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Selected indicators of brown hare (*Lepus europaeus* Pallas, 1778) population dynamics in northwestern Croatia

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ABSTRACT

Certain indicators of hare population dynamics (*Lepus europaeus* Pallas, 1778) were analyzed during the 2004/2005 hunting season in 5 hunting grounds of northwestern Croatia. Selected areas included both lowland and mountain habitats. In that period 279 eyes were collected following the regular hunting operations for the purpose of age determination according to the mass of eye lenses. Individual hares were divided into two groups, one included yearlings, while older hares were grouped in the second group. The results of our analysis showed that the average rate of yearlings in the selected areas was 50.4% of total hare population. The increase in population number, which was anticipated by the management plan, was not achieved in 3 hunting grounds. The reproduction index, which indicates that survival rate of offspring per female greatly varied from 1.33 to 3.40. The average value of the reproduction coefficient was 1.07. Population density in spring varied between 13 and 20.3 individual hares per 100 hectares of hunting ground. The sex ratio value 0.48 indicates the predominance of males. The average weight of hares according to age and gender ranged between 3.41 to 3.84 kg. The difference in weight among males was statistically significant ($P<0.05$).

Key words: hare, *Lepus europaeus*, eye lens, population dynamics

Introduction

Hare management is not an easy task in today's conditions of secondary ecosystems

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(agroecosystems) or landscapes cultivated by human activity. The decline in hare population in Croatia (CAR, 1973; ROMIĆ et al., 1980; ALEGRO, 1981; ŠINDILJ, 1986; TROHAR, 1997) as well as in other European countries (MARBOUTIN and PEROUX, 1995; HELL et al., 1997; ESKENS et al., 1999; KLANSEK, 1999; PANEK and KAMIENARZ, 1999) indicates the poor living conditions within these agroecosystems. Besides various biotic and abiotic factors which affect the hare population, the human factor is also very important (i.e. breeders and hunters), mainly through inadequate management (excessive and inappropriate hunting) (ŠELMIĆ, 1984; KOLAR, 2003). The essentials of rational (sustainable) management in these conditions are in permanent monitoring of populations through certain structural elements involving density, age structure, fertility, and population increase. According to these indicators it is necessary to plan annually the level, structure, manners and the period of hunting of the determined hare population (ŠELMIĆ, 1984).

The latest research that dealt with the proportion of yearlings among the hunted hares and increase in Croatia were conducted by Andrašić from 1972-1976 in Međimurje (Hunting Association Međimurje – Čakovec), who determined the age structure by examining the softness of the lacrimal bone, the softness of the auricle and Stroh's sign (ANDRAŠIĆ, 1977). Due to the subjectivity of the applied methods in age determination these results were not reliable (ŠELMIĆ, 1984).

Materials and methods

Research area and animals. The eyes were collected during the 2004/2005 hunting season, from October to December, on the territory of three northwestern Croatian counties: Krapina and Zagorje (108 samples), Međimurje (111 samples) and Zagreb (60 samples) (Fig.1). In total 279 eyes were collected. The research was conducted in 5 hunting grounds covering 6986 hectares managed by hunting associations.

Two most represented habitats (according to the height above sea level) were included in the sampling: lowland habitats (130-150 m above sea level) and mountain habitats (230-350 m above sea level). Lowland habitats were mainly comprised of meadows and small scale agricultural land planted with corn, wheat, barley, oats and potatoes. The researched mountain habitats were exposed to the south and they were dominated by small vineyards, meadows and agricultural land planted with corn, barley and oats. All animals were weighed and sexed after hunting.

Age determination of hares based on eye lens weight. The eye lenses were taken from the hares' eyes immediately after hunting. Following the extraction lenses were fixed for three days in 10% buffered formalin. After that, lenses were dried in a thermostat at 37 ºC for 72 hours, at normal pressure. When drying was completed the weight of the lenses was

measured on a precise analytic scale (OHAUS) with precision of 1 mg. The method of determining the age by measuring the weight of dry eye lenses is based on the fact that the eye lens grows during the whole life, more intensively up to the age of one year, and after that the growth is slower (LORD, 1959; RIECK, 1962; ŠELMIĆ, 1984; SUCHENTRUNK et al., 1991). The method applied was reliable enough to estimate the age of juvenile individuals (up to 9-10 months) and it distinguishes, with great precision, between juvenile hares (up to a year) and adult hares, older than a year (CARBON-RACZYNSKA and RACZYNSKI, 1972; PEPIN, 1974; ŠELMIĆ, 1984; SUCHENTRUNK et al., 1991). While determining the age, we put the hares into two groups, hares up to a year and hares older than a year. We determined the weight of 280 mg as the borderline value of eye lens weight between juvenile and adult hares (ŠELMIĆ, 1984; SLAMEČKA et al., 1997).

Fig. 1. Map of the researched area in NW Croatia with 5 hunting grounds (● lowland habitats, ■ mountain habitats).

Indicators of population dynamics. As indicators of population dynamics in this research we used: ratio of yearlings in the bag, reproduction coefficient, reproduction index, sex ratio, coefficient of population increase and population increase. Furthermore we set the criteria for the determination of population increase based on the ratio of yearlings in the bag – an increase of over 60% was considered as excellent, 50-60% as medium and less than 50% as poor (SLAMEČKA et al., 1997).

The formulas for calculating the each of indicators is showed below:

1. Ratio of yearlings in the bag

$$\%juv = \frac{N_{juv}}{N} \times 100$$

2. Coefficient of reproduction

$$R = \frac{N_{juv}}{N_{ad}}$$

3. Reproduction index

$$r = \frac{N_{juv}}{N_{adf}}$$

4. Sex ratio

$$Si = \frac{F}{N}$$

5. Coefficient of population increase

$$cPI = 0.7(\frac{N_{juv}}{N_{ad}} + 1)$$

6. Population increase

$$PI\% = \frac{\%juv - 30}{100 - \%juv} \times 100$$

Key: N-total number of individuals; Nad –number of adults; Nadf - number of adult females; F-number of females

While determining the spring number of hares in the researched areas, we applied the method of counting test areas (transect method), where we counted the spring number of hares as a mean number of hares per area units (ŠELMIĆ, 1984; SLAMEČKA et al., 1997).

Statistical analysis. Results were analyzed by GLM procedures of SAS (1999).

Results and discussion

The obtained results are presented in Table 1 and compared with the expected values according to the management plans. The mean weight of the analyzed hares according to the sex is presented in the Table 2.

Table 1. Certain indicators of population dynamics of the researched hunting grounds during 2004

Indicators	Hunting grounds				
	Lowland habitats			Mountain habitats	
	Mala Subotica	Hodošan	Sveta Nedjelja	Zlatar	Budinšćina
HPA (ha)	2300	1082	955	1595	1054
AcPI	1.7	1.7	1.4	1.3	1.3
API %	70	70	40	30	30
ASN1100ha^{-1}	27	27.4	19	14	13
ASN2100ha^{-1}	18	20.3	19	13.8	13
AN/HPA	501	358	282	248	240
N	67	44	60	58	50
% N	13.4	12.3	21.3	23.4	20.8
% juv	42	57	55	38	60
R	0.72	1.31	1.22	0.61	1.5
r	1.72	3.40	2.71	1.33	2.27
Si	0.42	0.39	0.45	0.46	0.66
cPI	1.20	1.62	1.55	1.13	1.75
PI%	20.7	62.8	55.6	12.9	75

Key: HPA (ha) – hunting and productive area for hare management
AcPI – anticipated coefficient of population increase; API% - anticipated population increase
ASN1100ha-1 - anticipated spring number of hares per 100 ha of hunting and productivearea,
ASN2100ha-1 - actual spring number of hares per 100 ha of hunting and productive area,
AN/HPA - autumn number of hares; N - number of samples; %N - sampled part of autumn population; %juv - ratio of yearlings in the bag; R - coefficient of reproduction; r - reproduction index; Si - Sex ratio; cPI - coefficient of population increase; PI% - population increase

Table 2. Average weight of hares, researched in NW Croatia, according to sex and age

age	sex	
	male LSM (SE)	female LSM (SE)
<1 year	3.58 (0.07) a	3.41 (0.08)
>1 year	3.84(0.07) b	3.66 (0.07)

LSM – Least Square Means; SE – Standard Errors; Values marked in different letters (a, b) statistically differ significantly for $P< 0.05$.

The safest way to define the optimal strategy of hare management is by understanding the population dynamics (MARBOUTIN et al., 2003). Therefore, several indicators of population dynamics were chosen as the basis of hare population research in northwestern Croatia during 2004. Depending on the hunting ground, the sample ranged between 12.3 and 23.4% of the autumn population. Although sampling in two hunting grounds included less then 20% of the autumn population, we find it relevant because the research involved sampling of free living populations. Selected areas, with their small and fragmented agricultural lands, offer relatively favorable life conditions for hares (PANEK and KAMIENARZ, 1999). During the research in 2004 the climatic conditions were within average parameters except for the snow in March and a rainy autumn (involving especially September and October) (according to the State Meteorological Office). According to several studies conducted in Slovakia (HELL et al., 1997) and Germany (NYENHUIS, 1995) these weather conditions could have influenced the survival and health conditions of the hares, but we cannot claim with certainty that they influenced the population significantly in the researched area in 2004.

The density of population, shown in Table 1 as the actual spring number of hares on 100 hectares of hunting and productive area (ASN2100 ha^{-1}), ranged between 13 (Budinšćina hunting ground) to 20.3 individuals/100ha (Hodošan hunting ground), which correspond well to data reported for other European countries, i.e. 15-20 hares/100 ha in Poland (PIELOWSKI and PINKOWSKI, 1992), 10-20/100 ha in France (REITZ and LEONARD, 1994), or 11.9-17.2/100ha in Germany (AHRENS, 1996a). According to available data (ANDRAŠIĆ, 1977), for the Međimurje region we can conclude that there have been no significant changes in population density for almost 40 years. Therefore, this population along with one from the Vojvodina region (Serbia and Montenegro) with a spring density of 11-30 hares/100ha can be seen as a stable population in Croatia and the neighboring countries (ŠELMIĆ, 1984). It is difficult to discuss the decline in hare population in the analyzed areas after a year of research, indicating the need for continuing monitoring. A reduction of the hare population to a larger extent was noticed in the majority of European countries and in Croatia this phenomenon was described by CAR (1973) and ROMIĆ et al. (1980).

Spring density of the population was higher in lowland habitats than in mountain habitats, and that is in accordance with management plans for the researched hunting grounds which anticipate higher population density and increased coefficients for lowland habitats. Among lowland habitats only the Sveta Nedelja hunting ground had spring population density as planned, which was not the case for the other two hunting grounds, Mala Subotica and Hodošan (Međimurje). Given the fact that same area (Međimurje) did not achieve the planned spring density in 1967 (67% of ASN1100 ha^{-1}), we might

suspect the quality of management plans which anticipate spring population density of 27 individuals/100 ha.

The dynamics indicator showing the ratio of yearlings in the bag during 2004 varied from 38-60%. It should be stated that the lowest and highest value of the ratio of yearlings in the bag was recorded in two hunting grounds that are in close proximity and that have almost the same conditions as mountain habitats. This variation of the ratio of yearlings in the bag in close proximity was also mentioned by other authors (ABILDGARD et al., 1972; PIELOWSKI, 1976; KOVACS and HELTAY, 1981; AHRENS, 1996b; SLAMEČKA et al., 1997; ŠELMIĆ et al., 1999; KOLAR, 2003; MARBOUTIN et al., 2003). The ratio of yearlings in the bag of 22-30% which was determined by ANDRAŠIĆ (1977) for the hunting ground H.A. Međimurje is extremely low and it can be ascribed to inadequate (subjective) methodology of age determination (Stroh's sign, the softness of auricle and lacrimal bone) due to which the ratio of yearlings was most likely miscounted (ŠELMIĆ, 1984). In 1950s and 1960s the ratio of yearlings in Europe ranged from 60-80% and in today's research the ratio of yearlings in a population remains around or below 50% (BENSINGER, 2002), and this was proved in our research for NW Croatia (50.4%).

Population increase in the researched hunting grounds ranged from a poor 12.9% (Zlatar) to an excellent 75% (Budinšćina), both in mountain habitats. These differences in increase in a relatively narrow area were described previously by ŠELMIĆ et al. (1988) in Vojvodina region (1973-1998 it ranged from 32-133%) and these are the only comparable data dealing with population increase, since other European researchers did not describe this indicator of population dynamics. The population increase anticipated in the management plan was not achieved in 3 hunting grounds (Mala Subotica, Hodošan and Zlatar). Besides the above mentioned differences in increase between the two neighboring hunting mountain habitats, there is also an evident increase difference within identical lowland habitats - Mala Subotica (low increase – 20.7%) and Hodošan (excellent increase – 62.8%).

Reproduction index (r) as an indicator of survival of litter per female ranged from 1.33 (Zlatar) to 3.40 (Hodošan). The results were similar to the 1.0 to 2.0 obtained in the Czech Republic (SEMIZOROVÁ and ŠVARC, 1987), or 2.24 in Slovakia (SLAMEČKA et al., 1997). The obtained data clearly shows that two spatially connected lowland hunting grounds, Mala Subotica and Hodošan and Zlatar and Budinšćina in mountain habitat, have very different reproduction indexes.

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).

The coefficient of reproduction (R) ranged from 0.61 (Zlatar) to 1.5 (Budinšćina) with average value of 1.07. SEMIZOROVÁ and ŠVARC (1987) determined the mean factor R of 0.74 in the Czech Republic in the period 1980-1984. In Slovakia, according to SLAMEČKA et al. (1997), the coefficient of reproduction was much higher (R=1.08) from 1987 to 1995, which can be easily compared to the average value obtained in northwestern Croatia and therefore we can conclude that favorable conditions exist in that area for the reproduction of hares.

In the overall sample (N=279) Si measured 0.48 and ranged from 0.39 (Hodošan) to 0.66 (Budinšćina). The same sex ratio was determined by SEMIZOROVÁ (1986) between 1980 and 1982 in the Czech Republic and RACZYNSKI (1964) in Poland. Some authors reported a sex ratio in favor of females: 0.51 (ŠELMIĆ, 1984; SLAMEČKA et al., 1997), 0.52 (KOLAR, 2003) and 0.54 (WASILEWSKI, 1991). In view of all this we can conclude that the ratio obtained in the research was normal, despite the slightly larger number of females.

The average weight of hares according to the age and sex ranged from 3.41 to 3.84 kg. The average weight of year-old-males was 3.58, while older males weighed 3.84 kg on average. The heaviest male was 5 kg. The difference in weight among males was statistically significant ($P<0.05$). The weight of year-old-females was 3.41 on average, and 3.66 kg for older ones. The studies in Slovenia and Poland (KRUPKA et al., 1981; KOLAR, 2003) revealed that males were heavier than females, contrary to some researchers from Germany and Slovakia who state that females are heavier on average (SLAMEČKA et al., 1997; BENSINGER, 2002).

The results of our research showed the heterogeneity of indicators of population dynamics in NW Croatia and they were comparable to the results obtained in the majority of European countries. In some hunting grounds we established good reproductive indicators. It is necessary to continue the research across the whole of Croatia to establish actual population trends, as a precondition of rational management.

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SAŽETAK

U lovnoj sezoni 2004./2005. u pet lovišta na području sjeverozapadne Hrvatske pretraživani su određeni pokazatelji populacijske dinamike zečeva (*Lepus europaeus* Pallas, 1778). Promatrana područja obuhvaćala su i nizinska i brdska staništa. U navedenome periodu, tijekom redovitih lovnih zahvata prikupljeno je 279 očiju zečeva za potrebe određivanja dobi pomoću težine očnih leća. Promatrani zečevi podijeljeni su u dvije grupe, starosti do jedne godine i starije od jedne godine. Naši rezultati pokazuju da prosječni udio zečeva mlađih od jedne godine iznosi 50,4% ukupne populacije. Predviđeni porast brojnosti zečeva (prema planu gospodarenja) nije postignut u tri promatrana lovišta. Rasplodni indeks, kao pokazatelj stupnja preživljavanja mladunčadi po jednoj zečici, znatno je kolebao, od 1,33 do 3,40. Prosječna vrijednost rasplodnog čimbenika iznosila je 1,07. Proljetna gustoća populacije kretala se od 13 do 20,3 jedinki na 100 ha lovišta. Spolni omjer od 0,48 ukazivao

je na veći udio mužjaka u populaciji. Prosječna težina zečeva kolebala je ovisno o spolu i dobi od 3,41 do 3,84 kg. Uočena je statistički značajna razlika ($P<0,05$) u tjelesnoj masi mužjaka.

Ključne riječi: zec, *Lepus europaeus*, očne leće, populacijska dinamika