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Density of the brown hare (*Lepus europaeus* Pall.) and selected population indicators

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SUMMARY

The paper presents the results of research on the body weight and population structures (age and sex) of hares in south-eastern Poland (Lublin Upland), conducted in 2019. The analysis included 205 hares from four regions differing in density, and thus in the hunting exploitation of the population. Due to low culling in two areas with low densities, the data from these areas were combined into one sample. The results showed that body weight was determined by the age of the individuals, while sex had no significant effect on this parameter. Despite the significant variability of body weight between research areas, no significant differences in this feature between regions of origin were found. The age structure was dominated by adults (over 1 year of age), especially in areas with low population densities. In terms of sex structure, females clearly dominated. It was demonstrated that the population structures described can have a direct impact on indicators of reproductive capacity and population continuity. Although the sample size was small in the low-density areas, the calculated indicators suggest that the viability of these populations is at serious risk. In areas with higher density indicators, limitations on hunting should be considered in order to maintain a density that guarantees the optimal functioning and persistence of the population.

KEY WORDS: brown hare, body weight, density, sex structure, age structure, reproduction factor

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INTRODUCTION

Since the 1970s, a downward trend in the population of hares has been observed in most European countries (Schmidt et al., 2004; Smith et al., 2005; Pintur et al., 2006; Méres et al., 2013; Farkas et al., 2016). A similar trend has been recorded since the 1970s in Poland, where the population density is now lower than the level of culling in the 1960s and 1970s (Pielowski, 1979; Mysłek et al., 2004; Misiorowska and Wasilewski, 2012; Flis, 2016). At the beginning of the 21st century, the average hare density in various regions of Poland ranged from 5 to 9 individuals per 100 ha, and no hunting exploitation of the population was carried out on most hunting grounds. Despite such low densities of this species and the relatively high culling rate, reaching even five individuals per 100 ha, there are still areas where the population density is still very high. This offers the possibility of annual hunting exploitation (Dziedzic et al., 2002; Misiorowska et al., 2014; Flis, 2015; Flis, 2016; Flis and Rataj, 2019).

Despite many studies on the functioning of the population and the causes of its decline, in many countries there is no clear position on this issue. The most commonly mentioned cause is the increase in the pressure of birds and predatory mammals, especially foxes, whose condition, due to cyclical oral immunization procedures, has significantly improved in recent decades (Goszczyński and Wasilewski, 1992; Panek et al., 2006; Panek, 2013; Demirbas, 2015; Hušek et al., 2015; Flis, 2018; Flis and Rataj, 2018; Ponjiger et al., 2020). However, intensive changes in agricultural landscapes caused by intensification of agriculture, which significantly simplifies the structures of agricultural ecosystems, are increasingly mentioned as the main reason for the persistent unfavourable trend. Hares show a clear preference for the edges of small fields, which have been rapidly decreasing in recent years (Schmidt et al., 2004; Ferretti et al., 2010; Kamieniarz et al., 2013; Schai-Braun et al., 2015; Flis, 2016; Freschi et al., 2016; Rizzardini et al., 2019). This was confirmed by a study in Austria, which showed a marked increase in hare survival depending on the proportion of set-aside land compared to land managed agriculturally (Schai-Braun et al., 2020). Also, climatic factors contribute to the decimation of the population, especially of juveniles, in which mortality is about 18% in the first month of life (Karp and Gehr, 2020).

The size of the hare population, and thus its reproductive potential, is also affected by numerous diseases of various etiological origins, mainly coccidiosis and other parasitic diseases (Pikula et al., 2004; Dubinský et al., 2010; Chroust et al., 2012; Kornaś et al., 2014). A number of other bacterial or viral diseases are also found in hares. Examples include brucellosis and EBHS – a haemorrhagic disease of hares that appeared in Europe in the early 1980s and contributed to the decimation of the population of the species in many regions. Current research has shown the presence of EBHS in over 80% of individuals from south-eastern and central Poland. Since 2010 there have been increasingly frequent reports of the recombinant strain of rabbit haemorrhagic disease virus (RHDV2), causing prolonged epidemics and up to 90% mortality (Frölich and Lavazza, 2008; Decors et al., 2011; Salvioli et al., 2017; Rataj et al., 2019; Flis and Rataj, 2020, Fitzner et al., 2022).

We hypothesized that intra-population factors, such as individual body condition and population structure, influence the reproductive capacity, growth, and continuity of hare populations in relation to density indicators. The research hypothesis was verified by determining the effect of the condition of animals, associated with their place of origin, the density index, and population structure, on reproduction performance, population stability, and forecasting of further population functioning.

MATERIAL AND METHODS

Animals and research area

The research was conducted using 205 hares culled in hunting districts located in the Lublin Upland, where the species is still harvested during hunting. Culling with hunting shotguns was carried out by group hunting using drive counts, and thus it was a random type of culling. The randomness of the sample was determined by the fact that not all hares were scared away by the beaters, and not all hares were present within the shooting range; it was also associated with hunters' shooting skills. Two districts (research area I and research area II) had had high harvesting rates in recent years, i.e. approximately five individuals per 100 ha. The first research area was located in the western part of the Lublin Upland (51.10701, 22.02496). The second area was in the western part of the Lublin region (51.00935, 22.10022). There was a relatively large share of perennial plantations and orchards in the crop structure, which resulted in significant habitat heterogeneity with a predominance of sheltered areas. The third research area was located in the central part of the Lublin region (51.25417, 22.71157), and the fourth was located in the southern part of the region (50.68023, 22.64599). All research areas were characterized by extensive open expanses with high intensification of agricultural crops, which contributed to the considerable heterogeneity of these open spaces. Assessment of the natural environment conducted as proposed by Schrödel (Schrödl, 1991) showed little differentiation in this respect in the study areas. The average size of single fields in research areas I and II was 0.91 and 1.05 ha. It was 1.17 ha in area III and 0.98 ha in area IV. The mean distances between landscape elements reflecting habitat heterogeneity were in the range of 0.4–0.6 km in research areas I, II, and IV and 0.7 km in area III. Similar research had been conducted two years earlier in areas II and II, but only included an assessment of indicators characterizing two populations from high-density areas (Flis and Rataj, 2019) and a comparison of the two populations with one another. The current research made it possible to assess the functioning of populations between contrasting regions in terms of density but with similar environmental conditions.

The samples from areas II and II consisted of 100 and 78 hares, respectively, while low harvesting rates not exceeding one individual per 100 ha were recorded in the other two areas (research areas III and IV). The culling rate in these areas was low: 12 and 15 hares, respectively. Due to the low density of hares in areas III and IV, the data obtained from these two areas were combined for further calculations. Thus in the presentation of the results, research areas I and II will refer to the high-density areas, and area III will refer to the two low-density areas combined. The research was carried out during group hunting in November and December 2019, i.e. when hunting for this species is permitted by Polish law. The hunts took place between November 30 and December 6 on non-working days, i.e. Saturday and Sunday. No hares had been introduced to any of these regions; therefore, the populations are natural components of ecosystems in terms of their functioning and management.

Methods and measurements

The following population parameters were assessed:

- gender structure index
- age structure index
- coefficient of reproduction

- reproduction index
- coefficient of population increase
- population increase

Additionally, individual body weight was used for comprehensive assessment of the functioning of the population. Although this parameter describes the condition of individual animals, in the case of a large sample size it reflects the quality of the population.

The coefficient of reproduction, the reproduction index, the coefficient of population increase and the population increase were calculated to describe the dynamics of the population size (Pintur et al., 2006).

Coefficient of reproduction:

1. $$\mathbf{W_r} = \frac{\mathbf{N_{juv}}}{\mathbf{N_{ad}}}$$

Reproduction index:

2. $$\mathbf{W_{sr}} = \frac{\mathbf{N_{juv}}}{\mathbf{N_{adf}}}$$

Coefficient of population increase:

3. $$\mathbf{W_{pp}} = (\mathbf{0.7}\frac{\mathbf{N_{juv}}}{\mathbf{N_{ad}}} + \mathbf{1})$$

Population increase:

4. $$\boldsymbol{W_p} \frac{\boldsymbol{\%_{juv}-30}}{\boldsymbol{100-\%_{juv}}} \times \mathbf{100}$$

where:
N_{juv} - number of juveniles
N_{ad} - number of adults
N_{adf} - number of adult females
$\%_{juv}$ - percentage of juveniles

The coefficient of reproduction enables assessment of the ability of the population to grow and develop by comparing the number of juveniles surviving to the hunting season per adult individual.

The reproduction index indicates the potential for population increase by comparing the number of juveniles surviving to the hunting season to the number of females at reproductive age (adults) in the population.

The coefficient of population increase describes the difference between the reproduction index (increase) and the mortality rate in the population.

The population increase indicator determines the potential population increase and development, and thus population stability and continuity in successive hunting seasons.

Field research

The body weight of the animals was measured immediately after culling. The hares were weighed to within 0.1 kg using a KERN HCB20K10 portable balance (Germany). Their age was determined based on the presence or absence of the Stroh sign, to distinguish juveniles (up to 1-year-old) and adults (over 1-year-old) individuals. Sex was determined based on the appearance of secondary sexual characteristics (Pielowski, 1979; Stroh, 1931).

Laboratory research

Additionally, the left eyeball was removed from each hare and preserved in 10% buffered formalin. The lens was removed from each eyeball in laboratory conditions to determine the animal's age, based on the weight ranges of the dried lenses, verifying the results obtained using the field method. The lenses were dried in a laboratory dryer SML 32 (Zelmer, Poland) at 100°C for 24 h to constant weight (Méres et al., 2013). After drying, the lenses were weighed on a laboratory balance (PIONEER OHAUS, Switzerland) to within 0.001 g. The method is based on the observation that the weight of the eye lens increases rapidly during the first year of life and more slowly in subsequent years. In accordance with this principle, the hares were classified as juveniles with lens weight up to 290 mg and adults with lens weight over 290 mg (Caboń-Raczyńska and Raczyński, 1972; Suchentruck et al., 1991; Pintur et al., 2006; Hruška et al., 2011, Méres et al., 2013). Additionally, to present a narrower age scale of young and adult hares, we applied the scale proposed by Misiorowska et al. (2014) following Pintur et al. (2006), which was slightly modified as in Meres et al. (2013). The following age ranges were established (Table 1):

Table 1.
Age ranges based on eye lens weight

Lens weight (mg)	Age of hares
45–100	3 months
101–200	3–6 months
201–290	6–12 months
291–310	1–2 years
311–370	2–3 years
Over 371	Older than 3 years

The data were divided into two age groups – juvenile and adult hares. In each group weight intervals of 0.005 mg were applied, and the data were presented in graphical form. The proportion of each age range for the young and adult hares was presented graphically as well.

Analysis

The entire material was divided into age and sex groups, which facilitated determination of the sex and age structure indices of the animals and body weight in the age and sex groups, separately for each harvesting area. The statistical analysis of the research results was carried out using the Statistica 13.1 PL statistical package. The compatibility of the distributions of the features examined with the normal distribution was assessed with the Shapiro–Wilk test. The distribution of variables was shown to deviate from normality, so non-parametric (rank) tests were used, and the Mann–Whitney U rank test was used to compare the average body weight values between sexes (within age groups). Statistically significant results were those at the typical significance level, i.e. when $p \leq 0.05$.

RESULTS

This study showed a slight difference in the body weight of young males and females, with individuals from the lower-density research areas having a higher body weight (Table 2). Comparison of the body weight of young males and females from different research areas showed that the differences in the body weight of young animals were statistically insignificant ($P > 0.05$). The effect of the density level on body weight was also observed in adult animals (Table 3), but the differences between individual regions of origin, as in juveniles, proved to be statistically insignificant ($P > 0.05$). It should be noted that the combined study areas with low densities (III and IV) had a much smaller share of perennial plantations, but a greater heterogeneity of open areas. The comparison of the average body weights of individuals without regard to sex also showed no significant differences in either young or adult hares. Thus, analysis of the effect of the animal's origin on adult body weight revealed that the place of origin had no significant effect on this trait ($p = 0.973$).

Table 2.
Body weight (kg) of young males (♂) and females (♀)

Item	Research area		
	I	II	III
		Males	
n	16	20	1
$\bar{x}$	4.03	3.93	3.90
SD	0.15	0.27	-
		Females	
n	22	17	4
$\bar{x}$	3.88	3.82	3.95
SD	0.35	0.37	0.10
Total (♂ and ♀)	3.95	3.88	3.94
P-values	0.573	0.437	-

Table 3.
Body weight (kg) of adult males (♂) and females (♀)

Item	Research area		
	I	II	III
	Males		
n	29	4	9
$\bar{x}$	4.52	4.56	4.61
SD	0.20	0.27	0.38
	Females		
n	33	25	13
$\bar{x}$	4.60	4.61	4.58
SD	0.29	0.25	0.33
Total (♂ and ♀)	4.57	4.59	4.59
P-values	0.098	0.279	0.893

The sex structure of the hare population showed little differentiation between study areas and was nearly balanced (Table 4). Female hares were predominant in regions I and III, while in region II the structure was almost even. In terms of age structure, adults dominated, especially in low-density areas; however, due to the small sample size, these data should be treated only as a guide. The most balanced age structure was noted in the second research area.

Table 4.
Sex (♂:♀) and age (juveniles:adults) structures in the hare populations from the research areas

Item	Research area		
	I	II	III
Juvenuiles (♂:♀)	1:1.4	1:0.9	1:4.0
Adults (♂:♀)	1:1.1	1:0.6	1:1.4
Total (♂:♀)	1:1.2	1:0.7	1:1.7
Males (J:A)	1:1.8	1:1.3	1:9.0
Females (J:A)	1:1.5	1:0.9	1:3.2
Total (J:A)	1:1.6	1:1.1	1:4.4

The analysis of the indicators of population size dynamics revealed the highest values of the individual parameters in the populations from the high-density areas (Table 5). Population growth rate exceeded 1.0 in all study areas, confirming higher reproduction rates over mortality rates. Nevertheless, in the areas with low density, the coefficient of population increase determining the potential for population continuity and development in subsequent years of life was negative, which clearly indicates a possible further decline in the population size in these regions.

Table 5.
Indicators of population size dynamics in hares from the research areas

Coefficient	**Research area**		
	I	**II**	**III**
W_r	0.61	0.90	0.22
W_{sr}	1.15	2.31	0.38
W_{pp}	1.43	1.63	1.16
W_p	12.90	32.08	-13.58

W_r – Coefficient of reproduction. W_{sr} – Reproduction index; W_{pp} – Coefficient of population increase; W_p – Population increase

This was confirmed by the low values of the reproduction index, which was well below 0.3 in these areas, as well as the value of the reproduction index, which did not exceed 0.5. In areas with higher density, the values of these parameters were much higher, but still alarming, as growth in the range of 13–32% may be insufficient for reproduction and growth processes that guarantee continuity, and above all, population development.

Irrespective of the area of origin, the analysis of the age of the culled hares assessed by measurements of eye lens weight indicated that the group of juvenile animals was dominated by 6–12-month-old individuals, while no hares under 3 months of age were found (Fig. 1). In both young and adult hares there was substantial variation in the weight ranges, and thus in the age of hares from different litters (young hares) and hares assessed in different years (adult hares). Regarding the lens weight ranges established with 0.005-mg intervals, the greatest number of animal lenses was in the range of 250–285 mg. This indicates the predominance of hares from spring litters in the population and confirms higher fecundity and survival of animals from these litters. It is difficult to precisely identify the reason for the very low share of the youngest individuals, i.e. in summer and especially autumn litters. Perhaps the reason is much higher losses of newborn hares in this period due to the specificity of living conditions associated with the intensification of field work in agrarian structures. The sample was more homogeneous in the group of adult hares, which confirms the higher survival stability after the age of 1 year.

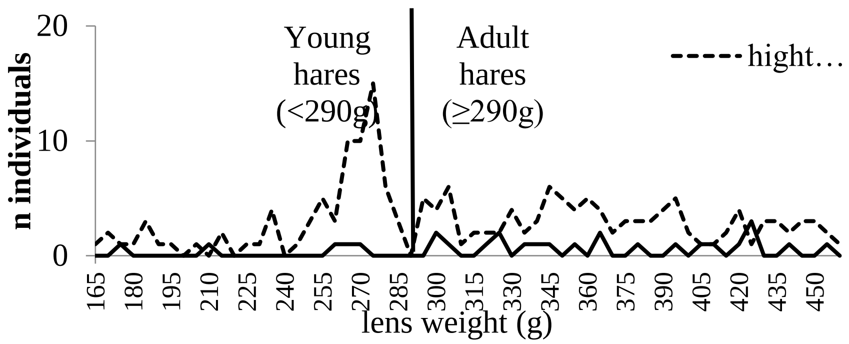

Fig. 1. Age distribution in culled hares in the research areas determined by measurements of eye lens weight

DISCUSSION

The present results confirm that the body weight of hares has been stable in Poland for many years. The body weight of approx. 4.0 kg in young hares and 4.6 kg in adults confirms the high condition of the animals, observed for almost 30 years in this area, with a clear tendency towards higher body weight in areas with lower density. Research conducted in the 1990s showed an average body weight of 4.3 kg in the Lublin Upland and 4.3 kg in the Podlasie region (Dziedzic et al., 1998). Another study conducted in the Lublin Upland in 2014 established body weight of hares in the range of 3.88–4.51 kg, with significant differences only between age groups. The number of adult hares was found to be twice as high as that of young individuals (Flis, 2015). In a study conducted in the same region in 2017, the average body weight of young and adult hares was 4.1 kg and 4.7 kg, respectively, and significant differences were found only between juveniles and adults, irrespective of the sex of the animals (Flis and Rataj, 2019). A study carried out near Krakow showed an average body weight of hares of 4.02 kg, which increased with the age of the animals (Wajdzik et al., 2012). Nationwide research conducted in regions with the highest population densities in 2009 showed an average body weight of hares in the range of 3.42–4.32 kg, with significant differences noted only between age groups. The research also demonstrated a clear predominance of adult hares over juveniles (Misiorowska et al., 2014). The average body weight of hares hunted in Wielkopolska in 1969–1971, when density was substantially higher than at present, was 3.86 kg. It was found to differ significantly only between young and adult hares (Takacs et al. 2009). The average body weight of hares in the Central Pomerania region was estimated at 4.13 kg, and differences between the means were found only between age groups (Mysłek et al., 2004). In a study conducted in north-eastern Croatia, the mean body weight of young and adult hares was in the range of 3.41–3.58 and 3.66–3.84 kg, respectively, and a statistically significant difference was found only between juvenile and adult males (Pintur et al., 2006). A study conducted in Hungary reported differences in body weight between sex and age groups, but the differences were statistically significant only between the age groups. Higher body weight was shown in males in both young and adult animals (Farkas et al., 2016). The results of a study on the body weight of continental and island hares in Sweden demonstrated higher body weight for hares living on the continent. There were no significant differences between the sex groups, whereas differences were found between young and adult hares (Thulin et al., 2012). Body weight may also be correlated with climatic conditions. Research comparing adult female hares from Belgium (moderate oceanic climate) and Lower Austria (temperate continental climate) showed that the animals from Belgium had higher body weight (4.3 kg) than those from Austria (3.4 kg) (Hackländer et al., 2011). Compared with literature data, the present results indicate no differences between the body weight values in hares from the same age groups living in local populations, whereas differences may be noted between populations living in different environmental and climatic conditions.

Sex and age structures play a role in the optimal functioning and development of hare populations. A study conducted in 2011–2012 in the Nitra region of Slovakia reported a similar proportion of males and females in the population, with differences in the age groups and between research seasons (Farkas et al., 2016). Similar results were obtained by Misiorowska et al. (2014) in the regions with the highest population densities in Poland. This confirms the findings of studies conducted in high-density areas and the results of previous research in the same area (Flis, 2015; Flis and Rataj, 2019). A study conducted in Hungary showed a slight predominance of males in the population, irrespective of the age group (Méres et al., 2013).

Some studies conducted in Poland and other countries have found markedly higher numbers of adult hares than juveniles (Farkas et al., 2016; Méres et al., 2013; Misiorowska et al., 2014; Flis, 2015). A study of hares in Croatia conducted in 2004 showed a balanced age structure (Pintur et al., 2006), while a similar study carried out in 2017 in regions with high population densities in the Lublin Upland showed higher numbers of juvenile individuals than adults (Flis and Rataj, 2019). These results indicate a clear predominance of adult hares, in particular those aged over 3 years. They confirm earlier reports from this region provided by Misiorowska et al. (2014), where this age group also accounted for over 50% of adult hares, whereas hares aged 1–2 years constituted the smallest group of adult animals.

The calculated indicators of reproduction dynamics and the development and continuity potential in the populations suggest that in the high-density areas these parameters ensure an appropriate population processes. The values of the coefficient of reproduction and reproduction index calculated in these areas are similar to those reported by Farkas et al. (2016), whereas the coefficient of population increase is markedly lower. At the same time, these authors reported a coefficient of population increase of approx. 65%, which is much lower than that calculated for the high-density areas in the present study. A study conducted in Croatia showed differences in hare population indicators depending on the place of origin; in most cases, their values were higher in lowland habitats than in mountain locations (Pintur et al., 2006). In comparison with the present findings, these results demonstrated substantially higher values of these indicators in most cases. The results of nationwide studies of hares conducted in high-density areas revealed differences in population indicators. Depending on the region, the coefficient of reproduction was in the range of 0.36–1.26 but did not exceed 0.5 in most cases. The value of the reproduction index was in the range of 0.7–2.7, with most values exceeding 1.0 (Misiorowska et al., 2014). The authors of a study conducted in high-density areas in the Lublin region in 2017 reported substantially higher values of these population indicators. The values of the coefficient of reproduction and reproduction index were estimated at 1.63 and 2.42, respectively (Flis and Rataj, 2019).

The research results indicate an urgent need to undertake action to optimize population management in order to protect the population and eliminate factors that pose a direct threat to the further functioning of the populations. These measures should involve constant monitoring of changes in the population, limitation or suspension of hunting exploitation of populations in areas with very low density, and elimination or mitigation of all factors that exert an adverse effect on population processes in this species.

CONCLUSION

The present results pertaining to the body weight of hares from areas with different population density levels are consistent with findings reported by other authors investigating this and other regions of Poland. They are also consistent with the results of similar research carried out in some European countries. Only the age of hares was shown to determine their body weight, while sex and region of origin had no significant effect on this parameter. In terms of sex structure, all study areas were dominated by females, irrespective of the age of the hares, with considerably greater predominance of females in the low-density areas. The age structure revealed predominance of adult hares over juveniles, especially in the low-density areas. This significantly influenced the indicators of the functioning and reproductive potential of the individual populations. Their values in the low-density areas were very low, and the coefficient of population increase was negative. This indicates that density is an important determinant of the continuity and development of hare populations. At the same time, at low and very low levels of density, such populations are endangered with extinction, as they are not able to function independently in the natural environment.

REFERENCES

1. Caboń-Raczyńska K., Raczyński J. (1972). Method of determination of age in the European hare. Acta Theriologica, 17: 75-86.
2. Chroust K., Vodnansky M., Pikula J. (2012). Parasite load of European brown hares in Austria and Czech Republic. Veterinarni Medicina, 57(10): 551-558. doi:https://doi.org/10.17221/6367-VETMED.
3. Decors A., Lesage C., Jourdain E., Giraud P., Houbron P., Vanhem P., Madani N. (2011). Outbreak of tularemia in brown hares (*Lepus europaeus*) in France, January to March 2011. Eurosurveillance, 16(28): 19913. doi:https://doi.org/10.2807/ese.16.28.19913-en.
4. Demirbas Y. (2015). Density of European hare and red fox in different habitats of Kirikkale Province (Central Anatolia), with a low level in hare number and an expected correlation in spring. Acta Zoologica Bulgarica, 67(4): 515-520.
5. Dubinský P., Vasilková Z., Hurníková Z., Miterpáková M., Slamečka J., Jurčík R. (2010). Parasitic infections of the European brown hare (*Lepus europaeus* Pallas, 1778) in south-western Slovakia. Helminthologia, 47(4): 219-225. doi:https://doi.org/10.2478/s11687-010-0034-7.
6. Dziedzic R., Flis M., Olszak K., Wójcik M., Beeger S. (1998). Hare body weight in the Lublin Upland and Podlasie Region. Annales UMCS, XVI 35 EE: 261-267.

7. Dziedzic R., Kamieniarz R., Majer-Dziedzic B., Wójcik M., Beeger S., Flis M., Olszak K., Żontała M. (2002). Przyczyny spadku populacji zająca szaraka w Polsce. Wyd. Ministerstwo Środowiska. Fundacja Ekonomistów Środowiska i Zasobów Naturalnych. Warszawa, pp. 7-48.
8. Farkas P., Kusza S., Majzinger I. (2016). Analysis of some population parameters of the brown hare (*Lepus europaeus* Pallas, 1758) in two hunting areas on the Hungarian great plain. Lucrări Ştiinţifice Management Agricol, 18(1): 71-74.
9. Ferretti M., Paci G., Porrini S., Galardi L., Bagliacca M. (2010). Habitat use and home range traits of resident andrelocated hares (*Lepus europaeus* Pallas). Italian Journal of Animal Science, 9(3): 278-284. doi:https://doi.org/10.4081/ijas.2010.e54.
10. Fitzner A., Niedbalski W., Kęsy A., Rataj B., Flis M. (2022). European brown hare syndrome in Poland: Current epidemiological situation. Viruses, 14(11): 2423, doi:https://doi.org/10.3390/v14112423.
11. Flis M. (2015). Diversity of age, gender, and body mass of hares living in low density in the Lublin Upland. Sylwan, 159(7): 579-585. doi:https://doi.org/10.26202/sylwan.2015004.
12. Flis M. (2016). Variability of density and habitat preferences of brown hare in hunting district located in the Lublin Upland. Sylwan, 160(10): 829-836. doi:https://doi.org/10.26202/sylwan.2016025.
13. Flis M. (2018). Preventive vaccination of foxes against rabies-economic and environmental aspect. Economics and Environment, 1: 220-230.
14. Flis M., Rataj B. (2018). Epizootic situation of rabies after 16 years of prophylactic vaccination of free-living foxes in Poland. Życie Weterynaryjne, 93(5): 312-314.
15. Flis M., Rataj B. (2019). Characteristics of population indicators of brown hare (Lepus europaeus Pall.) obtained during group hunting in the region with the highest density in western part of the Lublin Region in Poland. Applied Ecology and Environmental Research, 17(6): 13701-13711. doi:https://doi.org/10.15666/aeer/1706_1370113711.
16. Flis M., Rataj B. (2020). New viral threat to the brown hare (*Lepus europaeus* Pallas) population. Życie Weterynaryjne, 95(2): 86-88.
17. Freschi P., Fascetti S., Musto M., Cosentino C., Paolino R., Valentini V. (2016). Seasonal variation in food habits of the Italian hare in a south Apennine semi-natural landscape. Ethology Ecology & Evolution, 28(2): 148–162. doi:https://doi.org/10.1080/03949370.2015.1022906.
18. Frölich K., Lavazza A. (2008). European Brown Hare Syndrome. [in]: Alves P.C., Ferrand N., Hackländer K. (eds) Lagomorph Biology. Springer, Berlin, Heidelberg, pp. 253-261.
19. Goszczyński J., Wasilewski M. (1992). Predation of foxes on a hare population in central Poland. Acta Theriologica, 37(4): 329-338.
20. Hackländer K., Zeitlhofer C., Ceulemans T., Suchentrunk F. (2011). Continentality affects body condition and size but not yearly reproductive output in female European hares (*Lepus europaeus*). Mammalian Biology, 76(5): 662-664. doi:https://doi.org/10.1016/j.mambio.2011.05.001.
21. Hruška J., Matoušková J., Ernst M., Slamečka J. (2011). Populační dynamika zajíce polního v letech 2008-2010 na základe stanovení hmotnosti očných čoček In. Zajac poľný pred štvrťstoročím a dnes. Nitra: CVŽV Nitra.

22. Hušek J., Panek M., Tryjanowski P. (2015). Predation risk drives habitat-specific sex ratio in a monomorphic species, the brown hare (*Lepus europaeus*). Ethology 121(6): 593-600. doi:https://doi.org/10.1111/eth.12373.
23. Kamieniarz P., Voigt U., Panek M., Strauss E., Niewęgłowski H. (2013). The effect of landscape structure on the distribution of brown hare *Lepus europaeus* in farmlands of Germany and Poland. Acta Theriologica, 58: 39-46. doi:https://doi.org/10.1007/s13364-012-0091-z.
24. Karp D., Gehr B. (2020). Bad hare day: very low survival rate in brow hare leverets. Wildlife Biology, 2020(2) 1-8. doi:https://doi.org/10.2981/wlb.00645.
25. Kornaś S., Wierzbowska I., Wajdzik M., Kowal J., Basiaga M., Nosal P. (2014). Endoparasites of European Brown Hare (*Lepus europaeus*) from Southern Poland based on necropsy. Annals of Animal Science, 14(2): 297-306. doi:https://doi.org/10.2478/aoas-2014-0010.
26. Méres J., Ostrihoň M., Slamečka M., Kaštier J. (2013). Population structure of brown hare (Lepus europaeus): a case study in selected areas of Nitra region. Acta Facultatis forestalis Zvolen, 1: 43-58.
27. Misiorowska M., Ludwisiak Ł., Nasiadka P. (2014). Population parameters of brown hare (*Lepus europaeus* L.) in regions of the species highest density in Poland. Sylwan, 158(12): 901-910. doi:https://doi.org/10.26202/sylwan.2014106.
28. Misiorowska M., Wasilewski M. (2012). Survival and causes of death among released brown hares (*Lepus europaeus* Pallas, 1778) in Central Poland. Acta Theriologica, 57(4): 305-312. doi:https://doi.org/10.1007/s13364-012-0081-1.
29. Mysłek P., Kalasińska E., Bartyzel B. (2004). Size of the brown hare (*Lepus europaeus* Pallas 1778) living in Central Pomerania in Poland. Zoologica Poloniae, 49(1-4): 237-244.
30. Panek M. (2013). Long-term changes in the feeding pattern of red foxes *Vulpes vulpes* and their predation on brown hares *Lepus europaeus* in western Poland. European Journal of Wildlife Research, 59(4): 581-586. doi:https://doi.org/10.1007/s10344-013-0709-8.
31. Panek M., Kamieniarz R., Bresiński W. (2006). The effect of experimental removal of red foxes *Vulpes vulpes* on spring density of brown hares *Lepus europaeus* in western Poland. Acta Theriologica, 51: 187-193. doi:https://doi.org/10.1007/BF03192670.
32. Pielowski Z. (1979. Zając. Monografia przyrodniczo–łowiecka. PWRiL, Warszawa.
33. Pikula J., Beklova M., Holesovska Z., Treml F. (2004). Ecology of European brown hare and distribution of natural foci of tularemia in the Czech Republic. Acta Veterinaria Brno, 73(2): 267-273. doi:https://doi.org/10.2754/avb200473020267.
34. Pintur K., Popović N., Alegro A., Severin K., Slavica A., Kolić E. (2006). Selected indicators of brown hare (*Lepus europaeus* Pallas, 1778) population dynamics in northwestern Croatia. Veterinarski Arhiv, 76: 199-209.
35. Ponjiger I., Ristić Z., Marković V., Matejević M., Kovačević M. (2020). The dynamics of red fox (*Vulpes vulpes*) and brown hare (*Lepus europaeus*) population in the Vojvodina region (Serbia) in relation to rabies vaccination. Veterinarski Arhiv, 89(6): 839-850. doi:https://doi.org/10.24099/vet.arhiv.0334.
36. Rataj B., Flis M., Piórkowski J. (2019). Histopathological changes and bacteriological survey of internal organs in the aspect of the individuals condition of hare (*Lepus europaeus* Pall.). Applied Ecology and Environmental Research, 17(3): 6655-6667. doi:https://doi.org/10.15666/aeer/1703_6655667.

37. Rizzardini G., Fascetti S., Pietri C., Riga F., Cosentino C., Freschi P. (2019). Feeding preferences in dry season of the Italian hare (*Lepus corsicanus*) in two sites of Corsica. European Journal of Wildlife Research, 65(3): 1–10. doi:https://doi.org/10.1007/s10344-019-1284-4.
38. Salvioli M., Pasquali A., Lavazza A., Zanoni M., Guberti V., Chiari M., Gilioli G. (2017). EBHS in European brown hares (*Lepus europaeus*): disease dynamics and control. Hystrix the Italian Journal of Mammalogy, 28(2): 202-207. doi:https://doi.org/104404/hystrix-28.2-12299.
39. Schai-Braun S. C., Reichlin T. S., Ruf T., Klansek E., Tataruch F., Arnold W., Hackländer K. (2015). The European hare (*Lepus europaeus*): A picky herbivore searching for plant parts rich in fat. PLos One, 10(7): e0134278. doi:https://doi.org/10.1371/journal.pone.0134278.
40. Schai-Braun S. C., Ruf T., Klansek E., Arnold W., Hackländer K. (2020). Positive effect of set-asides on European hare (*Lepus europaeus*) populations: Leverets benefit from an enhanced survival rate. Biological Conservation, 244, 108518. doi:https://doi.org/doi.org.10.1016/j.biocon.2020.108518.
41. Smith R. K., Jennings N. V., Harris S. (2005). A quantitative analysis of the abundance and demography of European hare *Lepus europaeus* in relation to habitat type, intensity of agriculture and climate. Mammal Review, 35(1): 1-24. doi:https://doi.org/10.1111/j.1365-2907.2005.00057.x.
42. Schmidt N. M., Asferg T., Forchhammer M. C. (2004). Long-term patterns in European brown hare population dynamics in Denmark: effects of agriculture, predation and climate. BMC Ecology, 4(15): 1-7. doi:https://doi.org/10.1186/1472-6785-4-15.
43. Schrödl G. (1991). Ein Stichprobenverfahren zur Biotopcharakterisierung Niederwildgebieten. Beitrage zur Jagd und Wildforschung XVII: 93-98.
44. Stroh G. (1931). Zwei sichere Altersmerkmale beim Hasen. Berliner Tierärztliche Wochenschrift, Berlin 47, 180-181.
45. Suchentrunck F., Willing R. Hartl G. B. (1991). On eye lens weights and other age criteria of the Brown hare (*Lepus europaeus* Pallas, 1778). Zeitschrift für Säugetierkunde, 56, 365-374.
46. Takacs V., Zduniak P., Panek M., Tryjanowski P. (2009). Does handling reduce the winter body mass of the European hare? Central European Journal of Biology, 4(3): 427-433. doi:https://doi.org/10.2478/s11535-009-0020-6.
47. Thulin C. G., Malmsten J., Laurila A. (2012). Differences in body mass, health status and genetic variation between insular and mainland brown hares (*Lepus europaeus*) in Sweden. European Journal of Wildlife Research, 58: 897-907. doi:https://doi.org/10.1007/s10344-012-0633-3.
48. Wajdzik M., Tomek A., Kubacki T. (2012). Differentiation of craniometric and biometric characteristics of the European hare (*Lepus europaeus*) in the Małopolska region. Sylwan, 156(2): 147-158. doi:https://doi.org/10.26202/sylwan.2011059.