

Article

Long-Term Monitoring of European Brown Hare (*Lepus europaeus*) Population in the Slovak Danubian Lowland

Francesco Vizzarri ^{1,*}, Jaroslav Slamecka ², Tomas Sladeczek ¹, Rastislav Jurcik ¹, Lubomir Ondruska ¹ and Peter Schultz ²

¹ Department of Nutrition and Small Farm Animals, Research Institute for Animal Production Nitra, National Agricultural and Food Centre, Hlohovecká 2, 951-41 Lužianky, Slovakia; tomas.sladeczek@nppc.sk (T.S.); rastislav.jurcik@nppc.sk (R.J.); lubomir.ondruska@nppc.sk (L.O.)

² Faculty of Agrobiological and Food Resources, Institute of Animal Husbandry, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949-76 Nitra, Slovakia; jaroslav.slamecka@uniag.sk (J.S.); schultz.peter84@gmail.com (P.S.)

* Correspondence: francesco.vizzarri@nppc.sk

Abstract: In many European countries over the last few decades, arable fields dominate agricultural landscapes, leading to very intensive land-use practices. This seems to be the main cause of population declines for numerous farmland species, including the European brown hare (*Lepus europaeus* Pallas, 1778). The Research Institute for Animal Production (National Agricultural and Food Centre—NPPC, Lužianky, Slovakia) has been engaged in a long monitoring project (a project currently running), collecting certain indicators of brown hare population dynamics during hunting season from 1987 to 2023 in the Slovak Danubian Lowland. In the same macro-area (Čiližská Radvaň and Lehnice), a study was conducted on the influence of permanent semi-natural vegetation in relation to recruitment, population density and production. The entire monitored period was aggregated into 5-year intervals (for a total of seven time intervals), with the aim of analyzing the brown hare population dynamics. Spring hare density in the Danubian Lowland is currently 20.8 hares/km², with harvests of 4.6 hares/km². During the monitoring period, bag animals have been examined following the regular hunting operations for the purpose of age determination (weight of eye lenses), sex ratio and productivity. There was a large positive effect of set-aside with special mixtures created for hares in large-scale farmed agrarian landscapes on brown hare density, bag and recruitment. In-model hunting grounds with such set-asides increased the spring stock by 25%, bag by 100% and recruitment by 20%. This study reveals that the management of European brown hare is not sustainable in the Slovak Danubian Lowland, and the population is decreasing. This is proven through the decline in harvest brown hares and by population dynamic parameters. Our data suggest that improvements in the habitat quality of arable landscapes by the adoption of permanent semi-natural vegetation may be more effective in the increase in the brown hare population.

Keywords: biodiversity; conservation; game management; population dynamics



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1. Introduction

Population density and hunting bags of brown hare (*Lepus europaeus*) are currently at historically low levels throughout Europe. The decline in the populations of brown hare has been experienced in many areas across its geographic range in Europe, beginning in the 1960s, with the intensification of agricultural practices as the main cause [1]. Although the problem has been studied intensively and much new information has been obtained [1–3], the causes of this decline have not yet been adequately explained, and there are clearly regional differences. The population density of this species might be affected by external factors such as climate, food availability, diseases and predators but also by internal factors such as reproductive rate and the ability for adaptation and anthropogenic factors [4]. Some recovery is apparent in Germany [5,6], but in Slovakia, there has not yet been any

marked increase in brown hare density [7]. A similar negative trend has been reported in a number of European countries, such as France, Denmark, Poland, Serbia, and Italy [8,9]. Despite its currently declining numbers, the European brown hare represents one of the most important game species throughout Slovakia's countryside. The dynamics of brown hares seem resilient to even heavy hunting pressure, though local population dynamic data may be needed to ensure sustainable harvest [10].

We had expected that the changes in agriculture in Slovakia following the collapse of communism in 1989 would have resulted in increased small game populations, including hares, but this did not occur. In the branch of agriculture, hunting and related services, the number of employees in organizations with over 20 persons decreased by about 250 thousand employees in the period of ten years. The decrease was mainly influenced by the decline in employees in agricultural cooperatives. In the year 1989, there were almost 261 thousand employees in agricultural cooperatives, while in 1998, it was only 69 thousand employees (data source: Statistical office of the Slovak Republic, https://slovak.statistics.sk/wps/portal/ext/home!/ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfljo8ziA809LZycDB0NLPyCXA08QxwD3IO8TAwNTEz1wwkpiAJKG-AAjgZA_VFgJc7ujh4m5j4GBhY-7qYGno4eoUGWgcbGB07GUAV4zCjJjTDIdFRUBADse0bP/dz/d5/L0IDUmlTUSEhL3dHa0FKRnNBLzROV3FpQSEhL2Vu/) accessed on 26 June 2024. In addition, Slovakia has faced a decline in livestock production, a decrease in the cultivation of perennial fodder crops and a specialization of agricultural enterprises in the production of only a few crop types, mainly sunflower, rape and soybean. This loss of crop diversity was unfavorable for brown hares. Only locally, in some hunting grounds, was there an increase in hare density and hunting bags associated with crops such as sunflower, maize, soybean and melons, in which hares cause substantial damage [11].

This study aimed to evaluate any changes in the population size and trend of the brown hare in the Slovak Danubian Lowland in the last few decades (1987–2023). In particular, the analyses aimed to (i) identify the environmental variables that influence the fluctuations and trends in the brown hare population, (ii) identify the variations of dynamic indices (sex ratio, age structure and productivity) over the years, (iii) highlight population trend in relation to climate change. We used hunting bag data for this purpose. These offer a good monitoring strategy, as they can be used as a general index of long-term trends, and they can give indications regarding changes in population size and distribution [12,13].

2. Materials and Methods

2.1. Study Area

The research was performed on a set of selected hunting grounds in the Slovak part of the Danubian Lowland (Figure 1) on the left side of the river Danube. Elevation above sea level is 103–160 m; soil is predominantly chernozem and alkaline; annual precipitation depth is 550–600 mm. Average annual air temperature is 9.6–10.5 °C. Climate is continental, very warm and dry; summers are hot with temperatures higher than 30 °C, and winters are quite mild with low covering of snow for short duration. The area is deforested; forest percentage varies from 0 to 10%. Arable land is in absolute prevalence (66–97%); mainly cereals including maize (65–80%), sunflower and rape are grown on it [14]. There is intensive agriculture on large plots with average area of 61 ha. There are also orchards and vineyards, but many of these are being liquidated, which is very unfavorable for the wild game. Semi-natural vegetation was virtually eliminated during the communist era [15]. This preserves predominantly large agricultural units from the period before the political changes in 1989 with a high degree of specialization; this means that one farm grows only a low number of crops and realizes a so-called blockade of plots, so one and the same crop is grown on a very large, continuous area. Animal production was considerably reduced, and therefore, acreage of grown fodder crops decreased markedly. During the entire monitoring period (1987–2023), the climatic conditions were collected and evaluated according to available database of Slovak Hydrometeorological Institute (Bratislava, Slovakia).



Figure 1. Geographical location of the Slovak Danubian Lowland (A) and the two model areas, Čiližská Radvaň (B) and Lehnice (C), for semi-natural habitats. Source: National Agricultural and Food Centre archive.

2.2. Indicators of Population Dynamics

Brown hare count is mandatory for every hunting company under Hunting Act 247/2009 every year. The most used count method is counting the entire area of hunting ground, or a part of it, and the subsequent conversion per unit area. Hunting statistics for Slovakia are collected by the Ministry of Agriculture and Rural Development. The hunting season for brown hares lasts from 1 November to 31 December, but most are shot and caught (and live exported) in December. From 1987 to 2023, age structure, body weight (a total of 3119 animals immediately after their capture), sex ratio and productivity were determined by examination of brown hares in hunting bags. The whole monitored period was grouped into 5-year intervals (for a total of 7 time intervals), with the aim of analyzing the brown hare population dynamics.

Sex was determined by visual inspection of the genitalia. Brown hares were classified into juveniles (animals up to 12 months of age) or adults based on eye lens dry weight [16]. A total of 12,845 eye lenses were weighed (1 eye lens from each shot hare). Eyeballs were dissected from shot brown hares using forceps and scissors. Each eyeball with an indication of the number and location of the brown hare was placed in a tube with fixative (4% formaldehyde). After 14 days of the fixation, lenses were cut out and dried to constant weight at 100 °C (24 h). Weight was measured on a Sartorius balance to the nearest 0.001 g. After the construction of the frequency distribution graph according to the weight of the eye lens, the threshold was determined, which was around 280 mg. According to this value, brown hares were classified to this year's group and older.

As indicators of population dynamics, in this research, we used ratio of juveniles in the bag, reproduction coefficient, reproduction index, sex ratio, coefficient of population increase and population increase. Furthermore, criteria were set for the determination of population increase based on the ratio of juveniles in the bag—an increase of over 60% was considered excellent, 50–60% was considered medium and less than 50% was considered poor [14]. The formulas for calculating the studied indicators [13] are shown below:

- Ratio of juveniles in the bag

$$PYB = (N_{\text{juv}}/N) \times 100$$

- Coefficient of reproduction

$$R = N_{\text{juv}} / N_{\text{ad}}$$

- Reproduction index

$$r = N_{\text{juv}} / N_{\text{adf}}$$

- Sex ratio

$$Si = F / N$$

- Population increase

$$PI\% = ((\%_{\text{juv}} - 30) / (100 - \%_{\text{juv}})) \times 100$$

Legend: N: total number of individuals; Nad: number of adults; Nadf: number of adult females; F: number of females; PYB: proportion of juveniles in the bag.

While determining the spring number of brown hares in the researched areas, we applied the method of counting test areas (transect method), where we counted the spring number of brown hares as a mean number of hares per area units [14].

2.3. Semi-Natural Vegetation Model Area

The influence of permanent semi-natural vegetation in the model area of the Hunters Association Velky Grob (48°14'56" N, 17°29'25" E) was studied. The influence of small fields or grazing grounds for brown hares on their recruitment, population density and production were determined on model areas Čiližská Radvaň (47°52' N, 18°05' E; 1691 ha; of which 35 ha were forest) between years 1998 and 2008, and for Lehnice (48°4'9" N, 17°27'17" E; 1958 ha; 45 ha forest), between years 2001 and 2005. To improve the environment, we used a specially developed seed mixture consisting of 7 species of grass (*Festuca rubra*, *Festuca pratensis*, *Phleum pratense*, *Dactylis glomerata*, *Lolium multiflorum*, *Lolium perenne*, *Poa pratensis*), 3 species of cereals (*Avena sativa*, *Secale cereale*, *Fagopyrum esculentum*), 3 species of clover (*Trifolium pratense*, *Trifolium repens*, *Lotus corniculatus*), 5 species of other legumes (*Medicago sativa*, *Faba vulgaris*, *Pisum sativum*, *Glycine max*, *Vicia sativa*), 3 species of *Brassicaceae* (*Sinapis alba*, *Brassica napus*, *Brassica oleracea*) and *Phacelia* [17]. These model areas represent the first pilot study using semi-natural vegetation in Slovak Danubian Lowland; therefore, future experimental experiences will include other natural areas used as control.

2.4. Statistical Analysis

Statistical analysis was performed Statdisk v. 12.0.2 software using Student's *t*-test and Scheffe's test for data regarding brown hare weights, with the animal sex as source of variation. Data on indicators of brown hare population's dynamics were analyzed performing a linear regression (significance level 0.05), setting time intervals as independent variable, and a correlation (Pearson, *r*) to assess the strength of the relationships between the examined variables.

3. Results and Discussion

3.1. Brown Hare Population's Dynamic

In the first half of the 20th century, the brown hare was, per capita, the most important game species in Slovakia, forming more than 70% of total game production. At the beginning of the 1960s, it still formed more than 60% of total game production, but subsequently, red deer (*Cervus elaphus*) and then wild boar (*Sus scrofa*) displaced the brown hare from first place. The highest bags of brown hares in Slovakia were recorded in 1973 (341,005 individuals) and 1974 (344,727 individuals) during an era of intensive large-scale agriculture (data source: Statistical office of the Slovak Repub-

lic, https://slovak.statistics.sk/wps/portal/ext/home!/ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfljo8ziA809LZycDB0NLPyCXA08QxwD3IO8TAwNTEz1wwkpiAJKG-AAjgZA_VFgJc7ujh4m5j4GBhY-7qYGno4eoUGWgcbGBo7GUAV4zCjJjTDIdFRUBADse0bP/dz/d5/L0lDUmlTUSEhL3dHa0FKRnNBLzROV3FpQSEhL2Vu/) accessed on 15 February 2024. In 1975, hare bags collapsed. They recovered quickly during 1976–77 but collapsed again in 1978–1979. From 1980 until the end of 2007, bags were relatively stable around a much lower average of 40,223 per year but still showed a slight decline during this period. A sharp fall from 1995 to 1996 (the lowest recorded in Slovakia) was associated with a prolonged cold period during winter 1995–1996 and very heavy rainfall in 1996 (110% of the norm and 170% during May). Only slightly less extreme was the fall between 2002 and 2003; this time was associated with unusually high summer temperatures and drought in 2003. The annual air temperature of the year 2003 at the Hurbanovo Observatory was 1.2 °C above the 1961–1990 annual average. This value makes the year 2003 the sixth warmest one since 1871. This contribution is devoted to a profound analysis of unusually extreme high temperatures in the May–August season and very low precipitation totals in the February–August season in Slovakia in 2003. In 2007, 31,856 brown hares were shot or caught in Slovakia (data source: Statistical office of the Slovak Republic, https://slovak.statistics.sk/wps/portal/ext/home!/ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfljo8ziA809LZycDB0NLPyCXA08QxwD3IO8TAwNTEz1wwkpiAJKG-AAjgZA_VFgJc7ujh4m5j4GBhY-7qYGno4eoUGWgcbGBo7GUAV4zCjJjTDIdFRUBADse0bP/dz/d5/L0lDUmlTUSEhL3dHa0FKRnNBLzROV3FpQSEhL2Vu/) accessed on 15 February 2024, equivalent to 0.71 hares per km² of hunted area or 1.36 per km² of agricultural area; during 2010–2012, it was only 0.36 hares per km² of hunted area or 0.67 per km² of agricultural area on average (e.g., in the Czech Republic, it is 1.68 hares per km² of hunting area, or 2.96 hares per km² of agricultural area). Bags per 1 km² often differ considerably, even between neighboring hunting grounds with similar ecological conditions, and there are also marked differences among years. The bags vary from 0 to 30 hares per km². Up to less than one-third of gamebags result in live-caught animals intended mainly for export.

Based on data available on the Slovak Hydrometeorological Institute (Bratislava, Slovakia) database, a summary of data regarding the precipitation and temperature in the studied site is reported in Figure 2. The authors aggregated data into two blocks, the 1980–1990 period and the 2013–2023 period, in order to show the evolution of climate conditions during the monitoring period. Comparing the two blocks of data, precipitations have been markedly changing during the monitoring period in terms of mm of rain and distribution during the year. In fact, nowadays, the studied area is characterized by three distinct peaks of precipitations (July, October, December), mainly with storm phenomena. While comparing the dataset on average temperature, the distribution throughout the year is similar, but an average increase of 2.0 °C was observed. According to several studies conducted in Slovakia [18] and Germany [19], all parameters of weather conditions might have influenced the survival and health conditions of the brown hares, but our study did not reveal any significant influence of climatic conditions when correlated with the indicators of brown hare population dynamics in the Slovak Danubian Lowland. A lack of an effect on brown hare population dynamic parameters by ambient conditions is reported in a recent study conducted in Italy [20].

Data regarding brown hare body weights are reported in Table 1. No statistical differences were observed between males and females categorized as juveniles. The weight of adult females was significantly higher than that of adult males ($p < 0.05$). However, this parameter is unsuitable for age estimation, as the maximum recorded weight of a subadult individual was 4.9 kg and the minimum of an adult one was 3.0 kg.

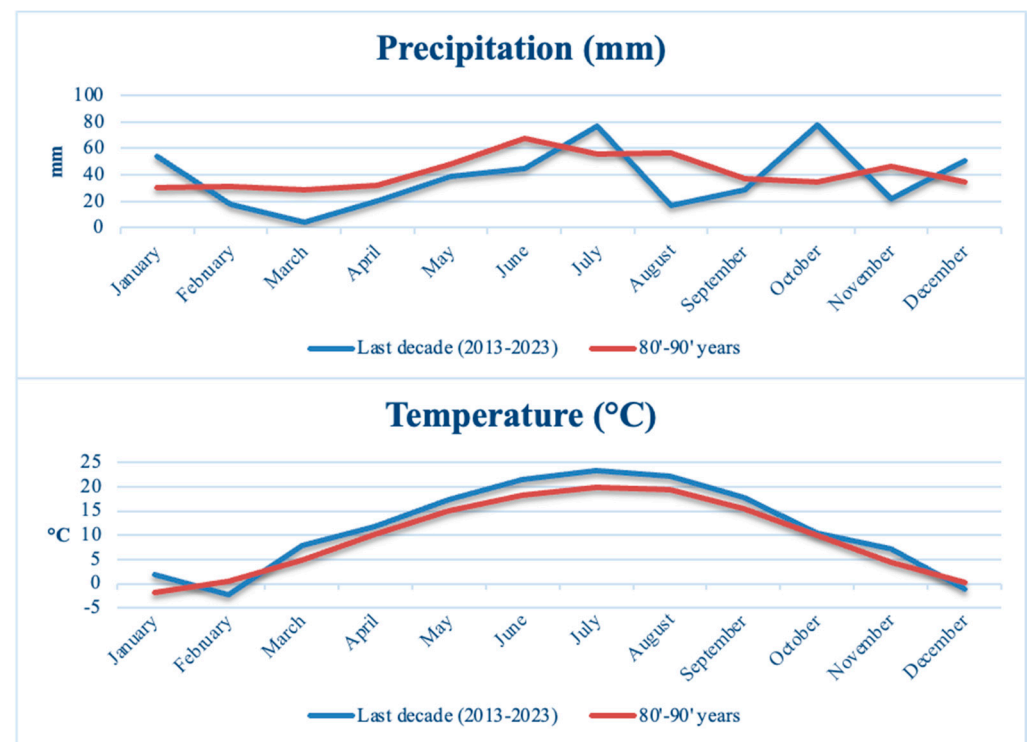


Figure 2. Average data on precipitation (mm) and temperature (°C) in Slovak Danubian Lowland.

Table 1. Average brown hare weights (kg) in Slovak Danubian Lowland.

	Male	Female	SD	<i>p</i> -Value *
Juvenile	3.83	3.85	0.014	0.6027
Adult	4.21 ^a	4.32 ^b	0.077	0.0491

* Different letters on the same row mean statistical difference for $p < 0.05$.

In the literature, similar data for juvenile weights are reported in northwestern Croatia [13], and lower weights were observed for adult animals. The studies in Slovenia and Poland [21,22] revealed that males were heavier than females, contrary to our data that state that females are heavier on average. Our data matched the literature, as reported in the previous experiences of other authors in Germany [23], Poland (western area) [24,25] and Slovakia [14].

As already mentioned, the entire period was grouped into 5-year intervals (for a total of seven time intervals), with the aim of analyzing brown hare population dynamics. According to [26], the optimal strategy of hare management relies on an understanding of the population dynamics. A potential limitation on the use of hunting bags is the assumption that the dataset is based on the effort of hunters to provide data (both spatially and temporally) constantly. A second consideration regards the quantity and the quality of the hunting effort, in terms of the number of hunters, number of hunting events and numbers of km walked during hunts, with the aim to standardize the bag's data. Based on the long-standing cooperation between NPPC and the hunters' associations active in the study area, the authors of the present study assumed that the hunting effort had been the same during the monitoring period (1987–2023). For this purpose, several indicators of population dynamics (Table 2) were analyzed based on the National Agricultural and Food Centre monitoring project, collecting data during hunting season from 1987 to 2023 in the Slovak Danubian Lowland. In the overall sample ($N = 3119$), a statistical ($p = 0.0496$) and strong decrease in caught animals was observed, varying from the highest number in the first time-interval (1987–1991; no. 1154) to the lowest number in the last time-interval (2018–2023; no. 206). Based on animal sex, female animals were tendentially always more

numerous than male animals, except for the time interval of 1998–2002. The sex ratio (Si) ranged from the lowest value of 0.48 (time interval of 2008–2012) to 0.52 (first time interval of 1987–1991 and last time interval of 2018–2023) in favor of female animals. A lower sex ratio was determined by [27] between 1980 and 1982 in the Czech Republic and [28] in Poland. At the same time, [14] (0.51), [21] (0.52) and [29] (0.54) reported very similar values of Si in favor of females. Considering the present data, we can conclude that the Si values obtained in the monitoring research were normal despite the slightly larger number of females.

Table 2. Indicators ⁺ of brown hare population dynamics in the Slovak Danubian Lowland.

Item	Time Intervals [#]							SE	<i>p</i> -Value [*]	Corr. Coeff.	Slope
	1	2	3	4	5	6	7				
N	1154 ^a	505 ^b	320 ^c	386 ^c	277 ^{cd}	271 ^{cd}	206 ^d	234.7	0.0496	−0.753	−102
Njuv	584 ^a	250 ^b	164 ^{bc}	196 ^{bc}	113 ^c	117 ^c	83 ^c	119.2	0.0431	−0.769	−54.3
PYB	49 ^a	50 ^a	51 ^a	46 ^{ab}	41 ^{ab}	45 ^{ab}	37 ^b	2.410	0.0212	−0.830	−1.52
R	1.00	1.00	1.05	1.00	0.70	0.88	0.65	0.098	0.0651	−0.725	−0.04
r	2.05	2.30	2.15	2.03	1.52	1.70	1.26	0.185	0.0213	−0.827	−0.12
Si	0.52	0.51	0.50	0.50	0.48 ^a	0.50	0.52	0.012	0.4971	−0.311	−0.01
adult female	283 ^a	115 ^b	78 ^c	96 ^{bc}	76 ^c	78 ^c	63 ^c	56.95	0.0495	−0.739	−26.4
males	558 ^a	247 ^b	162 ^c	197 ^c	125 ^{cd}	131 ^{cd}	97 ^d	104.6	0.0323	−0.795	−57.9
total females	596 ^a	258 ^b	157 ^c	201 ^{bc}	132 ^c	140 ^c	109 ^d	116.6	0.0390	−0.779	−61.1
% adult females in bag	25.04 ^c	22.58 ^d	24.57 ^c	25.89 ^c	27.87 ^b	27.85 ^b	31.26 ^a	1.170	0.0102	0.876	0.89
% young fem on total female	48 ^b	44 ^c	50 ^b	53 ^{ab}	58 ^a	55 ^{ab}	57 ^a	2.697	0.0123	0.863	1.95
PI%	40 ^a	40 ^a	44 ^a	40 ^a	19 ^c	31 ^b	16 ^c	6.920	0.0461	−0.732	−3.07

⁺ N: total number of individuals; PYB: proportion of younglings in the bag; R = coefficient of reproduction; r = reproduction index; Si = sex ratio; PI% = population increase; ^{*} different letters on the same row mean statistical difference for $p < 0.05$, resulting from linear regression, setting time intervals as independent variable, and a correlation (Pearson, r); [#] time intervals: 1 (1987–1991); 2 (1992–1997); 3 (1998–2002); 4 (2003–2007); 5 (2008–2012); 6 (2013–2017); 7 (2018–2023).

The dynamic indicator of the Slovak Danubian Lowland showing the ratio of yearlings in the bag (PYB) varied from the highest value of 51% (time interval of 1998–2002) to the lowest value of 37% (time interval of 2018–2023). In 1950s and 1960s, the ratio of yearlings in Europe ranged from 60 to 80%, and in today's research, the ratio of yearlings in a population remains around or below 50% [23]. The last (time interval of 2018–2023) and statistically ($p < 0.05$) decreased value of PYB, observed in our research, clearly proves that the studied area is experiencing a dramatic decline in its brown hare population.

Data regarding population increase (PI%) in the studied area ranged from a high value of 40–44% (long time interval of 1987–2007) to a low value of 16% (last time interval of 2018–2023). The analysis of the PI indicator seems to be poorly used since other European researchers did not describe this indicator of population dynamics. In Croatia, a wide range of 12.9–75% was reported in 2004/2005 [13], and in Serbia, a range of 32–133% was observed in the 1973–1998 period [30].

The reproduction index (r) as an indicator of the survival of litter per female ranged from 2.30 (time interval of 1992–1997) to 1.26 (time interval of 2018–2023). A high value from the 1990s years had already been reported in Slovakia by [14]. Similarly, low values from 1.0 to 2.0 were obtained in the Czech Republic [31]. In Croatia, ref. [13] reported a high value (3.40 and 2.27) in lowland and mountain habitats, respectively, for the hunting season of 2004/2005. The coefficient of reproduction (R) ranged from 1 to 1.05 during the long period from 1987 to 2007 to a statistically lower value of 0.65 in the last monitored period (2018–2023). In the literature, ref. [31] determined the mean factor R of 0.74 in the Czech Republic in the 1980–1984 period. Recently, ref. [13] reported values of 0.72–1.31 for the lowland habitat and 0.61–1.15 for the mountain habitat in Croatia, suggesting favorable conditions exist in that area for the reproduction of brown hares. The reasons for these differences across Europe in the increase in and survival of litter per female (r) and the coefficient of reproduction (R) can be traced to the methods of the territory's management and a complex variety of biotic and abiotic factors which can affect the survival of brown hares. According to [14], the real reasons for these differences should be researched individually. Of considerable interest are the data of the % adult females

in bags and the % of young females out of the total number of female animals. In the last period of monitoring (2018–2023), the highest value (31.26%) was recorded for the % of adult females in a bag, and there was an increased value of 57% for young females out of the total number of female animals. These positive increasing trends should make people think (researchers, associations, local authorities and policy makers) because they represent a potential natural resource to work on for developing concrete actions for wild game and territory management.

3.2. Improvement of Environment for Hares

Permanent landscape vegetation is of great positive importance for the brown hare population in large-scale, intensively managed agrarian landscapes, both in terms of trophic and topic aspects, mainly in the winter period. In the selected hunting district of Velký Grob, we found out, however, that the population density of brown hares is not directly connected with the distribution of forests and scattered vegetation but, in the first place, with accessible sources of feed [15]. Small field forests, windbreaks and game refuges are of the greatest importance for hares during winter in very adverse and windy weather. Vodnansky [32] reported that, with an average density of 30 hares per 100 ha, their temporary concentration at convenient localities can reach up to 300 individuals per 100 ha.

Based on our observations from a number of hunting grounds, in which we created small grazing fields for wild game, the great importance of determining the sufficient amount of feed for this game was clearly evident. In the hunting district, Čiližská Radvaň, the bag of brown hares rose by 100% with the increase in small-field acreage from 0 to 0.21% out of its total area (Figure 3). The dependence on the set-aside surface and the harvesting of brown hares is highly correlated ($r = 0.817$). Spring stocks are also highly correlated ($r = 0.884$).

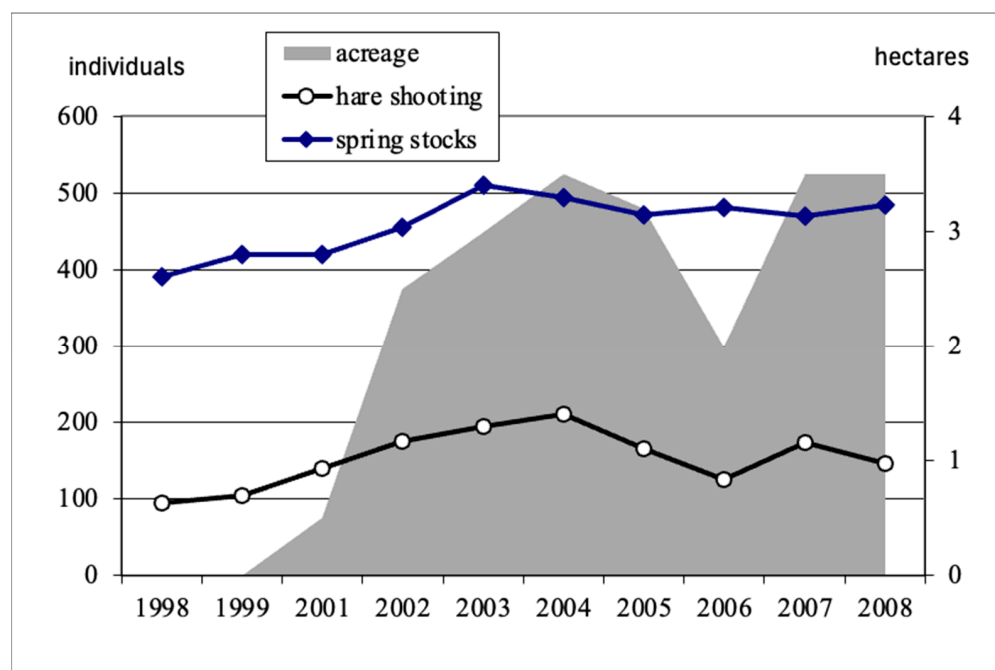


Figure 3. Development of hare shooting and acreage of tilled set-aside (Čiližská Radvaň).

Similarly, in the hunting district of Lehnice, the proportion of young and subadult hares increased in gamebag from 48% to 53% with the increase in small-field acreage from 0.05% to 0.23% of its total acreage ($r = 0.774$) (Figure 4). When evaluating this hunting ground, we took into consideration neither the great decrease in recruitment in the unfavorable year of 2003 nor its great increase in the next year but balanced values from the regression curve. It seems that these small fields had more influence on the

increase in density and the bag of hares than on the level of their recruitments, though they are not negligible either. Hares grazed intensively on these fields during the whole year; however, this was after the harvest and during the non-vegetation period, at the most. Our observations also confirm this, and based on this, an average of up to 39 brown hares per 1 ha in the fields during the autumn was counted. The presence of set-aside, according to [33], was associated with higher hare numbers in arable areas. The authors evaluated this fact as the influence of habitat richness. A positive evaluation of set-asides is given by [34]. This was also proven by findings of [35]; the large plots of agricultural monocultures had an extraordinary negative influence on the population dynamics of brown hares.

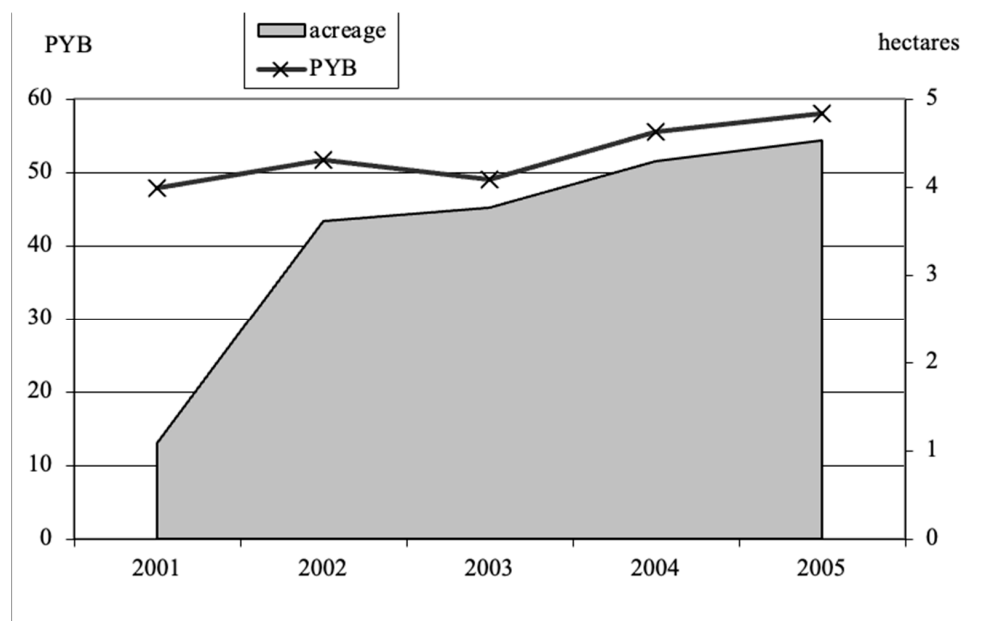


Figure 4. Recruitment of brown hares (PYB = ratio of juveniles in the bag) and acreage of set-asides (Lehnice).

Other authors [36] describe the increasing habitat heterogeneity as the main benefit for hares, especially in highly homogeneous, intensively managed landscapes. Tapper and Barnes [37] report that hares exploit parts of the farm where there is easy access to a variety of crops, and hare numbers in autumn were positively associated with landscape diversity. Hares prefer cropland and grassland over other habitats for foraging, thus selecting the two habitats characterized by most trophic resources [38]. Authors supposed that hare numbers have declined on farms where the landscape has been simplified by field enlargement and block farming, as also suggested by [39]. Ghenghini and Capizzi [40] monitored hares in Italy, and they found that brown hares avoided uncultivated fields while they selected habitat improvements and forage crops. Dubinsky et al. [7] underline the importance of habitat quality for the health status of hares.

Several authors have remarked, in their studies, on the importance of diversity in biotopes for hares [41–43]. Very heavy losses are also caused by road traffic, as we showed in our previous study [44]. If we want to improve the density and production of hares in the present agrarian landscape, we must concentrate, first of all, on the improvement of the biotope.

4. Conclusions

Our analyses have provided important insight into the structure of brown hares in the Slovak Danubian Lowland with the use of indicators of population dynamics, providing comparable data that will contribute to a more complete view of the European framework. The management of European brown hare is not sustainable, and the population is dramatically decreasing. This has been proven through the declining brown hare harvest and

by population dynamics parameters. Our data suggest that improvements in the habitat quality of arable landscapes by the adoption of permanent semi-natural vegetation may be more effective in the increase in the brown hare population. It is crucial, necessary and urgent to continue the research across the entire Slovakian territory to establish actual population trends as a precondition of rational management. To tackle population declines, it might be useful to enact on-place (at the local level), targeted restocking programs with the purpose of releasing captive-bred individuals into the wild. These wildlife restocking operations must be under strict control to avoid the risk of pathogen introduction in new areas and the threat posed to the integrity of locally adapted genetic diversity.

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