greater in the Kostelec area, and it is the same in the Doupov area and Šumava as in Switzerland. At the age of 13–18 months, the average body length in all our localities is substantially less than in Switzerland.

Concerning height at the withers, individuals from the Doupov area and Šumava are identical with Switzerland in all categories, but individuals from the Kostelec area show higher values (Table 1). Other morphometric data show a similar pattern (metatarsal length, tail length and ear size) (Table 1). The reason for these differences may lie in the different environment types in the localities. Moretti (1995) examined individuals in a mountainous region with an altitude of 200–1,800 m a.s.l., with forest coverage of 60% and an agricultural landscape (with an intensive type of agriculture) constituting only 10% of the area, similar to the Doupov area and Šumava.

The comparison of weights with other studies show a similar results. Compared to Wolf (1987), who was ascertaining weights of wild boars in the Kolín and Nymburk areas (areas similar to the Kostelec area), there are slightly lower values in the Kostelec area, however the maximum values are nearly identical. The Doupov area and Šumava have averages well below those reported by Wolf (1987). Weights found in this study fall within the ranges of survey data from other European countries (Briedermann 1971; Pedone et al. 1991; Gallo Orsi et al. 1995; Mattioli, Pedone 1995; Moretti 1995; Gethoffer et al. 2007; Hebeisen 2007). A more detailed comparison, however, would be misleading because of difference among the various studies in how the individuals were categorized into age classes.

Comparing of juvenile and sub-adult individuals only in the categories of piglet and sub-adult is very imprecise. Relative to the nearly linear growth of boars under 24 months of age, when during the first 12 months an individual gains 50% of its adulthood weight and it gains 70% within 22 months (Pedone et al. 1995), comparison of such broad categories is conditioned upon the unification of the samples compared.

Relation to environmental factors

Differences in morphometric parameters between different localities are probably caused by external conditions. At the age of 5–6 months, the differences are small and they become greater as the animals grow older. The accumulated data has been compiled into a growth curve without distinction by sex (Fig. 2).

The growth curve in boars from Doupov area can be expressed by the folloving equation

$$y = -2.2717 + 3.3348x - 0.0383x^2$$

where:
y – weight,
x – age in months.

The growth curve in wild boars from Kostelec area has a pattern similar to that for individuals from Doupov area, but it is shifted upward

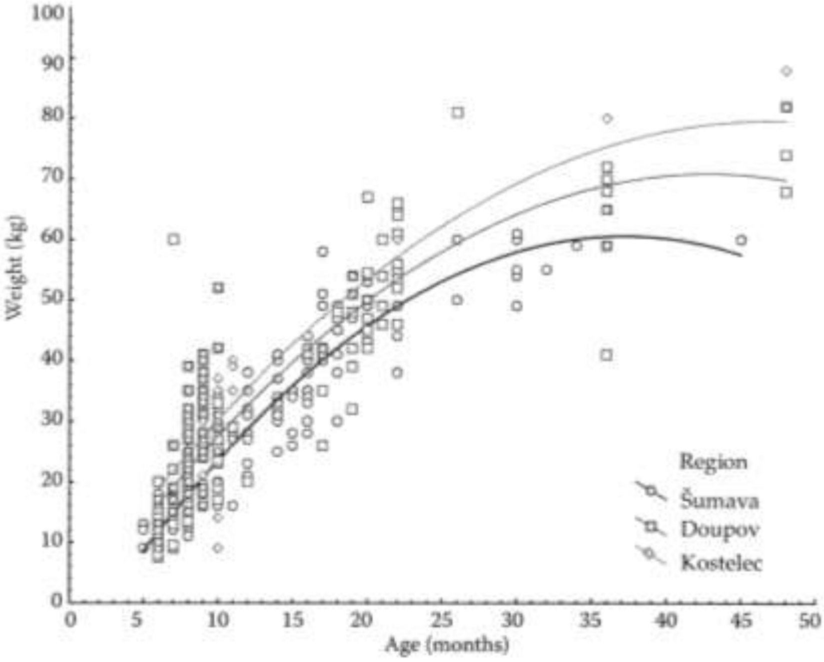

Fig. 2. Growth curves of wild boar

on the y axis (higher weight of wild boars in Kostelec area). It can be expressed by the equation $y = -3.7267 + 3.875x - 0.0465x^2$. For Šumava, we can express the curve using this equation $y = -1.8362 + 2.7262x - 0.0196x^2$.

The growth curves created for each of the studied areas show similar trends as do other studies from Europe (PEDONE et al. 1991; GALLO ORSI et al. 1995; MORETTI 1995; PERACINO, BASSANO 1995).

From the data in Šumava we can distinguish a weight differentiation between males and females at 18–20 months. The same age boundary for differentiation is indicated by PEDONE et al. (1991) in southern Italy, while in northern Italy GALLO ORSI et al. (1995) uses 14–15 months, and in Switzerland MORETTI (1995) uses 13–14 months. On the other hand, MORETTI's (1995) opinion that females grow faster than males within 12 months was not confirmed. The reason for weight differentiation given by those authors is a change in strategy of energy use, whereby the males invest all their energy into growth while females divide their energy after 12 months be-

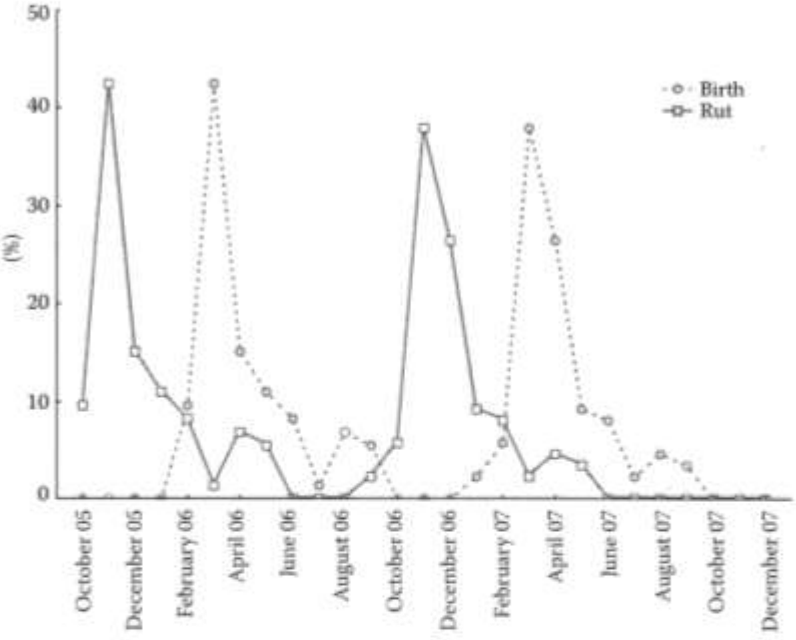

Fig. 3. Farrowing and rut in Doupov area

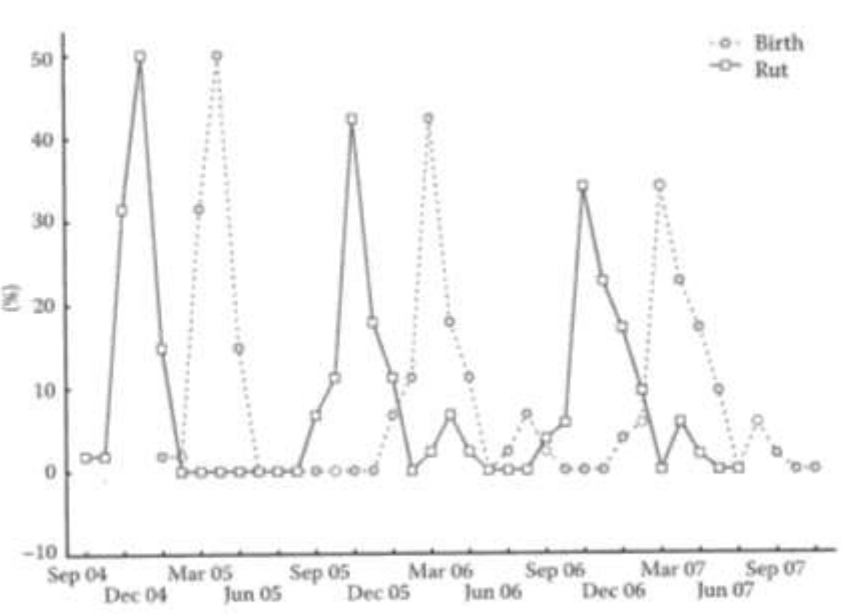

Fig. 4. Farrowing and rut in Kostelec area

tween growth and reproduction (PEDONE et al. 1991; MORETTI 1995; GALLO ORSI et al. 1995).

In all three locations the growth shows a polynomial character, whereby at a certain age weight starts to decrease. The polynomial character of the growth curve in wild boar is reported also by PEDONE et al. (1991). By contrast, MARKINA et al. (2004) report logarithmic growth.

Figures of farrowing and rut in the individual months of the year were created for all three areas (Figs. 3–5). For Kostelec and Doupov areas they were created for 2005–2007. For Šumava, due to a lack of data, they were only created cumulatively for 1995–2007.

In Kostelec area, the greatest part of females farrows in March (2006 – 43%; 2007 – 38%) and April (2006 – 16%; 2007 – 27%). A second peak occurs also in August, but this is not significant (2006 – 6%; 2007 – 5%). Most of the females are impregnated during November and December. In Šumava, the greatest number of females farrows throughout May (26%) and April (18%), and a second peak comes in October (7%). Most of the females are impregnated in November and December.

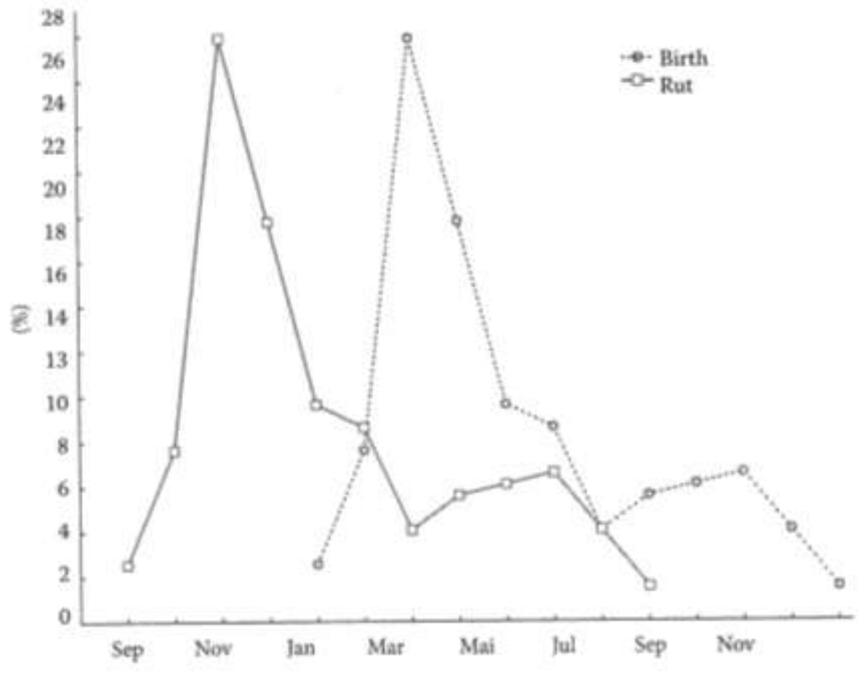

Fig. 5. Farrowing and rut in Šumava

The farrowing and rut times show a similar trend in all three localities. The reason for greater dispersal of farrowing during the year in the individuals from Šumava might be due to harsher weather conditions, which cause an early spring litter to die owing to low temperatures and the sows then rut again in the course of several following weeks and become pregnant (HEBEISEN 2007). Another reason why the second farrowing peaks occur from August to October might be the involvement of juveniles in reproduction during spring, provided they did not become pregnant already at the time of the main breeding period. GETHOFFER et al. (2007) indicates that 60% of juveniles which did not become pregnant in the main breeding season (November and December) will become pregnant in the spring months. Compared to other studies from Europe, the distribution of litters under Czech conditions is similar.

In Germany, according to GETHOFFER et al. (2007), most young animals are born at at the turn of March and April, while in Switzerland HEBEISEN (2007) indicates that it is March–May when 50% of young boars are born. These values correspond to the data found in this study.

In southern Europe, the distribution of farrowing is different during the year in a part of studies, or the time period is longer than that found in our study. In Spain and Portugal, FONSECA et al. (2004) indicate March–April as the most common farrowing period and Santos gives the beginning of March to the end of April. In southern France, MAILLARD and FOURNIER (2004) report April–May and MORETTI (1995) from the Southern Alps gives approximately the same distribution of farrowings in the months from May to July. The recorded second farrowing peak seen in all three Czech localities during July–September is the most notable in Switzerland (HEBEISEN 2007), where it represents a similar proportion (5–8%), and in Germany (GETHOFFER et al. 2007), where this second peak is generated by females of 13–16 months.

The high proportion of piglets farrowed in March and April in the Kostelec area (up to 80%), in contrast to the Doupov area (55%) and Šumava (46%), may again signify the influence of the area with regard to both the time of farrowing and the morphometric parameters. This confirms the findings of MAILLARD and FOURNIER (2004) that in case there is an abundance of food available during the preceding autumn and favourable environmental factors, the time of farrowing comes earlier and it is more synchronized than in those years with poor food availability. The study was conducted in southern France in an area where most of the wild boar's food consists of acorns and where the oaks' seed productivity varies by year. Under the conditions of the Czech Republic, the factor of food availability could be taken over, especially in the Kostelec area, by agricultural crops attractive for wild boar, and in particular corn grown for grain, whose share is very high in the Kostelec area but on the other side minimal in Šumava and the Doupov area, or possibly by year-round feeding of wild boar, which is practiced especially in the Doupov area. This effect of availability of food on the synchronization of farrowing was also reported for studies in Spain (SANTOS et al. 2006), Portugal (FONSECA et al. 2004) and Germany (GETHOFFER et al. 2007). The study of DELCROIX et al. (1990) shows an accurate synchronization in the reproductive processes within the social group of female wild boars, irrespective of the time of reproduction. It suggest the opinion, that in Doupov region can absent the dominate female. But on the other side, many of sudies describe the absence of adult male as main factor affecting the time of farrowing (BROOKS, COLE 1970; WALTON 1986; FERNANDÉZ-LLARIO, MATEOS-QUESADA 2005).

CONCLUSION

Environmental conditions influence the physical development of wild boar. The results suggest that the differences between areas vary considerably, and these increase with age. This may result in an earlier (Kostelec area) or later (Šumava) involvement of juvenile individuals in reproduction. Thus, the areas may significantly differ in their population dynamics. This finding is important for determining the appropriate management of a game population that is now a major issue in professional circles. As the main management suggestion is stopped the increasing of population density in all study regions, and change the social and age structure on behalf of dominant female and adult males in the Doupov and Šumava region.

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II

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EFFECT OF DIET SUPPLY AND CLIMATIC CONDITIONS ON POPULATION DYNAMICS OF THE WILD BOAR (*SUS SCROFA*) IN THE KŘIVOKLÁT REGION (CENTRAL BOHEMIA, CZECH REPUBLIC)

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Abundance of the wild boar (*Sus scrofa*) has rapidly increased in the Czech Republic and all over the world especially over the past 30 years. The main causes are high adaptability on changing environment, adaptive foraging strategies, and high fecundity. The aim of the paper is to put into context increase of the wild boar abundance (as estimated from numbers of hunted game in various age groups) with food offer in agricultural land and in the forest in hunting districts of the Křivoklát protected landscape area. As a correlation factor, minimum temperature at the ground surface in February and March was considered. All the monitored variables were divided into food and statistical factors and they were evaluated by principal component analysis (PCA). The highest variance in relation to the number of hunted wild boars is explained by breadths of spring crops (by 30%), followed by breadths of winter crops along with minimal temperatures above ground surface in February and early March (by 22%). Variance of minimal temperatures in the second and third decades of March in conjunction with occurrence of oak and beech mast years is explained only by 18%. More distinctive increase of hunted wild boars was always a year following the mast year.

Sus scrofa; population dynamics; abundance; feeding ecology; Czech Republic

INTRODUCTION

The wild boar (*Sus scrofa*, Linné 1758) is one of the few animal species whose abundance has rapidly increased within last few decades. Increasing population size is not the question only in the Czech Republic but also in many countries all over the world (Saez-Royuela, Telleria, 1986; Neet, 1995; Bieber, Ruf, 2005). While hunting wild boars was quite rare in free range in the 1950's, approximately 50 years later yearly hunting bags were higher than 120,000 individuals, with a permanently increasing trend. The wild boar is a species very adaptable to changing living conditions including food offer. Specific food spectrum is very broad with majority of plant component both in areas with intensive farming (Schley, Roper, 2003; Herrero et al., 2004, 2006) and in areas with extensive agriculture with higher proportion of meadows and grassland (Baubet et al., 2004). Percentage of plant components in the food of the wild boar varied from 80% to 99% (Frużiński, 1993). The main components of plant origin are seeds of forest tree species (acorns, beechnuts), green plant parts, agricultural crops, roots and bulbs (Schley, Roper, 2003). The majority of plant food (especially grain, roots, herbs, various seeds and fruits) was reported also by Malinová (2008). Representation of the above-mentioned plant components can differ according to the monitored area in connection with agricultural extent and representation of fructiferous tree species – oak (*Quercus*) and beech (*Fagus*) and occurrence of mast years and can vary in the course of the year. In Luxembourg, in the areas with higher intensity of agricultural production, the natural food of wild boars could be divided into three groups with occurrence of agricultural crops in food from the end of April and with culmination in July, August and September and followed up by rapid decline (Cellina et al., 2008). Natural plant component of food starts to dominate in March with culmination in April and May and with subsequent gradual decrease. The third food component were acorns and beechnuts; wild boars started to feed on them at the turn of August and September, with culmination during all winter months and rapid decline in March.

Connection between food offer in the field and in the forest and wild boar abundance (derived from hunting bags) was searched e.g. by Neet (1995) and Geisser, Reyer (2005). Their results show relationship between the number of hunted wild boars, areas of corn and occurrence of oak and beech mast years. Improved food offer along with mild climatic conditions especially in winter and spring influenced favourably condition of female wild boars, reproduction parameters and piglet natality in both studies. The same conclusions were made by Gethoffer et al. (2007) in Germany.

Similar results were reported also by Maillard and Fournier (2004). They monitored wild boar populations in southern France in areas with frequent evergreen oak (*Quercus ilex*). Natality of piglets (with culmination in February and March) was correlated with high crops of acorns. On the contrary, when the crop of acorns was low, natality culminated less markedly and appeared later (in April, May and June).

Abundance of wild boar population and average annual recruitment depend upon climatic conditions. J a d r z e j e w s k a et al. (1997) mention that the average annual recruitment of wild boar population is 19% in Poland in years with minimal or zero snow cover in winter. But in years when the snow cover exceeded 15 cm the annual increase tended to zero.

The high snow cover complicates game motion and frozen earth surface impedes food accessibility. G e i s s e r and R e y e r (2005) evaluated impact of ecological factors (food and climatic conditions) on wild boar abundance in Switzerland and they found out that the population growth relates especially to food availability and average air temperature. Unfavourable climatic conditions can influence negatively survival not only of juvenile, subadult, and adult individuals, but also piglet natality. Depth of the snow cover and minimal day temperature measured on earth surface are important.

With increasing wild boar abundance also the extent of damage to agricultural crops rises (M a c k i n , 1970; K r i s t i a n s s o n, 1985; G r o o t B r u i n d e r i n k , H a z e b r o e k , 1996; S c h l e y , R o p e r, 2003; B a u b e t et al., 2004; H e r r e r o et al., 2006; S c h l e y et al. 2008). There is obvious preference of wheat, corn, oat, and potatoes. S c h l e y et al. (2008) draw attention to the fact that there were no damages in the stands of cereals with awns (barley, rye).

The number of hunts, unsuitable structure of crops with majority of winter crops, winter rape and corn that form permanent cover for most of the year, all this contributes to the extent of damage in conditions of the Czech Republic (Š t í p e k et al., 2010). T h u r f j e l l et al. (2009), on the basis of monitoring in mixed areas (field – forest) in Sweden, adviced to utilize more supplementary feeding in forest areas, because it is more attractive than ripe farm crops.

MATERIAL AND METHODS

Study area

The Křivoklát region is situated in the northwest part of Central Bohemia. It is the protected landscape area which extends to five former townships of Central and Western Bohemia (Kladno, Rakovník, Beroun, Rokycany and Plzeň-North). The total area is 628 km^2 and covers the area of Křivoklát-Uplands and the northern part of Plasy-Uplands. The altitude varies from 223 to 616 metres above sea level. Forest coverage is 62% with dominance of broad-leaved and mixed stands. Fructiferous tree species (oak, beech) occupy 33% of the total forest area. The dominant soil type is brown soil; pararendzina and pseudogley can also occur.

Annual mean temperature varies from 7.5 °C to 8.5 °C. The whole area is situated in rain shadow of the Krušné Mts., the total annual rainfall is only 530 mm.

Data and statistical analysis

Our analysis of the wild boar densities is based on the data from 1994–2008. Data on number of hunted wild boars in hunting districts of the Křivoklát region were provided within hunting statistics – annual statements about hunting district and game hunting.

The statistical enquiry was realized in two hunting districts coming under municipal corporation with extended competence in Kladno, 36 hunting dictricts coming under municipal corporation with extended competence in Rakovník, 6 coming under municipal corporation with extended competence in Hořovice and 13 coming under municipal corporation with extended competence in Beroun. The development of the wild boar abundance was evaluated by correlation and regression analysis.

The data about areas with crops were got from the Czech Statistical Office and from the County Agrarian Associations in Beroun and Rakovník. The meteorological data were provided by the Czech Hydrometeorologial Institute; minimal temperatures registered at the ground surface in February and March from the meteorological stations in Lány and Kněževes.

Information about oak and beech mast years have been got from the company "Forests of the Czech Republic" of Křivoklát. Fruit production of deciduous trees can vary considerably between different years. Years with high fruit production are called mast years. In mast years mast availability is high, meaning that food conditions for wild boars are very good. Data on mast availability are based on yearly estimates of forest rangers.

The statistical treatment was performed by the principal component analysis (PCA) in the program Statgraphics Plus 5.1. Components with eigenvalue higher than 1 were considered significant. Sixteen variables, six describing temperatures in February (d1–d3) and March (d4–d6) and

Table 1. Independent variables tested for their potential effects on the population density of the wild boar from 1994 to 2008

Abbreviations
PC – principal component
d1 – first decade in February (temperature)
d2 – second decade in February (temperature)
d3 – third decade in February (temperature)
d4 – first decade in March (temperature)
d5 – second decade in March (temperature)
d6 – third decade in March (temperature)
wh – wheat
ba – barley
ry – rye
oa – oat
mg – maize for grain
ms – maize for silage
ra – rape
pc – pulse crops
po – potatoes
my – mast years of oak and beech

ten describing food, were available for each year of the study period. Variables are described in Table 1 and mast years of oak and beech are shown in Fig. 4.

RESULTS AND DISCUSSION

Number of hunted wild boars in years 1994–2008

The numbers of hunted wild boars in Křivoklát region represent an increasing trend in years 1994–2008 except for the years 2003, 2005, and 2006. Throughout the fifteen year period the rate between the number of hunted piglets and hunted hoggets increased from 109% to 200%. Perhaps, increasing division between grown piglets and hunted piglets can lead to more intensive increase of wild boar population in this area.

Abundance of wild boar population and biotope carrying capacity

The statistical evaluation of monitored variables via PCA indicates five main components. They represent 85% of the total variability of the data set. Top are food components (particularly spring crops), which explain 30% of dispersion of the values. Combination of food factors (represented by areas of winter crops) and climatic factors (minimal temperatures at the ground surface in February and early March) is the second most important component – 22%. The minimal temperatures in 2nd and 3rd decades of March along with occurrence of oak and beech mast years explain the variance only by 16%. The full mast was recorded in the years 1996, 1998, 2000, 2003, 2006 and 2008. Positive influence of the mast year always took effect in marked increase of wild boar population and consequently in large number of hunted wild boars in following years, which corresponds with conclusions of Neet (1995) and Geisser, Reyer (2005). The reason can be seen in increased food offer in connection with the fact, that individual hunting is more difficult in feeding places, where wild boars are attracted, because they prefer fruits of forest tree species (acorns and beechnuts) and do not visit these places regularly.

The trends in areas of particular grown crops (Fig. 3) represent marked impact of areas with winter crops (rape

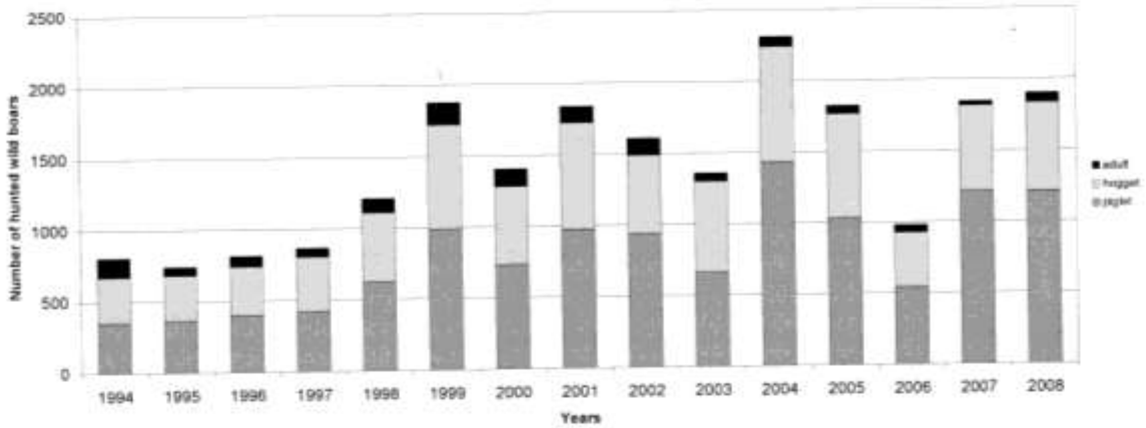

Fig. 1. Numbers of hunted wild boars in Křivoklát region in the years 1994–2008

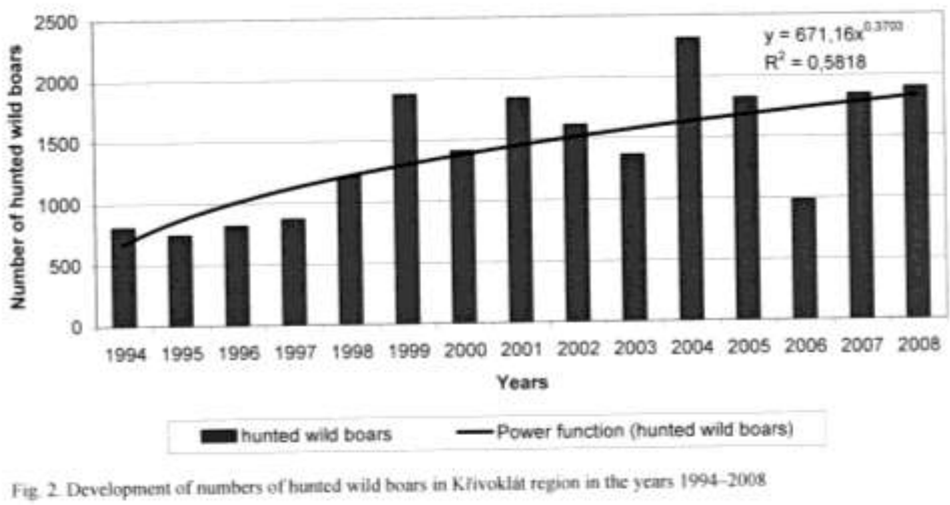

Fig. 2. Development of numbers of hunted wild boars in Křivoklát region in the years 1994–2008

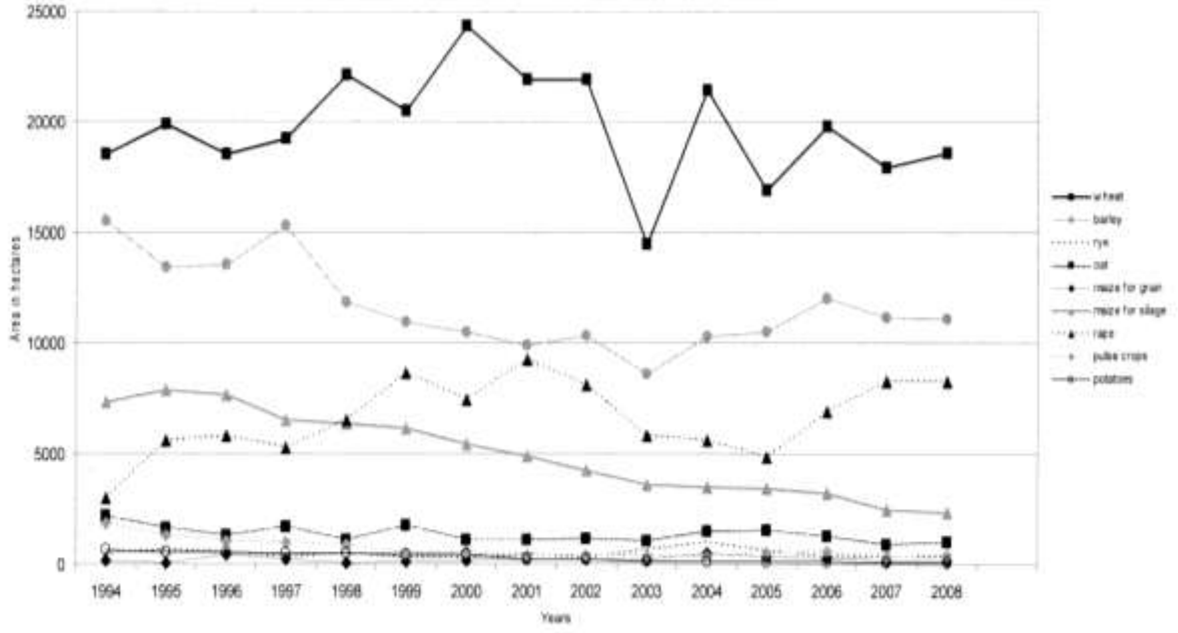

Fig. 3. Acreage development of the main farm crops in Rakovník and Beroun districts in the years 1994–2008

and wheat), which also provide very good cover conditions due to long vegetation period. This marked impact could influence the population number of wild boars in Křivoklát region and its neighbourhood. Portion of the winter crops was approximately 50% until 1997 and since 1998 was ca. 60% and nowadays it is within the range of 60–65%. Permanent increase of wild boar numbers in the region of Křivoklát is also evidently caused by high rate of autumn and winter supplementary feeding (especially by corn and waste cereals).

Evaluation of occurrence of oak and beech mast years in the area of Křivoklát was performed by the staff of the company Forests of the Czech Republic, namely by the forest administrations of Křivoklát and Lužná. The intensity of occurrence of mast trees in given year was evaluated by five-place scale.

Wild boar abundance and climatic conditions in early spring

If we accept correlation between yearly bags of wild boars and population size, then fluctuation in the years 2000 and 2005, but especially in 2003 and 2006 can be caused to a certain extent by climatic conditions. Very low air temperature at the ground surface could influence mortality of newborn piglets, which corresponds with conclusions of G e t h o f f e r et al. (2007). Figs 5 and 6 represent average minimal temperatures at the ground surface in decades in February and March when piglets incubate. It is obvious that very low temperatures were recorded especially in years 1996, 2003, 2005, and 2006. There is always marked fall of hunted wild boars with exception of 1996 (Fig. 1) in given year-direct impact of unfavourable climatic conditions at the time of piglet delivery. From the statistical evaluation by means of PCA arise to dispersion of the values that contribute particularly values measured in 2nd and 3rd decades of February and early March (PC2: 0.35; 0.37 or 0.32 – Table 2). Duration and depth of snow can be important factors affecting also natality and fecundity.

CONCLUSIONS

The results of the statistical enquiry of number of hunted wild boars in the Křivoklát region in period 1994–2008 show permanent increase of wild boar numbers together with increasing rate of piglets in population. Principal component analysis revealed that value variance of number of hunted wild boars is explained especially by food factors and partly by combination of food and climatic conditions in early spring. Minimal temperature measured at the ground surface partly influenced survival of piglets born in the second part of February and as early as March. Occurrence of oak and beech mast years led to increased numbers of hunted wild boars in the subsequent year. The reason can be the fact that increased food offer of acorns and beechnuts can influence positively wild boar reproduction but also it can influence negatively success of individual hunting on places where wild boars are attracted.

Acknowledgements

The authors would like to thank Jaroslava Nešvarová (Municipal Office in Beroun), Jiří Tomica (Municipal Office in Rakovník), Josef Konvalinka (Ministry of Agriculture), and Jiří Reich (ZZN Rakovník) for sharing their data.

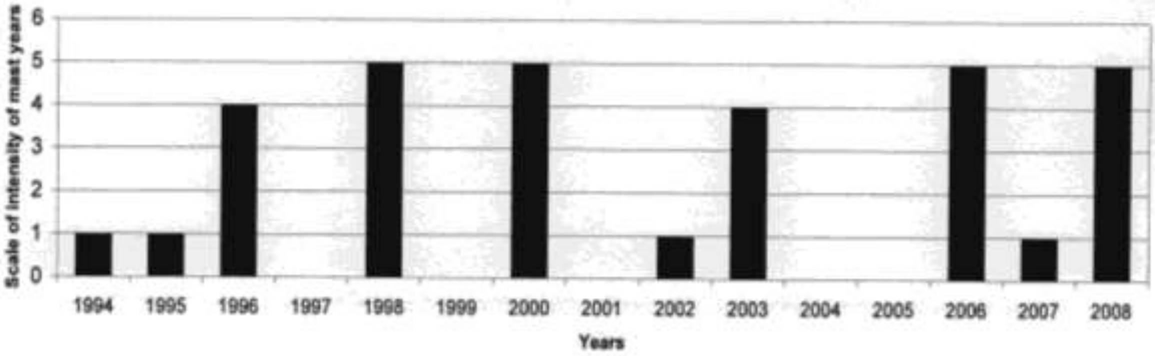

Fig. 4. Occurrence of oak and beech mast years in Křivoklát region in the years 1994–2008

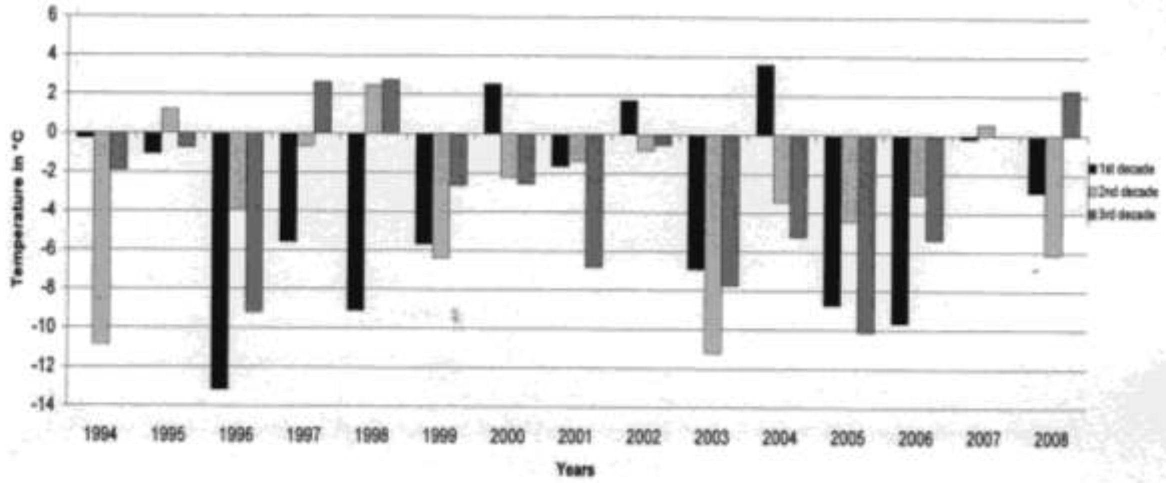

Fig. 5. Average minimal temperatures at the ground surface in February

Table 2. Results from a principal component analysis based on data from 1994–2008 for sixteen variables (bold type indicates statistical significance)

	Eigenvectors				
Variable	PC1	PC2	PC3	PC4	PC5
d1	−0.02622	0.203171	**0.469631**	0.194268	0.234808
d2	−0.02442	**0.348342**	−0.22902	**0.398284**	0.030568
d3	0.225101	**0.365058**	0.101638	0.134304	−0.19205
d4	0.22054	**0.324427**	0.210442	−0.11741	−0.24949
d5	−0.04755	0.044661	**0.510871**	0.255981	0.053927
d6	0.045853	−0.07187	**0.317117**	**−0.55027**	**0.395697**
wh	0.038968	**0.363634**	0.002906	0.167944	**0.626624**
ba	**0.399218**	−0.0736	−0.08554	0.075788	−0.00974
ry	−0.05517	**−0.33776**	0.077802	**0.501158**	0.012178
oa	**0.324017**	−0.24603	0.200869	−0.06789	0.163706
mg	−0.20646	**−0.3296**	−0.04922	0.252726	0.306198
ms	**0.401679**	0.00468	−0.11959	0.125344	0.073813
ra	−0.2362	**0.382062**	−0.05981	−0.11863	−0.01546
pc	**0.428726**	−0.12573	−0.00188	0.043307	−0.01997
po	**0.42583**	0.030293	−0.09	0.0478	0.097103
my	0.03491	0.089954	**−0.47822**	−0.12475	**0.395404**

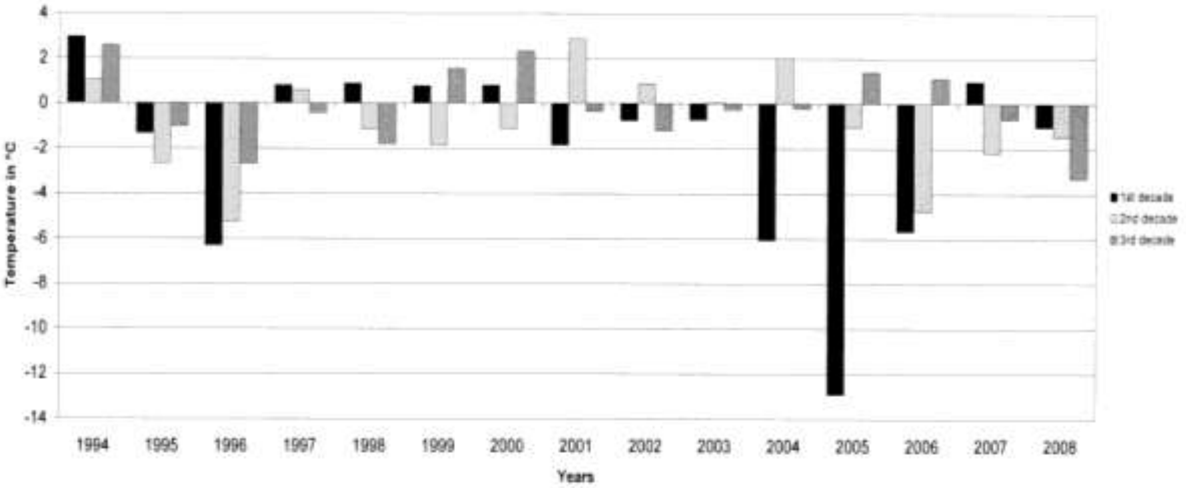

Fig. 6. Average minimal temperatures at the ground surface in March

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III

Hanzal, V., Ježek, M., Janiszewski, P., Kušta, T. (2012)

A contribution to determining craniometric values for wild boar (Sus scrofa) in the Czech republic

Sylwan, in press

A contribution to determining craniometric values for wild boar (*Sus scrofa*) in the Czech Republic

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Abstract

The research deals with evaluating craniometric values for wild boar mandibles in the České Budějovice district (South Bohemian region) of the Czech Republic. A total of 993 mandibles from individuals of various ages were measured. Six dimensions were taken for each mandible. Age was determined according to teeth development. Data was evaluated using basic statistical methods in Statistica 9.0. The wild boar occurring in the České Budějovice district do not significantly differ morphologically from those in other areas where they occur. Sexual dimorphism during growth of the mandible is already manifested in the youngest individuals (males having larger mandibles), and therefore mandible development differs from that of, for example, weight, where differentiation occurs only at later age. No statistically significant differences were determined between years 1999 and 2000.

Keywords: wild boar, morphometrics, mandible, sexual dimorphism

Introduction

The wild boar is one of the most common and widespread large mammals in the Old World. It occurs in most of Eurasia, where it is relatively common in woodlands and reed bed areas (Nowak 1999). The wild boar's wide geographic distribution results from the large physical variability in characteristic of the species. Accordingly, the species also has been subdivided into several geographical subspecies (e.g. Epstein 1971, Groves 1981, Mayer and Brisbin 1991, Genov 1999). However, currently from Variability is manifested not only on a geographical basis, but there also are significant temporal changes in growth and physical development (Pedone et. al. 1995, Stube et al. 1980). Food source availability plays an especially important role in physical development, and this is also manifested in female reproductive characteristics (Hebeisen 2007, Santos et al. 2006, Maillard et al. 2004, Ježek et al. 2011).

Materials and Methods

Mandibles from a total 993 wild boar hunted in the České Budějovice district (South Bohemian region) during 1999 and 2000 were collected within the study. The studied area has forest coverage of 32%. We measured 6 basic mandibular dimensions on the mandibles: mandible width (orale, between the lateral points of the coronoid processes), width at mandibular diastema (measured at the narrowest points of the mandible between C and P4), mandible height – orale (measured from the lower plane of the mandible), height at mandibular diastema, mandible length – measured from infradentales to the posterior edge of the condyloid process (Figure 1). Age was determined according to teeth development and each individual was placed into one of the following age classes (Briederman 1970) (Table 1).

age class	age
1	3-4 months
2	5-10 months
3	10-12 months
4	12-14 months
5	14-16 months
6	18-20 months
7	21-24 months
8	24 months and older

Table 1: Age classes according to Briederman (1970)

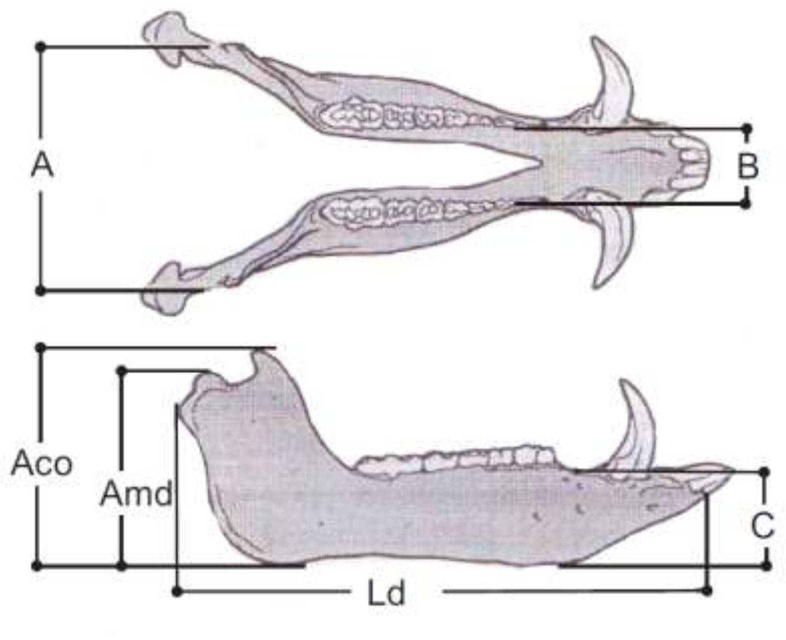


Figure 1: Measured mandible dimensions

The data was processed in Microsoft Excel 2007. Statistica 9.0 was used for statistical processing. Tests for normality and homogeneity were performed for all data. A test for distribution normality (Kolmogorov–Smirnov and Lilliefors tests for normality) and a test for homogeneity of variances (Cochran's, Hartley's and Bartlett's tests) were preformed for all variables. Data conforming to the normality condition was compared using Student's t-test. The non-parametric Kruskal-Wallis test was used for the analysis of variables which did not conform to the homogeneity of variance condition.

Results and discussion

Mandible dimensions were analyzed, and sexual dimorphism as well as year-on-year differences in growth development were monitored in the first 2 years of age. Statistically significant differences were proven for all dimensions in all age classes. Results are presented in Tables to . The range of morphometric indicators determined in all age classes fall within those values determined for the territory of the Czech Republic (Wolf 1987; Kratochvil et al. 1986) and Europe (Niethammer, Krapp 1986; Baubet et al. 1995; Gallo Orsi et al. 1995; Moretti 1995; Briedermann 1986).

It is evident from the results that sexual dimorphism is especially manifested in dimension B, where a difference occurs in most age classes. Although differences between males and females in other dimensions were not proven to be significant, sexual dimorphism is conclusively shown by the mandibular growth curves. The differences between males and females are discernible in all dimensions. The significant difference of dimension B supports the rule-of-thumb in popular science books that the males have wider and relatively shorter heads than do females (Hell 1986, Wolf 2000, 1987, 1984, Babička 1984, Krže 1982), and it is one of the identifying characteristics. From the viewpoint of mandibular development and growth, our findings do not support the hypothesis of wild boar sexual differentiation at a later age. For example, Gallo Orsi et al. (1995) and Pedone et al. (1995) report a weight differentiation between males and females at 14–15 months of age, Ježek et al. (2011) at 18–20 months, and Moretti (1995) already at 13–14 months. Our results also did not confirm the findings of Moretti (1995) that the females grow faster than males until 12 months of age. Those authors posit a change in energy utilization strategy as the reason for weight differentiation. The males put all energy into growth, while the females, from the 12th month onward, apportion the energy between growth and reproduction. It is evident from our findings, however, that this differentiation occurs much earlier. Our results can support the hypothesis that body weight need not be correlated with cranial dimensions (Hell, Paule 1983).

Age class	**Female**							**Male**						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	***19***	5.8	4.6	6.8	0.5	0.7	0.2	***23***	5.9	4.9	6.8	0.2	0.5	0.1
2	***55***	6.5	5.8	8.0	0.2	0.4	0.1	***31***	6.7	5.9	7.4	0.1	0.3	0.1
3	***387***	7.5	5.9	8.7	0.3	0.5	0.0	***313***	7.8	6.0	9.9	0.4	0.6	0.0
4	***1***	8.5	8.5	8.5				***16***	8.6	7.8	9.2	0.1	0.4	0.1
5	***54***	8.4	7.1	9.8	0.3	0.5	0.1	***41***	8.6	7.2	9.8	0.3	0.6	0.1
6	***3***	8.8	8.2	9.4	0.4	0.6	0.3	***29***	8.8	8.1	9.7	0.1	0.4	0.1
7	***6***	8.8	8.4	9.8	0.2	0.5	0.2	***7***	8.9	7.8	9.4	0.3	0.6	0.2
8	***12***	8.8	8.1	9.7	0.2	0.4	0.1	***1***	9.3	9.3	9.3			

Table 2: Dimension A in males and females (significantly different age classes are highlighted in red)

Growth in mandible width (orale) between the lateral points of the coronoid processes is the steepest within 1 year of age. By the 4th month of age (age class 1), the mandible width reaches 66% and 64% of that of an adult animal in females and males respectively. At 12 months of age (age class 3), females reach 85% and males 83% of the width for adult animals over 2 years of age.

Age class	Female							Male						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	19	2.6	2.2	2.9	0.0	0.2	0.0	23	2.9	1.9	3.7	0.1	0.3	0.1
2	55	3.0	2.5	4.9	0.2	0.4	0.1	31	3.2	2.9	3.5	0.0	0.2	0.0
3	387	3.3	2.2	8.6	0.3	0.5	0.0	313	3.3	2.4	7.3	0.1	0.4	0.0
4	1	3.6	3.6	3.6				16	3.4	2.7	3.7	0.1	0.3	0.1
5	54	3.4	2.8	4.1	0.1	0.3	0.0	41	3.7	3.3	4.8	0.1	0.3	0.0
6	3	3.6	3.5	3.7	0.0	0.1	0.1	29	3.9	3.4	4.4	0.1	0.3	0.0
7	6	4.1	3.6	4.4	0.1	0.3	0.1	7	4.1	3.8	4.7	0.1	0.3	0.1
8	12	3.9	3.7	4.3	0.0	0.2	0.1	1	3.8	3.8	3.8			

Table 3: Dimension B in males and females (significantly different age classes are highlighted in red)

Until 4 months of age, mandible width at the narrowest point (diastema) reaches 66% and 76% of the width of 2-year-old individuals in females and males, respectively, and at 1 year of age it reaches 84% and 86% of these values.

Age class	Female							Male						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	19	5.1	3.6	6.0	0.5	0.7	0.2	23	6.3	4.3	7.8	0.5	0.7	0.1
2	55	6.9	5.0	9.1	0.8	0.9	0.1	31	7.9	7.1	9.1	0.2	0.4	0.1
3	387	7.7	3.2	11.5	2.0	1.4	0.1	313	7.8	3.2	10.2	1.0	1.0	0.1
4	1	8.7	8.7	8.7				16	7.9	5.7	9.8	1.0	1.0	0.3
5	54	8.1	6.0	9.9	0.8	0.9	0.1	41	9.3	7.9	11.3	0.6	0.8	0.1
6	3	9.1	8.4	9.6	0.4	0.6	0.4	29	9.4	4.1	11.2	1.4	1.2	0.2
7	6	10.4	9.5	11.4	0.4	0.7	0.3	7	10.1	9.6	11.0	0.2	0.5	0.2
8	12	10.2	9.5	10.8	0.2	0.4	0.1	1	9.9	9.9	9.9			

Table 4: Dimension AMd in males and females (significantly different age classes are highlighted in red)

Up to the first year of age, mandible height (AMd – aborale) grows more slowly than its width. At 4 months of age, females reach 50% and males 62% of the mandible width of 2-year-old individuals. At 1 year of age, females reach 75% and males 77%.

Age class	Female							Male						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	*19*	*5.8*	*4.2*	*6.7*	*0.5*	*0.7*	*0.2*	*23*	*7.1*	*4.9*	*8.6*	*0.6*	*0.7*	*0.2*
2	*55*	*7.9*	*6.0*	*10.7*	*1.1*	*1.0*	*0.1*	*31*	*9.0*	*7.7*	*9.8*	*0.2*	*0.5*	*0.1*
3	387	8.8	3.3	12.9	2.3	1.5	0.1	313	8.9	3.8	11.4	1.1	1.0	0.1
4	1	10.3	10.3	10.3				16	9.1	6.4	10.8	1.2	1.1	0.3
5	54	9.3	7.0	11.4	1.0	1.0	0.1	41	10.5	8.9	12.6	0.6	0.8	0.1

6	3	10.5	10.5	10.6	0.0	0.0	0.0	29	10.8	9.7	12.8	0.4	0.7	0.1
7	6	11.6	10.9	12.6	0.3	0.6	0.2	7	11.4	10.7	12.7	0.5	0.7	0.3
8	12	11.3	10.6	12.3	0.2	0.4	0.1	1	10.9	10.9	10.9			

Table 5: Dimension ACo in males and females (significantly different age classes are highlighted in red)

At 4 months of age, mandible height (ACo) reaches 52% in females and 62% in males of the mandible height (ACo) of 2-year-old individuals. At 1 year of age, the females and males both reach 78%.

Age class	**Female**							**Male**						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	19	2.3	1.9	2.6	0.0	0.2	0.0	23	2.6	1.9	3.3	0.1	0.3	0.1
2	55	2.9	2.3	3.9	0.1	0.3	0.0	31	3.2	2.6	3.5	0.0	0.2	0.0
3	387	3.3	1.7	12.6	0.8	0.9	0.0	313	3.3	1.9	9.3	0.3	0.5	0.0
4	1	3.7	3.7	3.7				16	3.4	2.6	4.0	0.2	0.4	0.1
5	54	3.5	2.2	4.8	0.2	0.5	0.1	41	3.7	3.1	4.3	0.1	0.3	0.0
6	3	3.8	3.5	4.1	0.1	0.3	0.2	29	4.2	2.8	10.6	1.6	1.3	0.2
7	6	4.1	4.0	4.4	0.0	0.2	0.1	7	4.0	3.7	4.4	0.1	0.3	0.1
8	12	4.2	3.9	4.9	0.1	0.3	0.1	1	3.8	3.8	3.8			

Table 6: Dimension C in males and females (significantly different age classes are highlighted in red)

At 4 months of age, mandible height (C – diastema) reaches 54% in females and 68% in males of that of 2-year-old individuals. At 1 year of age, this figure is 79% in females and 83% in males.

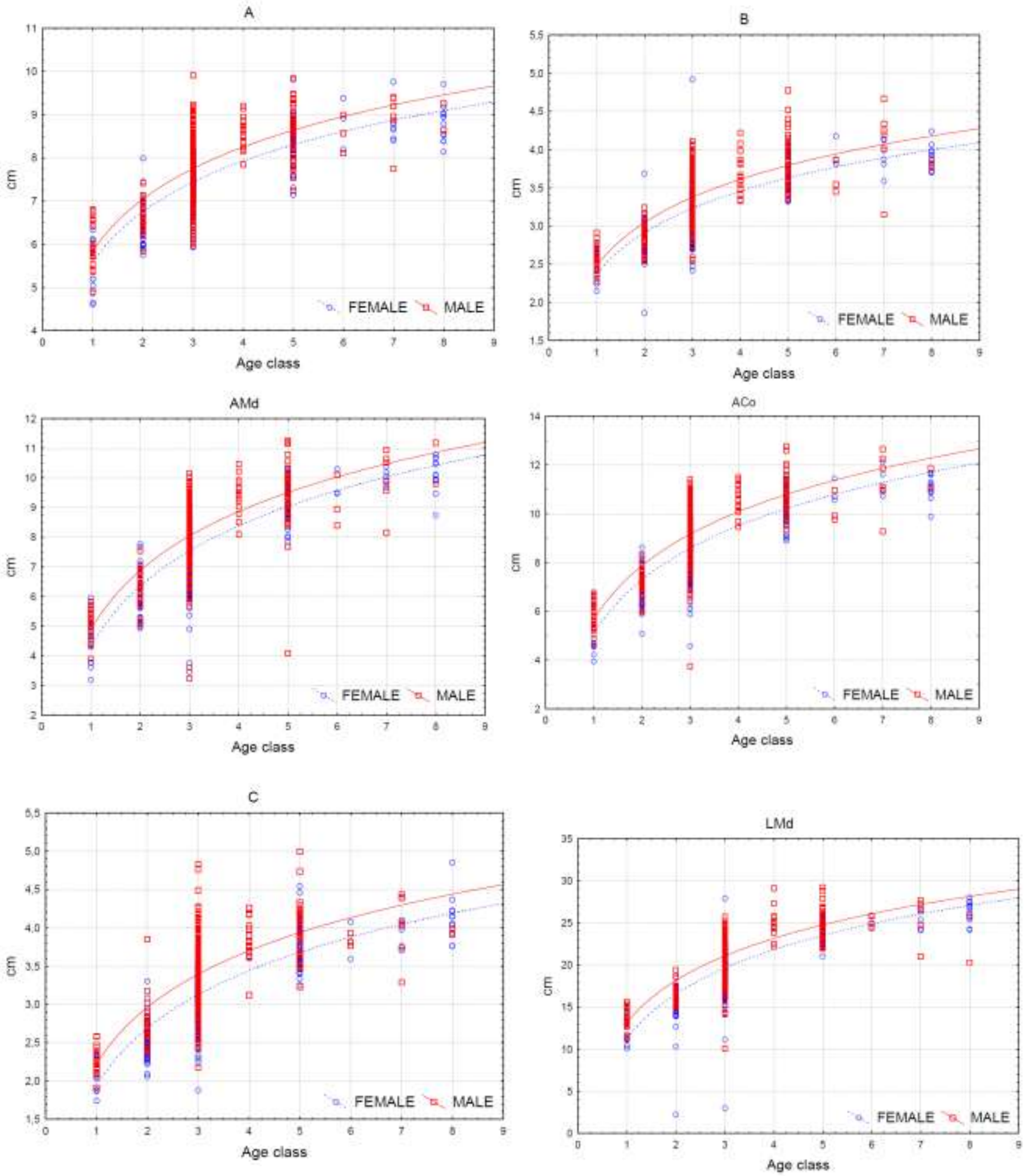
Age class	Female							Male						
	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error	Valid N	Mean	Min	Max	Var	Std. Dev.	Std. error
1	19	13.8	11.1	15.7	1.7	1.3	0.3	23	16.0	10.4	17.6	2.1	1.4	0.3
2	55	17.9	10.3	27.9	7.4	2.7	0.4	31	20.0	17.4	21.8	1.1	1.1	0.2
3	387	20.1	2.2	27.9	13.4	3.7	0.2	313	20.3	10.1	25.8	5.4	2.3	0.1
4	1	23.5	23.5	23.5				16	21.6	16.0	25.1	5.1	2.3	0.6
5	54	21.5	17.3	25.8	5.1	2.3	0.3	41	24.2	21.1	29.1	2.8	1.7	0.3
6	3	23.9	22.8	25.7	2.5	1.6	0.9	29	25.1	22.0	29.3	2.0	1.4	0.3
7	6	26.4	25.4	27.8	0.7	0.8	0.3	7	26.1	24.3	27.7	1.5	1.2	0.5
8	12	26.5	24.2	28.0	1.6	1.2	0.4	1	25.4	25.4	25.4			

Table 7: Dimension LMd in males and females (significantly different age classes are highlighted in red)

Mandible length (LMd) reaches 52% in females and 62% in males at 4 months of age. At 1 year of age it reaches 75% in females and 79% in males.

It is evident from the results that in the first 4 months a wild boar's mandible grows more quickly in width than in height and length. Until 4 months of age, dimensions related to mandible width reach almost 2/3 of the dimensions at 2 years of age in both males and females. On the other hand, dimensions relating to mandible height and length at 4 months of age reach 1/2 those of 2-year-old size in females, and the males within this age grow significantly faster – in 4 months reaching almost 2/3 of the adult height and width.

Mandible growth evidently does not correspond with the increase in weight. According to Wolf (1986), piglets at 1 year of age reach 37% of the weight of 2-year-old individuals. In Switzerland, Moretti (1995) reports this figure to be 40%, and in some areas, according to Ježek et al. (2011), the weight reaches even 45% of that of 2-year-old individuals.



Graph 1: Development of the measured mandible dimensions in females and males

In age class 1, no statistically significant difference was found between 1999 and 2000 in any of the dimensions. In age class 2, a statistical difference between 1999 and 2000 was proven for the dimensions AMd (t=3.331; p=0.001) and ACo (t=3.111; p=0.002). In age classes 3, 4, 5, 6 and 7, no significant difference in mandible dimensions between 1999 and 2000 were observed.

Conclusion

Wild boars occurring in the České Budějovice district do not morphologically differ from those in other areas where they occur. In mandible growth, sexual dimorphism occurs already in the youngest individuals (males having larger mandibles), and therefore the mandible development differs from that of, for example, weight, in which differentiation occurs only at later age. No statistically significant difference was observed between years 1999 and 2000.

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IV

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MORTALITY OF LARGE MAMMALS ON RAILWAY TRACKS*

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As linear structures, railways (rail corridors) significantly affect life in the wild, have negative impact on animal population levels, and affect the very form and structure of inhabited biotopes. This article analyses and quantifies mammal mortality on the Plzeň–Horažďovice suburban railway line. The research was conducted over the 12 months from 1 January 2009 to 31 December 2009. During this period total 60 animals were run down, among them, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (*Sus scrofa*) and 2% with red fox *(Vulpes vulpes)*. The aim of the research was to analyse in detail individual sections of the track, whose land cover, land use, migration rate and wildlife-train collisions vary. The outcome of this work is to evaluate and assess the overall animal mortality and to determine the most affected wildlife species. The aforementioned results show that rail transport is dangerous for wild mammals, and it can be clearly said that the most endangered species is roe deer (*Capreolus capreolus*).

game; migration; barrier effect; population; population fragmentation

INTRODUCTION

The issue of mammal mortality, often discussed in connection with road transport, is known only marginally in relation to railways. The length of railway lines in the Czech Republic was 9,430 km as at 31 December 2008, of which 3,078 km are electrified railways and 6,352 are non-electrified railways. On average, 9,000 passenger trains criss-cross the Czech Republic every 24 hours. Based on these facts, there is no doubt that with this intensity of rail traffic there are frequent wildlife-train collisions. There are, however, very few Czech studies that have focused on this issue. Foreign publications about the influence of rail transport on wildlife migration and mortality include, for example, Barry, Aitken (1991), Becker, Grauvogel (1991), Gundersen, Andreassen (1998), Rodriguez et al. (1996) and Selmić et al. (2010).

The frequency of wildlife crossing railway lines is influenced by a number of factors, the most significant of them are: (i) character of the surrounding landscape and concentration of mammals in the vicinity, (ii) grade level (height) of the railway in relation to the geomorphology of the surrounding terrain (large mammals run onto the railway particularly in those places where the grade level of the railroad is at the level of the surrounding terrain), (iii) age of the railway (mammals run more often onto newly constructed railways), and (iv) food and migration needs of mammals.

Generally, routes with high traffic create obstacles that are difficult for the mammals to overcome during their migration, and these are directly life-threatening for the mammals due to animal-vehicle collisions (Trocmé, 2003). For large mammals, routes are usually not an absolutely impermeable barrier. That is only the true in cases of high traffic density or fencing. Traffic density, speed of vehicles and overall technical design of routes are the main aspects influencing the extent of the barrier effect (Aanen et al., 1991; Iuell et al., 2003 etc.).

The phenomenon known as population fragmentation is thus becoming a serious and very complicated issue of environmental protection and can have catastrophic consequences for the future structure of ecocenoses, biotopes and consequently also entire ecosystems. Therefore, there are efforts to protect the integrity of valuable areas by means of various legislative instruments not only on the national but currently also on the European level (Hlaváč, Anděl, 2001; Iuell et al., 2003). Isolated locations gradually lose their ability to perform their natural functions as places for the existence of viable animal populations and where these populations are able to reproduce repeatedly.

Monitoring of traffic routes' impacts on wild mammals is described in Clevenger, Waltho (2005), Fahrig, Rytwinski (2009), Saeki, Macdonald (2004) and elsewhere. Mammals and birds tend to be very vulnerable to rail transport, as shown also by studies conducted in Spain, the Netherlands and Czech Republic (Brandjes, Smit, 1999; Van der Grift, 1999; Havlín, 1987). Differences in mortality between species are well documented by the research of train-animal collisions on Spain's Madrid–Sevilla railway line. Along this railway, the annual mortality was estimated to be 36.5 run-down individuals/km (SCV, 1996). Around 57% of these victims were birds and 40% were mammals, while only 3% were reptiles and amphibians. European and North American studies show that many species of wild mammals are often killed by rail transport (Van

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Tighem, 1981; Child, Stuart, 1987; Belant, 1995; Wells, 1996).

An important issue, however, is what part of a population is actually affected by mortality on routes, or, more precisely, railways. The published data vary considerably depending on the specific research location. For example, Iuell et al. (2003) and Trocmé (2003) state that transportation kills some 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (Righetti et al., 2003) focused on deaths of roe deer and red deer (data from 1999) points to the fact that mortality caused by traffic is clearly the most common cause of death for both species (49.3% for roe deer, 33.2% for red deer). The second most commonly stated cause of death of roe deer *(Capreolus capreolus)* is agricultural technology (19.8%), followed by other factors (9.1%), then age and diseases (7.1%). The second most common cause of death of red deer *(Cervus elaphus)* is other accidents (fall, avalanche, etc.), followed by other causes (14.7%), and then age and diseases (12.2%). The results show that the specific situation in a given territory must always be taken into account.

Species particularly sensitive to barrier effect and traffic mortality are: (i) rare species with small local populations and large individual territories, such as large carnivores (otter, lynx, etc.), (ii) species that migrate daily or seasonally between local biotopes (some ungulates use various environments during daytime and because of that they must cross roads and railways in most cases), (iii) species with long seasonal migrations from summer to winter territories, such as moose or reindeer (Pfister, 1999; Iuell et al., 2003).

According to Huijser and McGowen (2003), animal-vehicle collisions affect human beings' safety, their property and the animal population itself. In the USA, the total number of collisions with large ungulates has been estimated at more than 1 million a year.

Similar figures are available in Europe as well. In Europe (apart from Russia), more than a half million vehicle-ungulate collisions are recorded each year. These cause at least 300 human deaths, 30,000 human injuries, and property damage of more than EUR 1 billion (Trocmé, 2003). These figures show an increasing trend. Some species of mammals have come to the brink of extinction due to collisions with vehicles and trains.

MATERIAL AND METHODS

The period of study was from January to December 2009 and was monitored section of the railway line between Plzeň and Horažďovice suburb is interwoven with 18 hunting districts: Horažďovice, Velký Bor, Třebomyslice, Pačejov, Milčice, Štirka Mysliv, Nekvasovy, Mohelnice, Klášter, Srby Sedliště, Chejlava, Vlčice, Ždírec, Blovice, Zdemyslice, Žákava, Šťáhlavy and Starý Plzenec. Roe deer (*Capreolus capreolus*) populate all of those hunting districts named, and there are small numbers of common pheasant (*Phasianus colchicus*) and European hare *(Lepus europaeus)*. Moreover, wild boar (*Sus scrofa*) and red fox *(Vulpes vulpes)* regularly occur in all of the hunting districts. Moufflon *(Ovis musimon)*, fallow deer *(Dama dama)* and red deer (*Cervus elaphus*) occur locally along the monitored railway. In the Velký Bor hunting district, rock partridge (*Alectoris graeca)* occurs as well.

Species of animals occurring in individual localities were obtained from individual gamekeepers or workers of municipal environmental departments. Along the railway line in the monitored section, fields and grasslands make up 84.2%, forest 10.1% and brush 5.7% of the represented biotopes. The railway line was monitored by train drivers who passed through this section within the monitored period. They recorded the numbers of run-down animals along the line and localized the surroundings of any site of collision (forest, field, brushwood). Data acquired in this way were continuously collected and recorded in a field diary. In addition, the precise kilometer mark of the finding was recorded for every run-down animal according to the track kilometer system of the Czech Railways, particularly to enable precise identification of the section of railway with the highest number of run-down animals and to exclude inaccuracies arising from the possibility that two train drivers would record the same run-down animal for a kilometer of track. Game species that was run down by the driver when driving was recorded, as well as wildlife that was seen along the track and had been already run down by another rail vehicle. During the entire period, several walking inspections along the track were carried out, whereby photo documentation was taken and the surroundings of the track were described in individual sections. Also a video record of the railway track on the line between Plzeň and Horažďovice suburb was made using a video camera placed behind the front window of the train as agreed with the train driver.

When calculating the number of collisions of the most affected animals the number of trains on the line between Plzeň and Horažďovice suburb was first determined according to the Czech Railways timetable for 2008/2009, with differentiation for weekdays, Saturdays, Sundays and public holidays. When calculating the animal-rail vehicle collision for each month separately, the procedure was such that the number of run-down individuals of the given species in individual months was divided by the number of train kilometers for each month, which gave the number of run-down individuals per 1 km of track. The data obtained were further examined to identify, in which biotope the animal-train collisions occurred.

The monitored section of the railway is traversed by 326 passenger trains per week. Moreover, it was necessary to add freight trains, which amounted to 126 according to the findings of the drivers. Daily average for the monitored section of the track is thus 65 passenger and freight trains.

Statistical analysis was carried out using Kruskal-Wallis ANOVA and basic statistical variables. Numbers of individual species of animals run down on the track were compared. This test also analysed in which locations (forest, field, brush) the collisions are most frequent. Further-more, the measured data were analysed using chi-square test (observed vs. expected frequency). This test was used to determine whether the species of mammals are run down with the same regularity in individual months. The differences between run-down species of animals and between the localities where the collisions occur were graphically illustrated using cluster analysis.

RESULTS AND DISCUSSION

The data obtained were evaluated by a combination of several procedures on the basis of which we found that out of the total number of 60 wildlife-rail vehicle collisions 2 individuals were run down in January, 15 individuals in February, 4 in March, 5 in April, 4 in May, 3 in June, 4 in July, 5 in August, 5 in September, 4 in October, 4 in November, and 5 in December (Fig. 1).

By means of Kruskal-Wallis ANOVA, we recorded a statistically significant difference between the animals. [H (5, $N = 72$) = 40,89313 $p = 0.0000$) and Chi-square = 34,95201 $sv = 5$ $p = 0.0000$]

According to this test we recorded statistically significant difference in number of run down animals between roe deer (*Capreolus capreolus*) and pheasant (*Phasianus colchicus*) ($p = 0.469$), between roe deer (*Capreolus capreolus*) and wild board (*Sus scrofa*) ($p = 0.0001$), between roe deer (*Capreolus capreolus*) and red fox (*Vulpes vulpes*) ($p = 0.0000$), and between roe deer (*Capreolus capreolus*) and bird of prey ($p = 0.0002$).

When we examined the regularity of animal-train collisions in individual months in the monitored section of track using chi-square test (observed vs. expected frequency), we obtained these results:

- Roe Deer – chi-square = 12.66667, $sv = 11$, $p = 0.315674$
- Hare – chi-square = 6.800027, $sv = 11$, $p = 0.815037$
- Pheasant – chi-square = 1.000000, $sv = 1$, $p = 0.317311$

These results show that at the significance level of $p = 0.05$ there was no demonstration as to a statistically significant difference in animal-vehicle collisions between individual months.

Figs 2 and 3 indicate mortalities for individual species, which most often occur in places where there is a field or meadow. This can be explained by the fact that the landscape in the surroundings of the monitored track is mostly made up by fields or meadows (84.2%), where animals migrate to obtain food.

Fig. 4 clearly demonstrates how animal-vehicle collisions occur more frequently in fields and meadows, but Kruskal-Wallis ANOVA showed no statistically significant difference between the localities of the environments where these collisions occur [H (2, $N = 18$) = 4.012346,

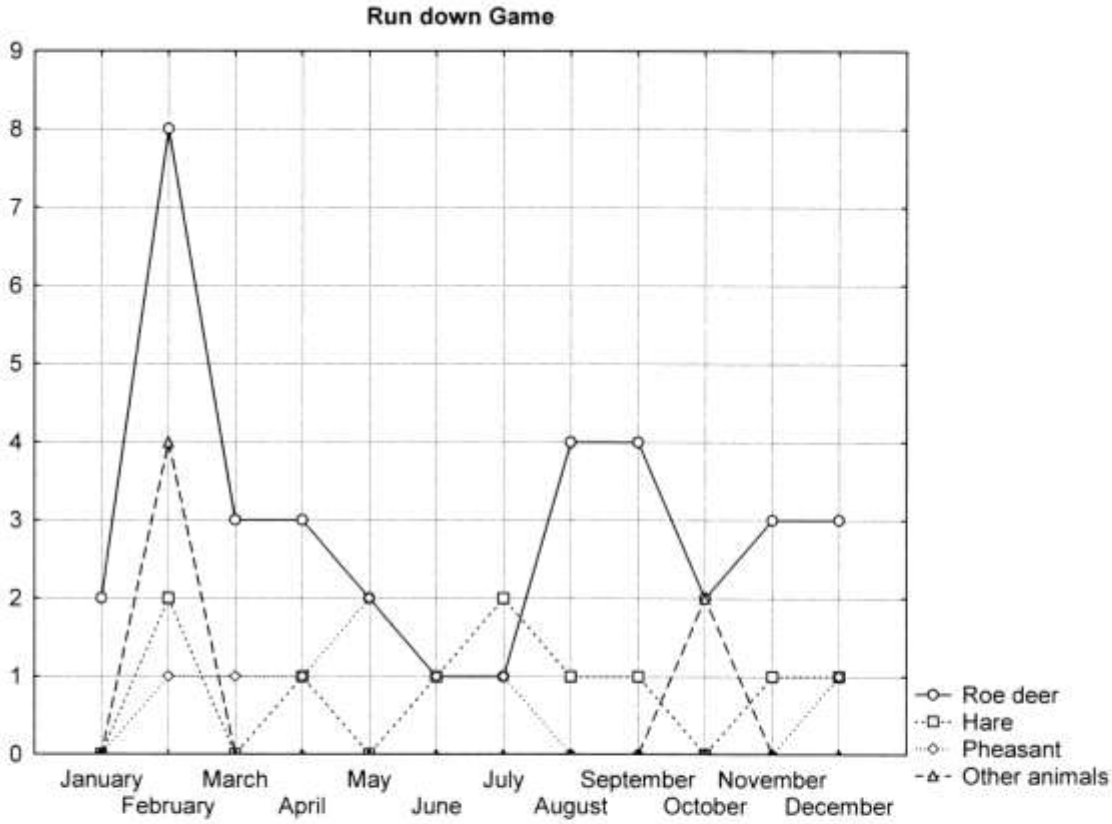
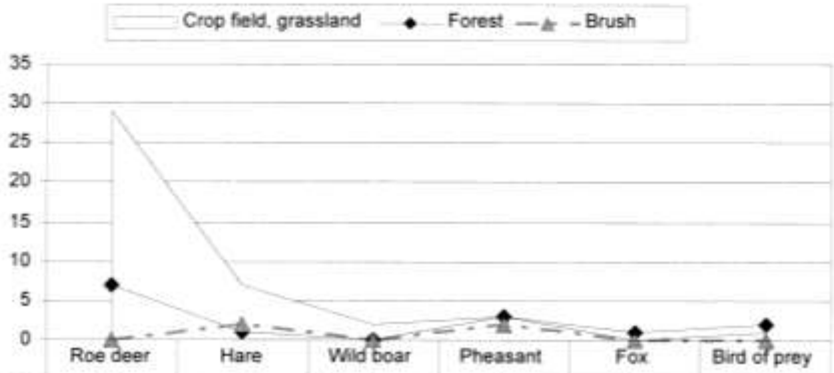


Fig. 1. Mortality of roe deer (*Capreolus capreolus*), European hare (*Lepus europaeus*) and common pheasant (*Phasianus colchicus*) and other animals in the monitored part of the railway



	Roe deer	Hare	Wild boar	Pheasant	Fox	Bird of prey
Crop field, grassland	29	7	2	3	0	1
Forest	7	1	0	3	1	2
Brush	0	2	0	2	0	0

Fig. 2. Mortality of animals in different types of environment

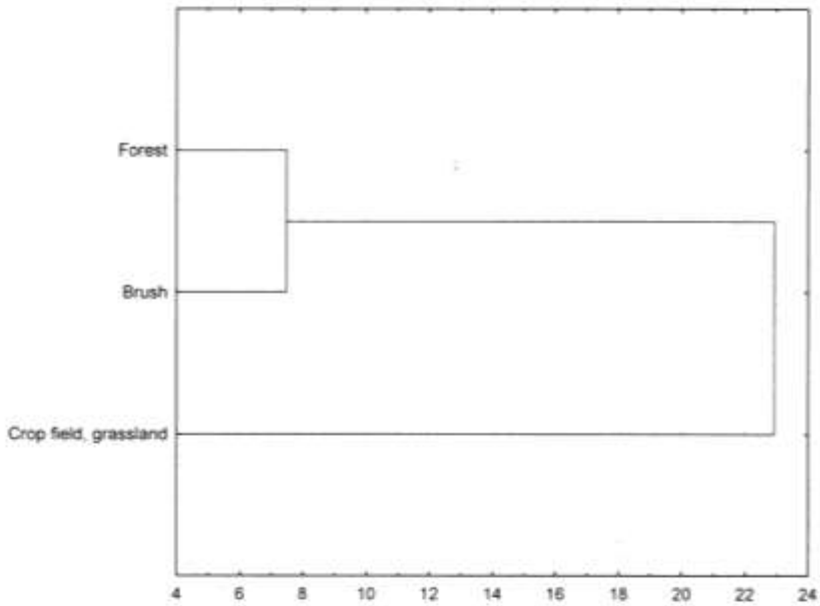


Fig. 3. Results of cluster analysis comparing animal mortality, depending on the type of environment

$p = 0.1345$ and chi-square = 1.333333 df = 2 $p = 0.5134$], and that was true also in relation to the different dimensions of individual areas that had not been taken into account.

At present, further research is known in the Czech Republic that is being conducted on the railway line between Trhový Štěpánov and Benešov u Prahy (Jankovský, Čech, 2001). It is a 33-km railway track, which crosses a number of very different biotopes and allows a more comprehensive view on the entire issue. The first research on this track was carried out in winter 1999–2000 and consisted of several walking examinations along the track and analyses of skeletal findings of animals run down by trains. The analysis showed that the most affected species mainly comprise roe deer (*Capreolus capreolus*) and European hare (*Lepus europaeus*). Leporids were run down in 32%, even-toed ungulates in 22% (roe deer in the absolute majority of cases), carnivores in 18%, birds in 10%, insectivora in 4% and reptiles in 2% of cases. Findings of body residues occurred in those sections where the line does not form a distinct height barrier, whether with its embankment or ditch. In these places, which are substantially elevated and often overgrown with brush, numerous carcasses of pheasants were found. Although there are several busy roe deer passages crossing the ditched railway, skeletal remains were never found at these intersections or in their vicinity. All killed individuals of roe deer (*Capreolus capreolus*) and European hare (*Lepus europaeus*) were found on open, flat sections of the track, in the vicinity of which the animals stayed over the long term. The most frequent animal-train collisions occur at night, according to Czech Railways personnel. In com-

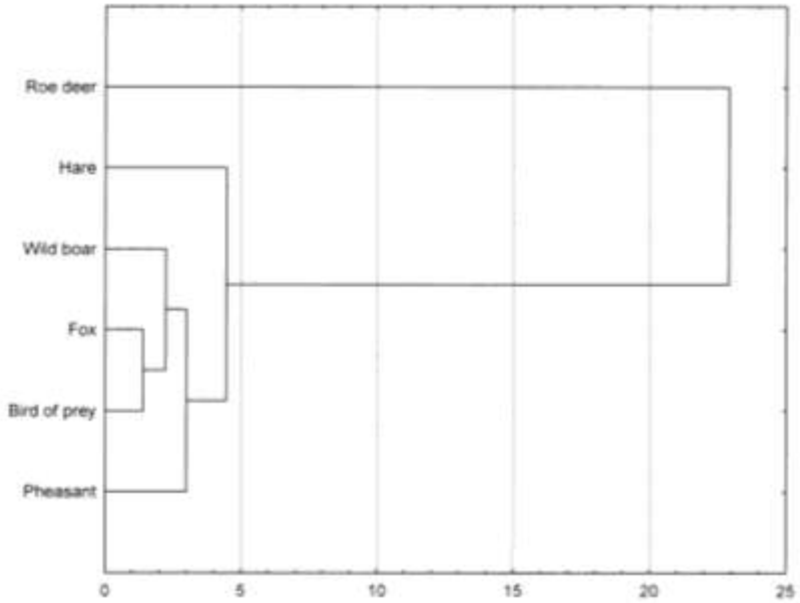


Fig. 4. Results of cluster analysis of comparing animal mortality in the monitored section of track

parison with our results can be found significant similarities, thus that the most affected kind of wildlife is roe deer (*Capreolus capreolus*) and hare (*Lepus europaeus*). The run down were frequently occurred in the open farmed landscape too like in our case study.

In May 2006, another research project on the railway line between Trhový Štěpánov and Benešov u Prahy was conducted. In analysing the second research, an increase in mortality of roe deer (*Capreolus capreolus*) was observed (Jankovský, Čech, 2008). In comparison with our results, this study indicates the fact that the high number of wildlife collisions with train occur in large forest complexes, too.

A 2008 research project from the Czech Moravian Highlands is known as well. In a 6-km section of the railway line (Dobrá voda u Pelhřimova – Hříběcí), an inventory of foot inspections performed on a regularly weekly basis had as its aim to quantify mortality of large mammals due to rail transport and to identify, which species are the most endangered due to this transport. Animals were searched for with the assistance of a trained blood-tracking dog. Almost the entire section passes through a forest complex. It is a line, which is used for regional trains only, and there is limited rail freight transport. Over the monitored interval (1 year), 10 dead roe deer (*Capreolus capreolus*), 3 European hares (*Lepus europaeus*) and one wild boar (*Sus scrofa*) were found (Kušta, Ježek, 2009).

Andreassen et al. (2005) analysed the efficiency of odour fencing, removal of vegetation along track and diversion feeding along a railway line in Norway. The research commenced in 1985 and ended in 1990, during which time 1,045 animal-vehicle collisions were recorded. Reduction of accidents by 46% was proven over the period when actions to reduce mammal mortality were taken on the track. Removal of vegetation and diversion feeding proved to be safe ways to reduce collisions. Noise barriers along the railway line are also very effective, although these create a complete barrier for most animals and significantly contribute to landscape fragmentation and significant increase of barrier effect. The effectiveness of odour fencing appeared to be very questionable in this research. According to the results of this study the most suitable mitigation measures recommended led to reduction of the number of wildlife collisions with train consist in removal of vegetation along the railway tracks.

By comparing this research to the aforementioned studies that have already been conducted, we can conclude that the most affected species due to linear structures in the Czech Republic is roe deer (*Capreolus capreolus*), followed by European hare (*Lepus europaeus*). Mortality is probably the most visible impact of traffic on wild animal species. Millions of individuals are killed and injured every year by land transportation. It is believed that over the last 30 years transportation has become a major human activity causing mammal mortality and has thus overtaken even hunting.

CONCLUSIONS

During research on the 50-km Plzeň–Horažďovice suburb railway line (1 January 2009 – 31 December 2009), 60 animal individuals were run down. Among these, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (*Sus scrofa*) and 2% with red fox (*Vulpes vulpes*) (Mach, 2010). The data obtained also show that animal mortality on a single track (36 km long) is 52% and on a double track (24 km long) is 48%. Based on this finding, we cannot clearly agree with the statement that common single tracks are not a significant barrier for large mammals and that only multi-track lines are (Anděl et al., 2005). The aforementioned results clearly show that rail transport is a danger for wild animals. The species most endangered by animal-train collisions is the roe deer (*Capreolus capreolus*).

Fragmentation of animals' natural environments and fragmentation of natural ecosystems into smaller and smaller isolated biotopes is one of the greatest global threats to environmental protection and biological diversity (Broker, Vastenhout, 1995). Maintaining the migration potential of a landscape must be an integral objective of landscape planning policies and landscape planning itself. This assumption is one of the main theoretical bases for the concept of territorial systems of ecological stability. It must be taken into consideration in the case of large linear structures, which are a cause of both landscape fragmentation and decreased possibilities for animal migration (Sklenička, 2003).

The issue of ensuring migration permeability of the landscape (for species with large space requirements, like large ungulates and large carnivores) has for some time already been given great attention, particularly in relation to transportation structures, and there are currently specialized methodologies describing basic prerequisites and necessary measures (Anděl et al., 2006; Hlaváč, Anděl, 2001). Methodologies for evaluating fragmentation and migration permeability have been worked out for designing transportation structures. In practice, however, these methodological approaches are used very rarely. Detailed analysis in terms of fragmentation and migration permeability for linear structures is prepared only very rarely, and the implementation of necessary measures is itself also not very common.

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KUŠTA, T. – JEŽEK, M. – KEKEN, Z. (Česká zemědělská univerzita, Fakulta lesnická a dřevařská, Fakulta životního prostředí, Praha, Česká republika):

Mortalita velkých savců způsobená železniční dopravou.

Scientia Agric. Bohem., *42*, 2011: 12–18.

Železniční tratě (koridory) jako liniové stavby podstatně ovlivňují život ve volné přírodě, negativně působí na populační stavy živočichů a ovlivňují samotnou podobu a strukturu obývaných biotopů. Článek analyzuje a kvantifikuje mortalitu savců na železniční trati Plzeň–Horažďovice předměstí. Průzkum byl prováděn po dobu 12 měsíců od 1. ledna 2009 do 31. prosince 2009. Během tohoto období bylo nalezeno 60 uhynulých zvířat. Nejvíce kolizí (60 %) bylo zjištěno u srnce obecného (*Capreolus capreolus*), 17 % u zajíce polního (*Lepus europaeus*), 13 % u bažanta obecného (*Phasianus colchicus*), 5 % u řádu dravců (*Falconiformes*), 3 % u divokých prasat (*Sus scrofa*) a 2 % kolizí u lišky obecné (*Vulpes vulpes*). Cílem bylo podrobně zmapovat jednotlivé úseky tratě, které se liší krajinným typem (land cover), využitím krajiny (land use) a četností migrace a střetů živočichů s vlaky. Výstupem práce je vyhodnocení a posouzení celkové výše mortality zvěře a určení nejvíce ohrožených druhů živočichů. Z uvedených výsledků vyplývá, že železniční doprava je nebezpečím pro volně žijící savce, a jednoznačně lze říci, že nejohroženější zvěří je srnec obecný (*Capreolus capreolus*).

zvěř; migrace; bariérový efekt; populace; fragmentace populace

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Methodological aspects of monitoring of large mammals along traffic corridors: A case study (Lagomorpha, Carnivora, Artiodactyla)

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Methodological aspects of monitoring of large mammals along traffic corridors: A case study (Lagomorpha, Carnivora, Artiodactyla)

Různé metodické aspekty sledování velkých savců podél dopravních koridorů: Případová studie (Lagomorpha, Carnivora, Artiodactyla)

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Abstract. Roads comprise an extensive network in the Czech Republic that fragments the landscape. Such linear structures significantly and negatively affects wildlife and animal populations, and influences the appearance and structure of habitats. This study was aimed to monitor the occurence of lagomorphs, artiodactyls, and carnivorans in the vicinity of roads in the Nová Pec – Přední Zvonková – Zadní Zvonková – state border area using a combination of several methods. With the aid of tracking in snow, night monitoring, and photo traps, the incidence of 18 species of mammals from monitored groups was evidenced in an extended area along the monitored traffic ways. Differences in results between the individual methods were due to the use of different methodological procedures in the vegetation and non-vegetation seasons. For this reason, the observation frequency for individual species also varied.

Key words. Wildlife, monitoring, migration, road, habitat fragmentation.

INTRODUCTION

Roads have a wide spectrum of ecological effects, both direct and indirect, and impact on animals (Forman & Alexander 1998, Iuell et al. 2003, Trombulak & Frissel 2000). This results in frequent animal-vehicle collisions, reduced reproductive potential (Bjurlin & Cypher 2003), decreased dispersion of populations, and increased mortality (Mader 1984), as well as altered population density (Bjurlin & Cypher 2003), biological diversity (Chen & Roberts 2008), and food availability (Bjurlin & Cypher 2003). Traffic also cause disturbance and stress of animals (Alexandr & Waters 2000, Clarke et al. 1998, Lodé 2000, Olsson & Widen 2008, Shepard et al. 2008, Whittington et al. 2005).

Some countries have issued their own comprehensive reference guides concerning the impacts of roads on populations of large mammals (e.g. Broker & Vastenhout 1995, Ericsson & Skoog 1996, Hlaváč & Anděl 2001, Müller & Berthould 1997).

Possibilities and methods of wildlife monitoring play an important role in evaluating the impact of human transportation infrastructure upon animals. Methods of monitoring mammals and their habitat preferences during migration of selected species have been described by e.g. Aberg et al. (2000) or Swenson & Angelstam (1993) and, specifically in the Czech Republic by e.g. BUFKA et al. (2003), ČERVENÝ et al. (2007), KOCUROVÁ et al. (2004) and/or ŠUSTR & JIRSA (2007).

General census methodologies have been presented by CAUGHLEY (1977) and EBERHARDT (1978). Their methods emphasized the use of all technical possibilities as well as the variability among mammal populations. According to these authors, mammal monitoring methods can be divided into direct and indirect ones.

Direct methods include, for example: (a) drive counts – this technique requires a large number of observers who walk in a line through the area of interest and record the mammals moving among them. This method was supported, for example, by MCCULLOUGH (1979); (b) aerial counts – this method is suitable in open locations, such as grasslands, open shrublands, deciduous forests in winter, etc. where animals are recorded directly by the pilot or by assistant observers (e.g. BLEICH 1983); (c) transect counts – this method consists in walking or riding (a horse, a bike, etc.) through the field along pre-planned transects (e.g. BURNHAM et al. 1980, KIE & WHITE 1985); (d) spotlight counts – a method consisting in animal census at night using spotlights (e.g. PROGULSKE & DUERRE 1964); (e) Remote sensing – thermal infrared sensing equipment which monitors animals from an aircraft (e.g. PARKER & DRISCOLL 1972); (f) Infrared flash camera – animal monitoring using photo traps and video cameras (e.g. VEENBAAS 2003, PFISTER et al. 1997).

Indirect methods include, for example: (a) mark-recapture methods (CAUGHLEY 1977), (b) Change-in-ratio and related methods (CAUGHLEY 1977), (c) track and trail counts – monitoring of footprint paths in the snow (SALWASSER 1976), (d) footprint paths on sand and paper sheets (VEENBAAS 2003), (e) pellet-group counts (CONNOLLY 1981).

This paper aims mainly to compare various methods of monitoring large mammals in the vicinity of a linear structure. As a monitored area we chose the surroundings of a section of the III/1634 road from the Přední Zvonková intersection to the state border, which is part of the Sites of Community Importance Šumava and the Šumava Protected Landscape Area. From the perspective of migration and abundance of large mammals, especially red deer (*Cervus elaphus*), European elk (*Alces alces*), and Eurasian lynx (*Lynx lynx*), this area is included in the category of extraordinary importance (ANDĚL et al. 2005).

MATERIAL AND METHODS

Monitored area

The section of the road III/1634 from the Přední Zvonková (48°44' N, 14° 00' E) intersection to the state border is located at the altitude of 770 m a. s. l. (Přední Zvonková) to 860 m a. s. l. (border crossing). Except for the area of Zadní Zvonková, where there is the edge of a forest on the bordering ridge, and the last section before the state border which leads through the forest, most of the communication leads through non-forested areas. The non-forested area is comprised of cultivated pastures and meadows, as well as protected areas, and numerous linear, scattered and clustered greeneries. The area is drained by the Hamry stream, Pestřice river, and the Schwarzenberg channel.

From the climatological viewpoint, the monitored area belongs to the MT 3 moderate climatic region. Average annual temperature reaches 6.2 °C, average precipitation is 797 mm, and the average January temperature is 3.6 °C (values from the nearest meteorological station Nová Pec, Želnavské Myslivny). According to data from the former Zvonková meteorological station (824 m a. s. l.), there are on average 104 days with snow cover in the monitored area and an average snow depth of 65 cm (VESECKÝ 1961). During the monitored period of 2009/2010, snow cover lasted for 109 days from 19 November 2009 to 31 March 2010 at the nearest station where snow characteristics are monitored in Volary (760 m a. s. l.).

Among mammals, we monitored only larger species that may potentially be threatened by road transportation or may cause collisions with passing vehicles. These included lagomorphs (*Lepus europaeus*), artiodactyls (*Sus scrofa, Cervus elaphus, Capreolus capreolus, Alces alces*) and carnivors (*Mustela erminea, Mustela nivalis, M. putorius, Martes martes, M. foina, Meles meles, Lutra lutra, Vulpes vulpes, Nyctereutes procyonoides, Lynx lynx*). In addition, we monitored also hedgehog (*Erinaceus europaeus*) and red squirrel (*Sciurus vulgaris*).

Methods

There were used three counting methods in the research.

Animal count in the snow

In the winter period with snow cover, the frequency of animal road crossings was examined on the base of recording of footprints and footprint paths. Tracking was carried out three times per month from 19 November 2009 to 16 March 2010. During every examination of the site, all footprint paths on both sides of the road were destroyed in order to prevent potential repeated recording during the follow-up inspection. We recorded the total numbers of road crossings as well as estimated numbers of individuals which had entered the road.

Animal count using night vision devices

In the periods without snow cover, 4–30 October 2009 and 6 April – 14 August 2010, the point count method was used from sunset to sunrise, always three times per month. Monitoring was carried out using standard binoculars with good light intensity (at twilight) and night vision binoculars, i.e. night vision devices, (at absolute darkness) at four stable points along the communication.

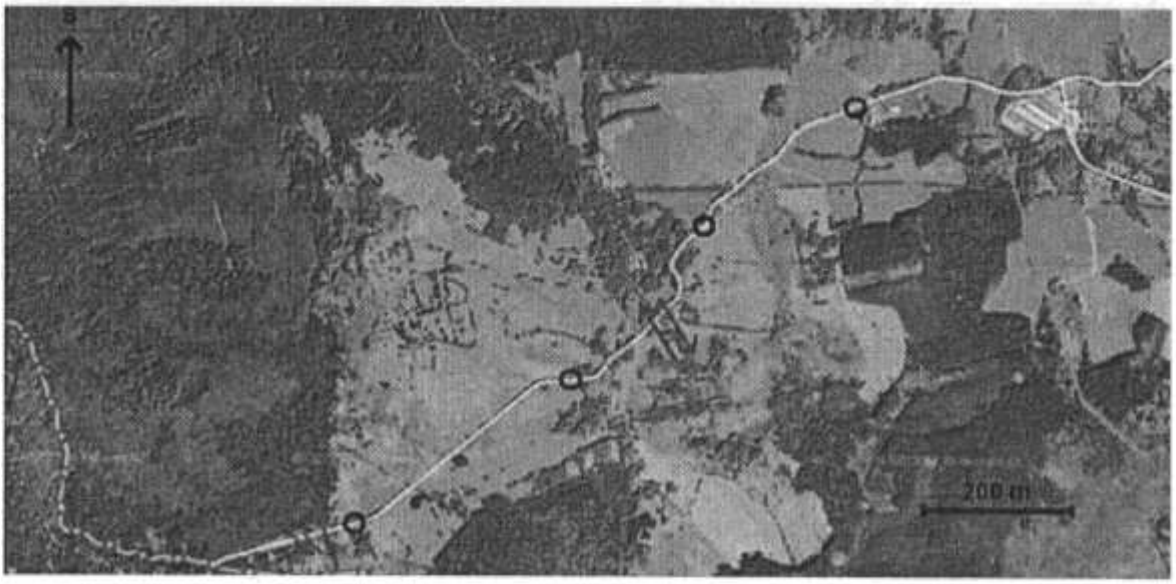

Fig. 1. Monitored section of the road III/1634 from Přední Zvonková intersection to the state border. Legend: → anticipated and actual most frequent direction of migrations of the sudied species; ■ locations of photo traps; **O** points of night monitoring.

Obr. 1. Sledovaný úsek silnice III/1634 Přední Zvonková (křižovatka) – státní hranice. Vysvětlivky: → odhadované a skutečné nejfrekventovanější směry migrace sledovaných živočichů; ■ umístění fotopastí; **O** body nočního sledování.

Table 1. Identified species of mammals according to monitoring method: winter tracking (average number of fresh footprint paths over the road on snow), night monitoring (average number of crossings/night), and photo traps (monitored species)

Tab. 1. Zjištěné druhy savců jednotlivými metodami sledování: zimním stopováním (průměrný počet čerstvých řad otisků ve sněhu přes cestu), nočním sledováním (průměrný počet přechodů za noc) a fotopastmi (sledovaný druh)

species \ method / druh \ metoda	winter tracking / zimní stopování	night monitoring / noční sledování	photo traps / fotopasti
Lepus europaeus	91	45	Yes
Sus scrofa	47	81	Yes
Cervus elaphus	32	37	Yes
Capreolus capreolus	157	105	Yes
Alces alces	0	1	No
Martes sp.	11	9	Yes
Meles meles	2	3	Yes
Lutra lutra	0	1	No
Vulpes vulpes	149	41	Yes
Lynx lynx	1	1	No

Monitoring using photo traps

During the period 19 November – 28 December 2009 and from 6 April – 26 June 2010, five automatic still cameras, so-called photo traps, were gradually installed at 16 covered places in the surroundings of the monitored section of the communication (more preciously location of photo traps and points of night monitoring at Fig. 1). To avoid theft, these cameras were not installed in the area during the period of intense touristic activity. Though records were kept of the acquired images, they were only summarized in a list of identified species. The reason for this lies in the fact that the results obtained in no way expanded the knowledge acquired using the aforementioned methods and population densities of the monitored mammal species could not be determined or estimated from the results achieved.

The dependence of animal road crossings among the respective species of mammals for individual monitoring methods (winter tracking and night monitoring) was evaluated statistically using the non-parametric Kruskal-Wallis ANOVA test. Differences between mammal crossings for individual monitoring methods (winter tracking and night monitoring) were graphically represented by means of cluster analysis.

RESULTS

According to monitoring method was recorded following species variability and their number, during monitored period (Table 1).

Winter tracking

In 16 winter inspections, at least eight species of mammals crossing the road were observed in the monitored section (for the most part, it was not possible to distinguish reliably between European pine marten and beech marten based on footprints in the snow).

The aim was to monitor the occurrence of mammals from orders of rabbits, artiodactyls and carnivores in the neighbourhood of communications Nová Pec – Přední Zvonková – Zadní Zvonková – state border by combination of several methods. More accurate data on the occurrence of individual orders (lagomorphs, artiodactyls and carnivores), their number, date of observation, assumed number and real number of recorded individuals see Figs. 2–4.

The more detailed results interpreted using cluster analysis according to methods winter tracking (Fig. 5) shows that the most distinguished difference number of foot print tracks among monitored species was recorded especially at badger and lynx, whose transitions were recorded at least.

According to Kruskal-Wallis test for data with non-normal distribution H [(7; N=128) =80.827, p=0.0000], a statistically significant difference was recorded among road crossings of individual species based on winter tracking (Table 2). Marked in bold are statistically significant differences between mammals at significance level p=0.05.

Night monitoring

In 22 night examinations, at least 10 species of mammals (it is impossible to distinguish reliably between European pine marten and beech marten according to their silhouettes) crossing the road were observed in the monitored section. It was always emphasized, however, that the same individuals must not be counted multiple times.

According to Kruskal-Wallis test for data with non-normal distribution H [(9; N=220) =87.110; p=0.0000], a statistically significant difference was recorded among road crossings of individual species based on night monitoring (Table 3). Statistically significant differences between mammals are shown in bold at significance level p=0.05. The more detailed results interpreted using cluster analysis according to methods night monitoring (Fig. 6) shows that the most distinguished difference number of observations among monitored species was recorded again especially at badger and lynx, whose transitions were recorded at least.

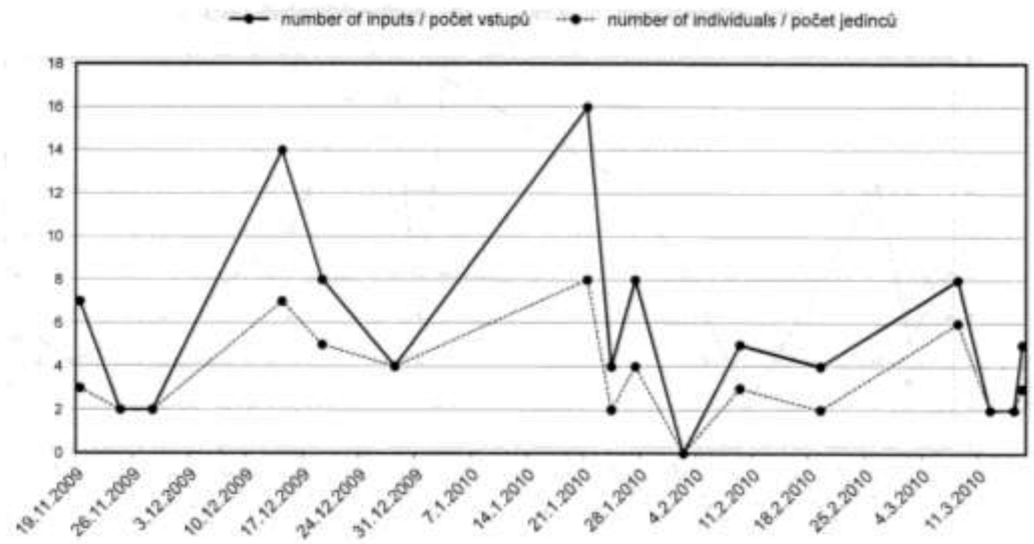

Fig. 2. Number of inputs and assumed number of European hare (*Lepus europaeus*) individuals on the road.
Obr. 2. Počet vstupů a předpokládaný počet jedinců zajíce polního (*Lepus europaeus*) na silnici.

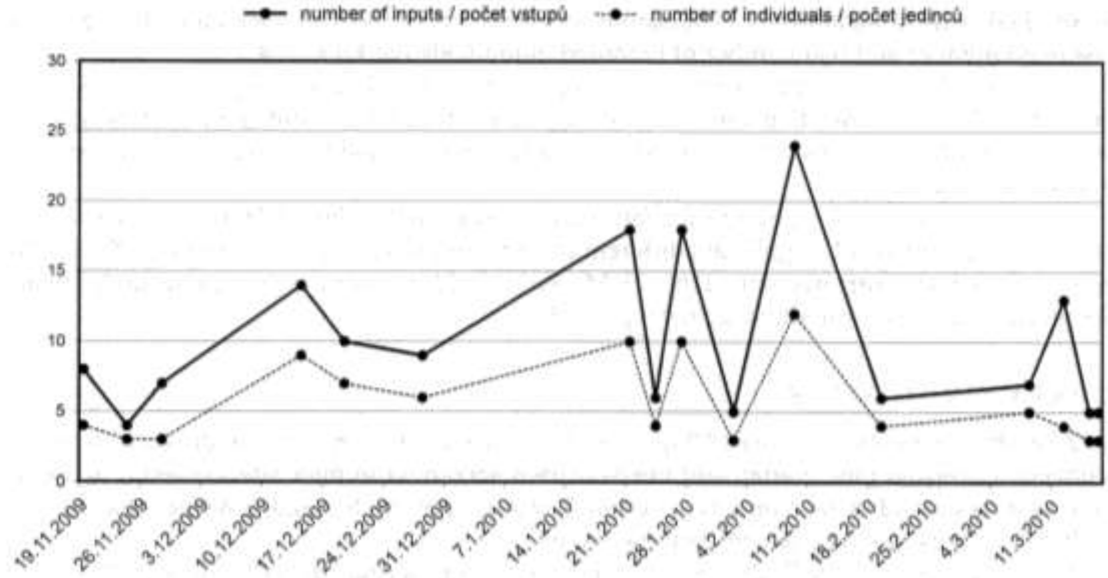

Fig. 3. Number of inputs and assumed number of roe deer (*Capreolus capreolus*) individuals on the road.
Obr. 3. Počet vstupů a předpokládaný počet jedinců srnce obecného (*Capreolus capreolus*) na silnici.

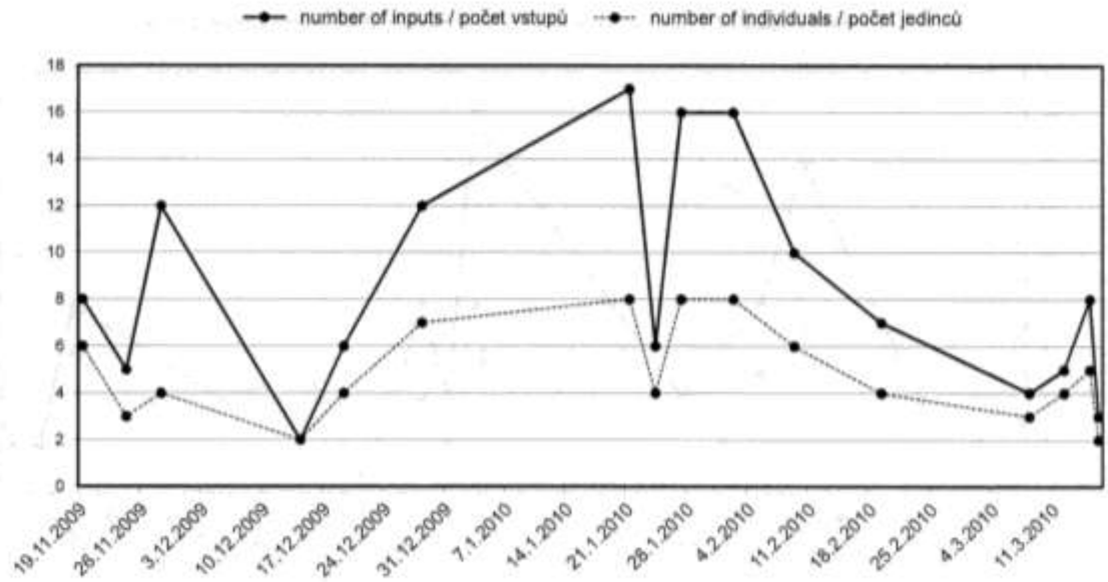

Fig. 4. Number of inputs and assumed number of red fox (*Vulpes vulpes*) individuals on the road.
Obr. 4. Počet vstupů a předpokládaný počet jedinců lišky obecné (*Vulpes vulpes*) na silnici.

Table 2. Comparison of the numbers of road crossings among recorded species based on winter tracking (p-value, Kruskal-Wallis ANOVA). Statistically significant differences between species are **bold** typped at significance level p=0.05

Tab. 2. Srovnání počtů přechodů silnice při zimním stopování zaznamenanými druhy (hodnota p, Kruskal-Wallisova ANOVA). Statisticky významné rozdíly mezi druhy jsou vyznčeny **tučně** při hodnotě p nižší než 0.05

		1	2	3	4	5	6	7	8
1	*Lepus europaeus*		0.395	0.360	1.000	**0.036**	***0.001***	1.000	***0.001***
2	*Sus scrofa*	0.395		1.000	***0.002***	1.000	1.000	***0.009***	1.000
3	*Cervus elaphus*	0.360	1.000		***0.002***	1.000	1.000	***0.008***	1.000
4	*Capreolus capreolus*	1.000	***0.002***	***0.002***		***0.000***	***0.000***	1.000	***0.000***
5	*Martes* sp.	***0.036***	1.000	1.000	***0.000***		1.000	***0.000***	1.000
6	*Meles meles*	***0.001***	1.000	1.000	***0.000***	1.000		***0.000***	1.000
7	*Vulpes vulpes*	1.000	***0.009***	***0.008***	1.000	***0.000***	***0.000***		***0.000***
8	*Lynx lynx*	***0.001***	1.000	1.000	***0.000***	1.000	1.000	***0.000***	

Photo traps

The following species of mammals were identified by this method: *Capreolus capreolus*, *Cervus elaphus*, *Sus scrofa*, *Vulpes vulpes*, *Lepus europaeus*, *Martes foina*, and *Meles meles* (Table 1). The species are ranked according to decreasing numbers of acquired images. This method seemed to be only of supplementary value. It facilitates the identification of individual species, and particularly large mammals, but not their number.

Lepus europaeus, *Capreolus capreolus*, and *Vulpes vulpes* were the most frequently monitored by the winter tracking method. *Sus scrofa*, on the other hand, was most often observed by the night

Table 3. Comparison of the numbers of road crossings among recorded species based on night monitoring (p-value, Kruskal-Wallis ANOVA). Statistically significant differences between species are **bold** typped at significance level p=0.05

Tab. 3. Srovnání počtů přechodů silnice při nočním sledování zaznamenanými druhy (hodnota p, Kruskal-Wallisova ANOVA). Statisticky významné rozdíly mezi druhy jsou vyznačeny **tučně** při hodnotě p nižší než 0.05

		1	2	3	4	5	6	7	8	9	10
1	*Lepus europaeus*		1.000	1.000	1.000	0.779	0.057	1.000	***0.014***	***0.014***	***0.014***
2	*Sus scrofa*	1.000		1.000	1.000	1.000	0.209	1.000	0.060	0.060	0.060
3	*Cervus elaphus*	1.000	1.000		0.172	1.000	1.000	1.000	0.616	0.616	0.616
4	*Capreolus capreolus*	1.000	1.000	0.172		***0.002***	***0.000***	1.000	***0.000***	***0.000***	***0.000***
5	*Martes* sp.	0.779	1.000	1.000	***0.002***		1.000	1.000	1.000	1.000	1.000
6	*Meles meles*	0.057	0.209	1.000	***0.000***	1.000		0.084	1.000	1.000	1.000
7	*Vulpes vulpes*	1.000	1.000	1.000	1.000	1.000	0.084		***0.022***	***0.022***	***0.022***
8	*Alces alces*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***		1.000	1.000
9	*Lynx lynx*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***	1.000		1.000
10	*Lutra lutra*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***	1.000	1.000	

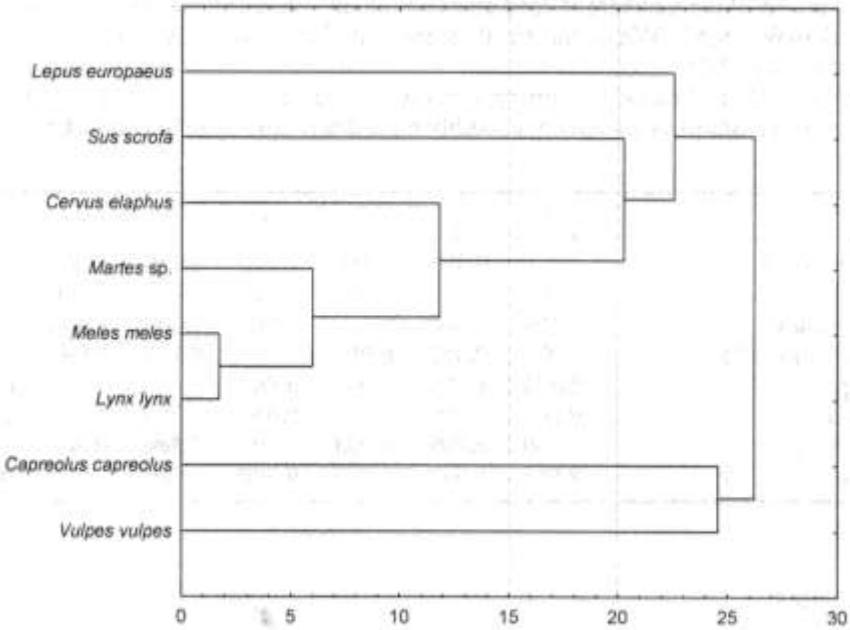

Fig. 5. Cluster analysis of numbers of particular species crossings based on winter tracking.
Obr. 5. Shluková analýza počtů přechodů jednotlivých druhů při zimním stopování.

monitoring method. This is probably due to the biology of this species, which does not occur very often at these altitudes in winter. *Alces alces* and *Lutra lutra* were observed in the surroundings of the road only using the night monitoring method, and in both cases only once.

Only a few small predators were found dead on the monitored stretch of road: one female *Mustela erminea*, one *M. putorius*, one *Martes martes*, two *Vulpes vulpes*, and one *Erinaceus europaeus*.

DISCUSSION

The monitored area is extremely important for the European elk and Eurasian lynx, which belong to specially protected, highly endangered species of mammals (Decree 335/1992). The latter is listed in Annex II of the EU's Habitats Directive and is a subject of protection in the Šumava special conservation area. The individuals of these species which live in low population density throughout Šumava may be endangered by passing vehicles while crossing the roads, thereby threatening their entire populations.

Eight species of mammals were observed by means of winter tracking and 10 by means of night monitoring. Overall, the presence of 18 species was confirmed in the greater area of the monitored communication. These differences arise from the varied methodological procedures in vegetation and non-vegetation seasons. For the same reason, the frequency of observation of individual species also varies. The total number of individuals for the entire monitored period is not evaluated, as this could involve indefinite repetition of road crossings by the same individuals during different examinations, in the case of both winter tracking and night monitoring.

Capreolus capreolus, *Vulpes vulpes*, *Lepus europaeus*, and *Sus scrofa* were the species most often observed according to both methods.

The acquired results suggest the importance of the road for mammal migration in the winter period, particularly if snow cover is high. Under these conditions, it often happens that wildlife does not cross the communication but uses it for moving in less demanding terrain, as is offered by a road cleaned off snow. The probability of animal-vehicle collisions on roads is higher in the winter period than in the vegetation period. In winter, however, road conditions typically do not enable fast driving and thus animals are likely to escape a collision. In the vegetation period, herbivores often feed on the vegetation that grows at the edges of roads and predators in turn search the roads for animals that have been hit as an easily obtainable food source. Generally, the considerable number of wildlife–vehicle collisions (road kill) in this period presumably is due to the high speed of vehicles whereby animals do not manage to move away from the road in time (particularly at blind sections).

Newhouse (2003) evaluated migration along a two-kilometre long section of road in Canada using camera recording of 1,131 observations of large ungulates. The highest intensity of crossings was observed at night (0:00–7:00), followed by evening hours (19:00–0:00), and the lowest during daytime hours (7:00–19:00). The number of passages was two times higher at night (0:00–7:00) than in the evening (19:00–0:00), and more than 15 time higher at night (0:00–7:00) than during the day (7:00–19:00). Nevertheless, more risk events were recorded during the day (more unsuccessful road crossings). This was due to higher traffic intensity. Newhouse (2003) therefore concluded that the risk of animal-vehicle collision was higher during the day.

No collisions of artiodactyls were recorded in the monitored section during the study period. The most frequently hit species included small mustelids, red foxes (2) and the European

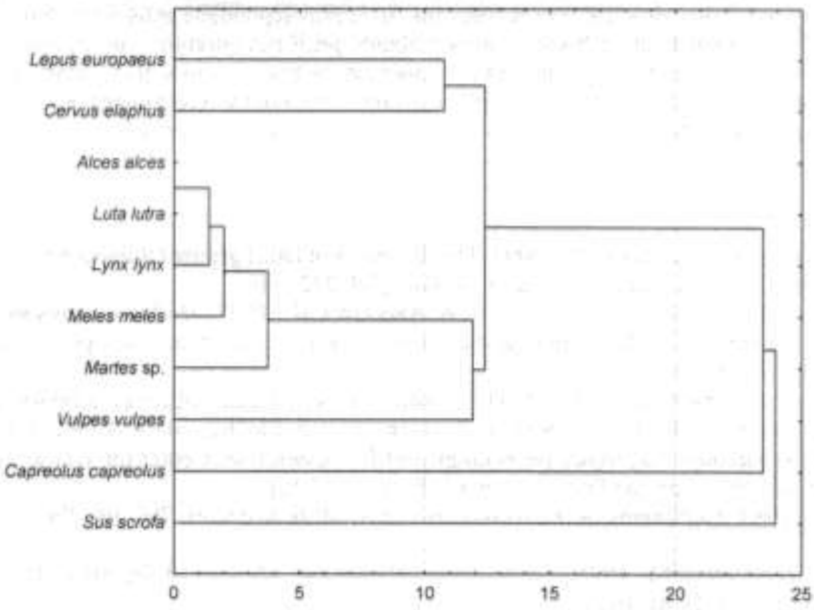

Fig. 6. Cluster analysis of numbers of particular species crossings based on night monitoring.
Obr. 6. Shluková analýza počtů přechodů jednotlivých druhů při nočním sledování.

hedgehog (1). Larger mammals most often used the sections at Zadní Zvonková to cross the communication (edge of the forest extends up to the road) and the forest corridor prior to the state border. These sections are the most risky for wildlife.

It is important to determine what proportion of a population is actually affected by mortality on road networks. The published data significantly differ in relation to specific research locations. For example, Iuell et al. (2003) and Trocmé (2003) state that traffic kills ca. 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (Righetti et al. 2003) on the mortality of roe deer and red deer (data from 1999) also points out that transportation mortality is clearly the most frequent cause of death for both species (roe deer 49.3%, red deer 33.2%). The second most common cause of death for roe deer is due to agricultural machines (19.8%), followed by other factors (9.1%), then age and disease (7.1%). For red deer, the second most frequent cause of death indicated is other accidents (fall, avalanche, etc.), followed by other causes (14.7%), then age and disease (12.2%). The results clearly show that this always depends upon the specific situation in a given area.

SOUHRN

Pozemní komunikace vytvářejí na území ČR rozsáhlou síť, kterou fragmentují krajinu. Liniové stavby podstatně ovlivňují život ve volné přírodě, negativně působí na populační stavy živočichů a ovlivňují samotnou podobu a strukturu obývaných biotopů. Cílem výzkumu bylo monitorovat výskyt savců tří řádů (zajíci, sudokopytníci, šelmy) v okolí komunikace Nová Pec – Přední Zvonková – Zadní Zvonková - státní hranice kombinací několika metod. Pomocí zimního stopování na sněhu, nočního sledování a fotografických pastí byl v širší oblasti sledované komunikace prokázán výskyt 18 druhů savců sledovaných skupin. Rozdíly ve výsledcích mezi jednotlivými metodami vyplývaly z použití odlišných metodických postupů ve vegetační a nevegetační sezóně. Z téhož důvodu byli rozdílné i početnosti pozorování jednotlivých druhů. Zajíc polní, srnec obecný a liška obecná byli nejčastěji monitorováni metodou zimního stopování. Naopak prase divoké metodou nočního pozorování. To je pravděpodobně způsobeno biologií této zvěře, která se v těchto nadmořských výškách v zimním období příliš nevyskytuje. Los evropský a vydra říční byli v okolí silnice monitorováni pouze metodou nočního sledování, a to u obou druhů pouze v jednom případě. Na sledovaném úseku silnice bylo nalezeno pouze několik usmrcených drobných šelem (po 1 ex. lasice hranostaje, tchoře tmavého a kuny lesní a 2 ex. lišky obecné) a jeden ježek západní.

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