



TEMPORAL CHANGES IN THE STATUS OF THE EUROPEAN HARE (*LEPUS EUROPAEUS* PALLAS, 1778) POPULATION OF MEĐIMURJE, CROATIA

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A total of 383 European hares (*Lepus europaeus* Pallas, 1778) were sampled from three separate hunting grounds within the Međimurje region from 2004 to 2006 including, Čakovec, Hodošan and Mala Subotica. Based on the eye lens mass the age structure of hares was determined. Reproductive effort per capita varied from 0.62 to 1.54 leverets per hare with female reproductive effort varying from 0.62 to 3.40 leverets per female. On average 46.7% of the hunting bag consisted of yearlings. The sex ratio varied between years from 0.39 to 0.69 females:males. Weight varied significantly between juveniles and adults regardless of sex ($p < 0.05$) and ranged from 3.64 to 4.17 kg. Spring densities varied from 15–23 hares/km² between hunting grounds. Analysis of data from the management plans of Međimurje region over the last 38 years showed that game bag record decreased approximately 9-fold and the relative hare abundance declined by 56% from 1967 to 2005. According to management plans the area productive for hunting hares declined by 62% in that period and this is probably one of the main reasons for the current trend of population decline in Međimurje.

Keywords: age structure, population density, weight, reproductive statistics

Popović, N., Pintur, K., Alegro, A., Slavica, A., Lacković, M. & Sertić, D.: Ekološki parametri populacije zeca običnog (*Lepus europaeus* Pallas, 1778) na području Međimurja nakon pada brojnosti posljednjih 40 godina. *Nat. Croat.*, Vol. 17, No. 4., 247–257, 2008.

U razdoblju od 2004.-2006. god. provedeno je istraživanje zeca običnog (*Lepus europaeus* Pallas, 1778) na tri lovna područja Međimurja (Mala Subotica, Hodošan, Čakovec.). Nakon odstrjela obrađena su 383 zeca. Temeljem mase očnih leća određivana je dobna struktura zečeva. Za istraživana lovna područja prosječan udio mladih jedinki iznosio je 46.7 % od ukupne populacije zečeva. Reprodukcijski indeks varirao je od 0.62 do 3.40, a koeficijent reprodukcije od 0.62 do 1.54. Proletna gustoća populacije kretala se od 15 do 23 jedinki/100 ha lovno-produktivne površine. Omjer spolova ovisno o godini varirao je od 0.39-0.69. Razlika u težini mladih i starih jedinki oba spola bila je statistički značajna ($P < 0.05$). Utvrđena prosječna težina zečeva prema dobi i spolu kretala se od 3.64 kod mladih do 4.17 kg kod odraslih. Analiza podataka iz planova gospodarenja za posljednjih 40 godina pokazala je da je odstrjel zečeva na istom području smanjen za 9 puta, a brojnost populacije 2005. god. u odnosu na 1967. god. smanjena je za 56 %. Analizom veličine lovno-produktivne površine iz planova gospodarenja utvrđeno je njeno smanjenje za navedeno razdoblje za 62 % pa je to vjerojatno i glavni razlog sadašnjem trendu pada brojnosti populacije u Međimurju.

Ključne riječi: dobna struktura, gustoća populacije, težina, reproduktivna statistika

INTRODUCTION

European hare populations have declined markedly since the mid-1970s across Europe (MARBOUTIN & PEROUX, 1995; HELL *et al.*, 1997; KLANSEK, 1999; PANEK & KAMIENIARZ, 1999; ESKENS *et al.*, 1999; SMITH *et al.*, 2004) including throughout Croatia (CAR, 1973; ROMIĆ *et al.*, 1980; ALEGRO, 1981; ŠINDILJ, 1986; TROHAR, 1997; VUKOVIĆ & TVRTKOVIĆ, 2006). Whilst no clear consensus has been reached to explain these declines, land management changes brought by agricultural intensification including increased use of herbicides and pesticides, changing predator numbers and climate change have all been implicated (SCHMIDT *et al.*, 2004). The hare is highly prized as a game animal but over-exploitation throughout unsustainable hunting can negatively affect local populations (ŠELMIĆ, 1984; KOLAR, 2003; SMITH *et al.*, 2005). Conservation strategies rely on a knowledge of population dynamics including temporal changes in distribution, density, abundance, population age structure and reproductive success (STRAUB & POHLMAYER, 2001). A sound understanding of hare population dynamics should form the basis of local and national species management plans including limits on the total number of animals and the maximum area over which hares may be permitted to be taken (ŠELMIĆ, 1984).

The ability to distinguish between age-classes is fundamental to many ecological studies. A knowledge of age structure is necessary for an understanding of population processes and sensible management. A very low percentage of juveniles indicates a decreasing population.

Previous research into the age structure of the hare population of Međimurje (ANDRAŠIĆ, 1977) was unreliable due to the subjectivity of the methods used to determine age (ŠELMIĆ, 1984). The latter included only examination of the lacrimal bone, auricle and Stroh's sign (ANDRAŠIĆ, 1977).

The current study examines the changing status of the European hare population in the Međimurje region over the last 40 years. Game bag records, obtained from management plans, were analysed to describe temporal changes in hare abundance from 1967 to 2005 while shot hares were examined to describe the reproductive status of the population from 2004 to 2006.

MATERIALS AND METHODS

Study sites

Three main hunting areas positioned between the Mura and Drava rivers of the Međimurje region were examined including Čakovec, Hodošan and Mala Subotica. Lowland areas between 130–150 metres above sea level are dominated by agriculture and consist of a mosaic of small field parcels planted with barley, corn, oats, oilseed rape, potatoes, sugar beet and wheat. Arable areas are interspersed by areas of grassland meadow. The climate is mild and humid with warm summers (SELETKOVIĆ & KATUŠIN, 1992). Soils are free draining and characterised by heterogeneous soil types. Such areas are judged highly suitable for the rearing of small game including hares. The three study sites had a combined area of 10,321ha. The area productive for hunting hares was measured based on specialised background, a document issued by Department for Hunting at the Ministry of Regional Development, Forestry and Water Management. The area productive for hunting was determined according to a realistic proportion of particular agricultural strains, vegetation structure and according to the hunting area cadastre. Based on the specialised background document, the area was defined as lowland hunting area.

Field-sampling

The number of hares in each of the three study areas was determined each spring from 1967 to 2005 using daylight flushing counts on line transects (ŠELMIĆ, 1984; SLAMEČKA *et al.*, 1997). Relative abundance was expressed as the mean number of hares per unit area (i.e. hares.km⁻²). Dividing the total number of hares observed by the total area is likely to result in inaccuracies of density estimate. Therefore, this measure is used here as a proxy of absolute abundance. A total of 383 hares were sampled during the 2004, 2005 and 2006 hunting seasons from October to December. Each animal was weighed, sexed and aged by the dry weight of the eye lens. For age determination the eyes were extracted and fixed in 10% buffered formalin for three days after the animal was shot. The lenses were dried at 37 °C for 72 hours at normal atmospheric pressure and weighed to a precision of 1mg (PINTUR *et al.*, 2006). Due to known rates of growth, hares can be accurately aged using eye lens weight up to one year (LORD, 1959; RIECK, 1962; ŠELMIĆ, 1984; SUCHENTRUNK *et al.*, 1991). For the purposes of this study it was sufficient to categorise hares into two age classes: juveniles less than 1 year old or adults greater than 1 year old (CARBON-RACZYNSKA and RACZYNSKI, 1972; PEPIN, 1974; ŠELMIĆ, 1984; SUCHENTRUNK *et al.*, 1991). The cut-off point for the weight of an eye lens belonging to an adult hare was taken to be 280 mg (ŠELMIĆ, 1984; SLAMEČKA *et al.*, 1997).

Measures of reproductive status

Six measures of the reproductive status of the hare population were calculated for each hunting region during each year from 2004 to 2006 including sex ratio, age structure and a number of reproductive and population indices (Tab. 1).

Tab. 1. Measures of the reproductive status of the hare game bag used during 2004, 2005 and 2006 for Čakovec, Hodošan and Mala Subotica.

Variable name	Description	Calculation
Sex ratio	Ratio of females to males in each game bag	$Si = \frac{F}{N}$
Age structure	Ratio of yearlings to adults in each game bag	$juv = \frac{N_{juv}}{N} \times 100$
Coefficient of reproduction	Number of juveniles per adult in each game bag	$R = \frac{N_{juv}}{N_{ad}}$
Reproductive Index	Number of juveniles per female in each game bag	$r = \frac{N_{juv}}{N_{adf}}$
Coefficient of population increase	Ratio of yearlings to adults reduced by the level of survival (0.7)	$kRP = 0.7 \left(\frac{N_{juv}}{N_{ad}} + 1 \right)$
Population increase	Increase >60% was considered excellent, 50-60% average and <50% as poor (SLAMEČKA <i>et al.</i> , 1997).	$RP = \frac{juv - 30}{100 - juv} \times 100$

Where N = total number of individuals; N_{ad} = number of adults; N_{adf} = number of adult females and F = number of females.

Statistical analyses

The statistical software program SAS (1999) was used to analyze mean weight of hares, according to sex and age. Statistical analysis was carried out with a significance level of 0.05. An overview of trends in spring abundance, number of juveniles and number of hares shot in the Međimurje region from 1967–2005 was produced, based on yearly reports collected from the investigated hunting areas (Fig. 2).

Game bag records

Hunting records were obtained from the management plans of the Međimurje region over a 38 year period, from 1967 to 2005. The total number of hares shot and the proportion of the game bag were collated and recorded.

RESULTS

The area of the Međimurje region productive for hunting hares declined by 62% from 1968 to 2006 decreasing from 57,200ha to 21,511ha (Fig. 1). During the same period the relative abundance of hares during spring decreased by 43%, the number of juvenile hares in the game bag declined by 77% and the total number of hares shot declined by 88% (Fig. 2). During 2006, only 1,199 hares were taken in Međimurje region.

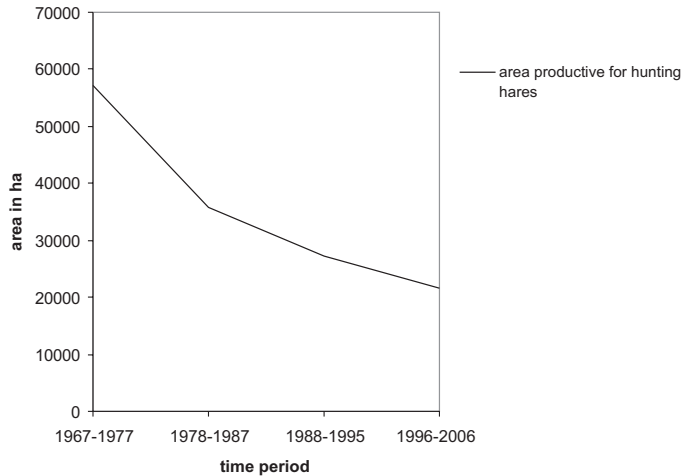


Fig. 1. Reduction in the area productive for hunting hares, taken as a proxy of the area of suitable hare habitat in Međimurje region from 1967 to 2006. Data from management plans.

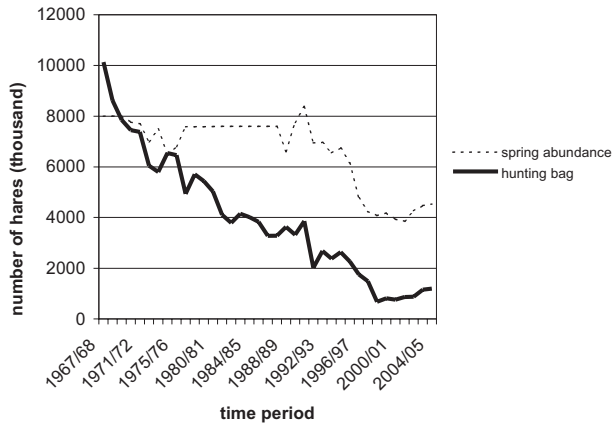


Fig. 2. Temporal trends in spring abundance and number of hares shot in the Međimurje region from 1967-2005. Data from management plans.

Spring hare density varied from 15–23 hares/km² (in Hodošan during 2006 and 2005 respectively). In all years across all regions hare density failed to meet the anticipated density of 27 hares/km² set out in the hare management plans (Tab. 2).

The proportion of the game bag that was juvenile varied across years and study sites from 38 to 61% despite all three hunting grounds being in close geographical proximity (Tab. 2). Population increase also varied across years and study sites from a poor 12.9% (Čakovec during 2005) to 78.1 % (Hodošan during 2006). Rates of anticipated population increase were only achieved in Hodošan hunting ground

Tab. 2. Comparative overview of recorded selected indicators of population dynamics divided by hunting ground and year, compared with anticipated indices from management plans.

Population Indicator	Hunting grounds and year								
	Čakovec			Hodošan			Mala Subotica		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Productive hunting area (ha)	2,000	2,000	2,000	1,082	1,082	1,082	2,300	2,300	2,300
Sample size (n)	47	41	38	44	50	28	67	41	65
Coefficient of reproduction (R)	0.88	0.62	0.76	1.31	0.72	1.54	0.72	0.86	0.80
Reproduction Index (r)	1.66	0.62	1.30	3.40	1.23	2.83	1.72	1.46	1.93
Percentage juvenile (% <1yr old)	47	38	43	57	42	61	42	46	45
Sex ratio (SI)	0.52	0.69	0.58	0.39	0.50	0.50	0.42	0.54	0.46
Anticipated coefficient of population increase (AcPI)	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Recorded coefficient of population increase (cPI)	1.32	1.13	1.23	1.62	1.20	1.78	1.20	1.30	1.26
Anticipated population increase (API%)	70	70	70	70	70	70	70	70	70
Recorded population increase (PI%)	32	13	23	63	21	78	21	31	26
Anticipated spring density (hares.km ⁻²)	27	27	27	27	27	27	27	27	27
Actual spring density (hares.km ⁻²)	20	19	19	20	23	15	18	18	19

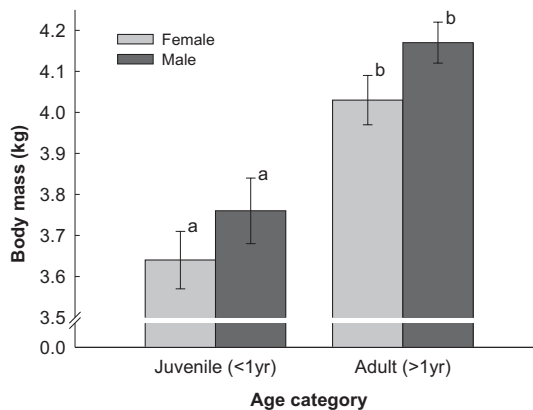


Fig. 3. Mean hare body mass (kg) ± standard error in the Međimurje region, Croatia during 2004 to 2006. Lower case letters indicate statistical differences at p<0.05.

during 2006. The reproduction index (r), as an indicator of leveret survival per female, varied from 0.62 (Čakovec during 2005) to 3.40 (Hodošan during 2004) with a mean value equal to 1.79. The sex ratio varied from 0.39 (Hodošan during 2004) to 0.69 (Čakovec during 2005) with a mean value equal to 0.51, being biased towards females.

In general hare body mass was greater within the three study areas than in the wider region of north-west Croatia (3.41 to 3.84kg; PINTUR *et al.*, 2006) with mean body mass varying from 3.64 to 4.17kg. Body mass varied significantly between juveniles and adults with males tending to be heavier than females (Fig. 3).

DISCUSSION

European hare populations have declined in many European countries (SMITH *et al.*, 2005; SCHMIDT *et al.*, 2004), largely because of habitat loss due to intensification of agriculture and cultivation of natural habitats, infrastructure development leading to habitat fragmentation and urban sprawl. Some of the reduction in the area productive for hunting hares in Međimurje region can be explained by changes in the method of calculation. During 1988 the area within a 300 m radius of each human settlement (e.g. houses, farmyards etc) was excluded from the area counted as productive for hunting. Increasing urbanization of the countryside and rapid development of transport infrastructure (highways) leading to habitat fragmentation may account for the rapid decline in suitable areas for hunting and this could also be an explanation for the population decline. Currently, the total area of Međimurje deemed suitable for hunting is just 29.4% (ca. 73,052 ha).

Hunting bags are considered a reasonable proxy of relative hare abundance (SMITH *et al.*, 2005; SCHMIDT *et al.*, 2004; MARBOUTIN & HANSEN, 1998). Thus a reduction of the hunting bag in the Međimurje region by 88% to only 1199 hares taken during 2006 may reflect a considerable decline in European hare numbers.

Population density was lower on all hunting grounds and across all years than that anticipated by management plans. However, densities were comparable to other European regions including 10–20 hares/km² in France (REITZ & LEONARD, 1994), 15–20 hares/km² in Poland (PIELOWSKI & PINKOWSKI, 1992) and 12–17 hares/km² in Germany (AHRENS, 1996).

In the investigated period none of the hunting grounds achieved the anticipated spring population density of 27 individuals/100 ha, which is almost twice as much as in the period between 1968 and 1977. In that period plans anticipated a spring population density of 14 individuals/100 ha, but over a much larger area productive for hunting. Because of reduction of the area productive for hunting hares and poor management, we might suspect the quality (reliability and feasibility) of management plans. Results of field research conducted in the study sites also showed that all regions failed to meet the anticipated density set out in management plans.

Variation in the percentage of the game bag that was juvenile was within the range of that recorded by previous authors (ABILDGARD *et al.*, 1972; PIELOWSKI, 1976;

KOVACS & HELTAY, 1981; AHRENS, 1996; SLAMEČKA *et al.*, 1997; ŠELMIĆ *et al.*, 1999; KOLAR, 2003; MARBOUTIN *et al.*, 2003). ANDRAŠIĆ (1977) suggested that the ratio of juveniles in yearlings in the Međimurje hunting bag from 1972 to 1976 ranged from 22–30%. These figures cannot be compared to those presented here as they are likely to be negatively biased due to the subjective methodology used by Andrašić to determine age i.e. Stroh's sign, the softness of auricle and lacrimal bone (ŠELMIĆ, 1984). The current study suggests that approximately 47% of the hunting bag of Međimurje region is juvenile (less than one year old) which is in agreement with that reported elsewhere in Europe, which ranges up to 50 % (BENSINGER, 2002).

Population increase anticipated in management plans was achieved only in 2006 in the Hodošan hunting ground.

Other researchers have observed similar reproduction index results in the Czech Republic (SEMIZOROVA & ŠVARC, 1987) and Slovakia (SLAMEČKA *et al.*, 1997).

The reasons for these differences in the increase and survival of litter per female (r) can be found in the ways of management and a whole range of biotic and abiotic factors which can affect the survival of hares. The real reasons for these differences however should be researched individually (ŠELMIĆ, 1984; SLAMEČKA *et al.*, 1997).

Sex ratios skewed toward females have been reported by most authors (RACZYNSKI, 1964; ŠELMIĆ, 1984; SEMIZOROVA, 1986; WASILEWSKI, 1991; SLAMEČKA *et al.*, 1997; KOLAR, 2003). Heavier males than females were determined by KOLAR (2003) and KRUPKA *et al.* (1981), in contrast to some researches in Germany and Slovakia, which determined averagely heavier females (BENSINGER, 2002; SLAMEČKA *et al.*, 1997).

It would appear that the suitable hare habitat has decreased in area in the Međimurje region with a subsequent hare population decline during the last 40 years. The best indicator of population declines is relative abundance derived from standardised counts. Bag records are considered crude indicators of population declines compared to standardised counts, but may still be useful indicators of the long-term trends in European hare numbers (SCHMIDT *et al.*, 2004).

Here we demonstrate that population dynamics of the European hare vary across time and hunting grounds within Međimurje region, Croatia but are similar to those recorded elsewhere in Europe. The status of the population was better in some areas than others. Management strategies should take into account interannual population fluctuations. A sound understanding of hare population dynamics should form the basis of local and national species management plans including limits on the total number of animals and maximum area over which hares may be taken.

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S A Ž E T A K

**Ekološki parametri populacije zeca običnog
(*Lepus europaeus* Pallas, 1778) na području Međimurja
nakon pada brojnosti posljednjih 40 godina**

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U razdoblju od 2004.-2006.god. provedeno je istraživanje zeca običnog (*Lepus europaeus* Pallas, 1778) na tri lovna područja Međimurja (Mala Subotica, Hodošan, Čakovec.). Nakon odstrjela obrađena su 383 zeca. Temeljem mase očnih leća određivana je dobna struktura zečeva. Za istraživana lovna područja prosječan udio mladih jedinki iznosio je 46.7 % od ukupne populacije zečeva. Reprodukcijski indeks varirao je od 0.62 do 3.40, a koeficijent reprodukcije od 0.62 do 1.54. Proletna gustoća populacije kretala se od 15 do 23 jedinki/100 ha lovno-produktivne površine. Omjer spolova ovisno o godini varirao je od 0.39–0.69. Razlika u težini mladih i starih jedinki oba spola bila je statistički značajna ($P < 0.05$). Utvrđena prosječna težina zečeva prema dobi i spolu kretala se od 3.64 kod mladih do 4.17 kg kod odraslih. Analiza podataka iz planova gospodarenja za posljednjih 40 godina pokazala je da je odstrjel zečeva na istom području smanjen za 9 puta, a brojnost populacije 2005. god. u odnosu na 1967. god. smanjena je za 56%. Analizom veličine lovno-produktivne površine iz planova gospodarenja utvrđeno je njeno smanjenje u navedenom razdoblju za 62%, pa je to vjerojatno i glavni razlog sadašnjem trendu pada brojnosti populacije u Međimurju.