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Fallow Deer (*Dama dama*) Population and Harvest Changes in Europe since the Early 1980s

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Abstract: Fallow deer is one of the most common and widespread cervid species in Europe. To make informed management decisions on any scale, it is essential to have long-term data on the abundance of populations and their harvest. We provide missing information on the changes and status of fallow deer populations in Europe and analyse the relationships between population and harvest changes using a numerical approach. To conduct our analyses, we collected national statistical data on population sizes and hunting bags for all European countries for four periods: 1984, the mid-2000s, mid-2010s, and early 2020s. The fallow deer population increased five-fold from 1984 to the early 2020s and the harvest increased six-fold in the same period. Although the correlations between the population growth rate and harvest growth rate are not strong, removing outliers strengthened the correlation. This indicates that the hunting effort increases as the population increases. Overall, the lack of some data shows that consistent, reliable data collection (monitoring programs) is needed to efficiently manage the increasing fallow deer populations as a renewable natural resource and mitigate the potential negative impacts in a holistic and responsible manner.

Keywords: *Dama dama*; Cervidae; status; abundance; expansion; hunting bag; harvest; population; management; dynamics

Citation: Bijl, H.; Csányi, S. Fallow Deer (*Dama dama*) Population and Harvest Changes in Europe since the Early 1980s. *Sustainability* **2022**, *14*, 12198. https://doi.org/10.3390/su141912198

Academic Editor: Linas Balčiauskas

Received: 22 August 2022
Accepted: 23 September 2022
Published: 26 September 2022

1. Introduction

The fallow deer (*Dama dama*) is one of the most common cervid species occurring in Europe and the most widespread cervid in the world [1]. It is a western Palaearctic species whose origin from Western Asia can be traced back at least two millennia [2,3]. The species has been introduced to the majority of Europe and is native to only southern Anatolia, Sicily, southern Italy, and the southern Balkan peninsula, as these regions were probably post-glacial refuges [2,4]. The fallow deer is a highly farmed species with fragmented free-ranging populations. Consequently, the species has been reported in all continents but Antarctica [5]. Its successful range expansion is the result of the translocation and introduction to new areas for trophy hunting, ornamental or aesthetical reasons, and game meat production [5]. However, as an alien species, they can have deleterious effects as well, including negative effects on vegetation diversity and structure, competition with native cervids [6–8], and the occurrence of diseases [9]. Currently, the fallow deer is listed as one of the most widespread and detrimental non-native mammals in Europe [10]. Therefore, providing information on the status of the species is crucial for effective management.

A comprehensive, up-to-date review on the worldwide distribution of fallow deer has been performed by Esattore et al. (2022) [11], which builds on the review of Chapman & Chapman (1980) [1]. However, they did not include numerical analyses of the population and the harvest of the species throughout time. Therefore, by analysing the population and harvest dynamics, we aim to provide an additional foundation for cervid management in

Europe on which to base future management plans. This allows for a better understanding of the expansion of the species in Europe over the last few decades. Moreover, to make informed management decisions, constant and careful monitoring is required so adaptive management implications can be applied. By taking a numerical approach, we aim to provide a bigger picture of the status of the species and its changes over time in Europe as well as analyse the extent to which the harvest is following population changes.

Details on ungulate management and harvesting in various European countries can be found in Putman et al. (2011) and Ahl et al. (2021) [12,13].

In this study, we: (1) compare the magnitude of population and harvest changes of the fallow deer for four different periods, namely 1984, the mid-2000s, mid-2010s, and the early 2020s, based on available national statistical data and (2) analyse the relationship between population size and hunting bags between these four periods.

This paper expands on the work of Burbaitė and Csányi (2009, 2010), which covered the population and harvest changes of roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) in Europe [14,15]. As these cervid species have increased in the last four decades, a similar increase is expected for the fallow deer, in both population and hunting bag. It is also hypothesised that there will be a strong correlation between the increase in population size and hunting bags for all periods.

2. Materials and Methods

2.1. Data Collection

Population size and hunting bag data were collected for four different periods: 1984, the mid-2000s, mid-2010s, and early 2020s. These four periods were chosen based on the intervals of five or ten years. as it takes at least five years to detect any long-term changes in deer populations. Moreover, in some countries, population censuses are carried out every five years or more. Data from 1984 was the earliest systematically collected data available for the fallow deer [16]. Data were collected from statistical yearbooks from national statistics websites, national game management databases, as well as other published sources. If no data was publicly available for a specific country, data was then obtained from contacts made with national hunting associations, ministries, and other personal relations with wildlife researchers. Data were collected from all European countries, except for Turkey and the European part of Russia due to geographical reasons and unknown regional coverage of the data. If only a range was provided, instead of a single (estimated) number, we calculated the average based on the range. This was the case for the population estimations in Greece (for 2005) and Luxembourg (for 1984). This study focused on wild or free-ranging fallow deer; therefore, if a distinction was made in the dataset between deer in captivity or in the wild, then data was collected only for wild fallow deer. Data from the mid-2000s was mainly from the 2005/2006 hunting season, data from the mid-2010s was mainly from the 2015/2016 hunting season, and data from the early 2020s was mainly from the 2020/2021 hunting season.

Data for the mid-2000s, mid-2010s, and early 2020s were collected from various sources with added comments (Table 1). Data for 1984 or earlier were obtained from Gill (1990) [16] and from the proceedings of the CIC fallow deer symposium held in Budapest in 1984 [17]; this included the countries Germany, Ireland, Lithuania, Luxembourg, Romania, Spain, Switzerland, Ukraine, and the United Kingdom.

Table 1. Data sources on population estimations and harvests from European countries with data for the mid-2000s, mid-2010s, and early 2020s.

Country	Data Source	Comments
Austria	Statistics Austria *	Only hunting bag; no estimations on wild populations
Belgium	INBO *	Only data from Wallonia from mid-2000s; only hunting bag data from Flanders for 2021
Bulgaria	National Statistics Institute [18,19]; Stoyanov & Stoyanova [20]	No hunting bag data from 2020s
Croatia	Ministry of Agriculture	Data obtained from Croatian Hunting Association (pers. comm.)
Czech Republic	Czech Statistical Office *	N/A
Denmark	Aarhus Universitet (hunting bag) *; Aarhus Universitet (for population size 2010s) [21]; Danmarks Jaegerforbund (population size 2020s) [22]	N/A
Finland	National Resources Institute Finland *	Only hunting bag; pers. comm. for population estimations
France	ONCFS (for 2000s and 2010s) [23]; Réseau Ongulés sauvages (for 2020s) [24]	N/A
Germany	Bayerischer Jagdverband e.V. (for 2000s and 2010s) [25]; Deutscher Bundestag (for 2020s) [26]	N/A
Greece	Mattila & Hadjigeorgiou (2010s) [27]	No data for 2020s; fallow deer only enclosures; hunting ban
Hungary	Országos Vadgazdálkodási Adattár [28–30]	N/A
Ireland	National Parks and Wildlife Service (for 2000s), pers. comm.	N/A
Italy	Carnevali et al. 2009 (for 2000s) [31]; ISPRA 2013 (for 2010s) [32]	N/A
Lithuania	Lithuanian State Forest Service [33–35]	N/A
Luxembourg	Le Gouvernement de Grand-Duché de Luxembourg (pers. comm. for 2000s); The Statistics Portal (LUSTAT) (for 2010s and 2020s) *	No population estimations
Macedonia	State Statistical Office of the Republic of Macedonia *	No data for mid-2000s
The Netherlands	Vereniging Wildbeheer Veluwe (for 2000s and 2010s) [36]; Faunabeheereenheid (for 2020s) [37]	Data for 2020s was collected per province
Poland	Central Statistical Office [38,39]	N/A
Portugal	ICNF Divisão Recursos Cinegéticos e Aquicolas (pers. comm.)	N/A
Romania	National Institute of Statistics [40]	No data for 2020s
Serbia	Statistical Office of the Republic of Serbia (for 2019) [41]; Pers. comm. (for 2000s and 2010s)	N/A
Slovakia	National Forestry Center Zvolen (for 2020s) *; Pers. comm. (for 2000s and 2010s)	N/A
Slovenia	Slovenia Forest Service (for 2010s and 2020s) [42,43]; Pers. comm. (for 2000s)	No recent population estimations available, only for 1995
Spain	Ministry of Agriculture, Fisheries and Food [44–46]	No recent population estimations available, only for 2000s
Sweden	Danell & Bergström, 2010 (for population estimation for 2000s) [47]; Viltdata (for hunting bags) *	No population estimation for early 2020s
Ukraine	State Statistics Service of Ukraine [48–50]	N/A
United Kingdom	NatureScot [51]; Mammal Society (for size for 2020s) [52]	Hunting bag for 2010s and 2020s from Scotland only

* Publicly available dataset—see Data Availability Statement.

The fallow deer has a scattered but widespread distribution in Europe [3]. They can be found in all European countries; if they are not present in the wild, then they are kept in farms, reserves, or parks [1]. However, it is not uncommon to have free-ranging deer that escaped from enclosures that have developed small but stable populations in the wild (e.g., in Norway). As it is an introduced species with scattered populations, it is difficult to find reliable data about population size. Consequently, data for the fallow deer was not available for ten countries. These countries included Albania (hunting ban and only found in enclosures [53]), Belarus (introduced in 1890 and eradicated by 1920 [54], currently only in enclosures [55]), Bosnia and Herzegovina (only in reserves [56]), Estonia (hardly present due to removal from the wild), Latvia (not a game species and only found in enclosures), Liechtenstein (not a game species), Montenegro, Moldova, Norway (only escaped individuals), and Switzerland (can only be found in wildlife parks).

The reliability of the data sources greatly varied between countries. Various factors such as poaching, under-/overestimation of population sizes, incorrectly reported harvest numbers or causes of mortality other than hunting (roadkill, diseases, etc.) included in the harvest data, and timing of the population census (spring/autumn) may strongly influence actual values. However, a country claiming to have 10,000 deer is much more than 100, which still gives valuable information about the magnitude of the fallow deer population in a country, even though it is not precise; however, these estimations should be considered minimum values [1]. Overall, despite these shortcomings, the data was deemed acceptable for a general overview of the status of the fallow deer in Europe, similar to the papers on roe deer and red deer [14,15].

2.2. Data Analysis

Corrections were made to the population size numbers when the harvest rate exceeded 40%. It can be assumed that a harvest rate higher than 40% is not realistic (unsustainable in the long term) under typical management conditions. Based on model calculations with the use of the sex ratio and average reproduction rate of the population, harvest rates above 30 or 40% result in the long-term overharvest (decline) of the exploited cervid population [57]. Additionally, according to the principles of the behaviour of harvested populations from Silliman and Gutsell (1958) and Caughley (1976), harvest rates that exceed the maximum sustainable yield level can result in extinction if the overharvest is continued over time [58,59]. However, harvest rates below a certain level may result in more resilient populations to compensate for the removed individuals [58,59]. Therefore, the harvest can usually be maximised up to 50% of the carrying capacity [60]. Generally, harvest numbers are considered more precise and more reliable than population censuses as they have large uncertainties [61]. Therefore, in these cases, the harvest rate was changed to a harvest rate of 30% and the population number was calculated based on this 30% rate of removal. For example, the collected data from the Czech Republic in 2021 shows that the population size is 39,058 individuals and the harvest is 30,982 individuals, which gives an unrealistic harvest rate of 79.32% (Appendix A; Figure A4). Therefore, assuming that the harvest size is unbiased (reliable), it was assumed that the harvest rate is 30% and the population size has been corrected according to this, which gives a more acceptable population size of 103,273 individuals. This has been calculated by dividing the harvest by 0.3. If only the hunting bag was given, then it was assumed that this was 30% of the whole population and the population size was calculated according to this by dividing the harvest by 0.3. Corrections were also made when only the population estimation was available in a certain period. Then, it was assumed that the harvest rate is 30% and the hunting bag was calculated according to this, if hunting was permitted in the country in question.

For each country, we calculated the overall fallow deer population and its harvest numbers in Europe, along with the harvest rates (H% = bag/population), growth factor, and average growth rate for the population sizes and harvests for the six periods: 1984–2000s; 1984–2010s; 1984–2020s; 2000s–2010s; 2000s–2020s; 2010s–2020s. The growth factor was calculated by dividing the population size or harvest of one (later) time period by

the population size or harvest of the other (earlier) period. The average growth rate (exponential growth rate, r [59]) was calculated by taking the logarithm of the growth factor and dividing it by the difference in years between two time periods.

3. Results

According to the collected data, there are currently at least 634,075 fallow deer in Europe; however, corrected numbers reflected a population of 951,521 individuals. Numbers have significantly increased from 120,263 (138,009 corrected) in 1984 to 429,278 (519,519 corrected) individuals in the mid-2000s, to an increase of 516,519 (789,849 corrected) in the mid-2010s (Figure 1). This suggests that the fallow deer population increased five-fold from 1984 to 2020 and increased almost seven-fold if considering the corrected values.

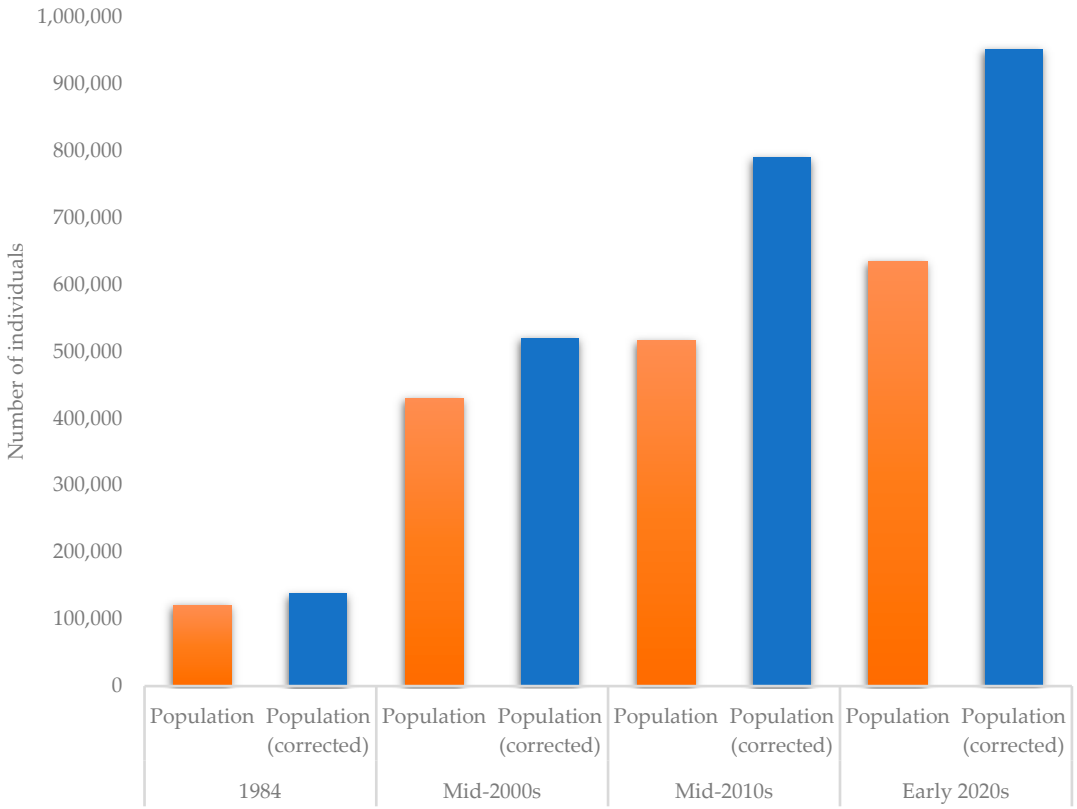


Figure 1. Total number of fallow deer in Europe, with corrections, for 1984, the mid-2000s, mid-2010s, and early 2020s. Legend: original data (orange), corrected numbers (blue).

The known harvest was only 31,225 individuals in 1984 and increased to 154,916 individuals in the mid-2000s, with a further increase to 197,308 animals harvested in the mid-2010s, and most recently measured at 199,968 animals harvested (Figure 2). As harvest numbers are less biased than population estimates, the corrected data shows little difference from the non-corrected data, and no difference at all in the mid-2010s, with 35,347 individuals harvested in 1984; 155,606 in 2005; 197,308 in 2015; and 202,896 in 2020. The harvest increased six-fold from 1984 to 2020, as well as for the corrected data.

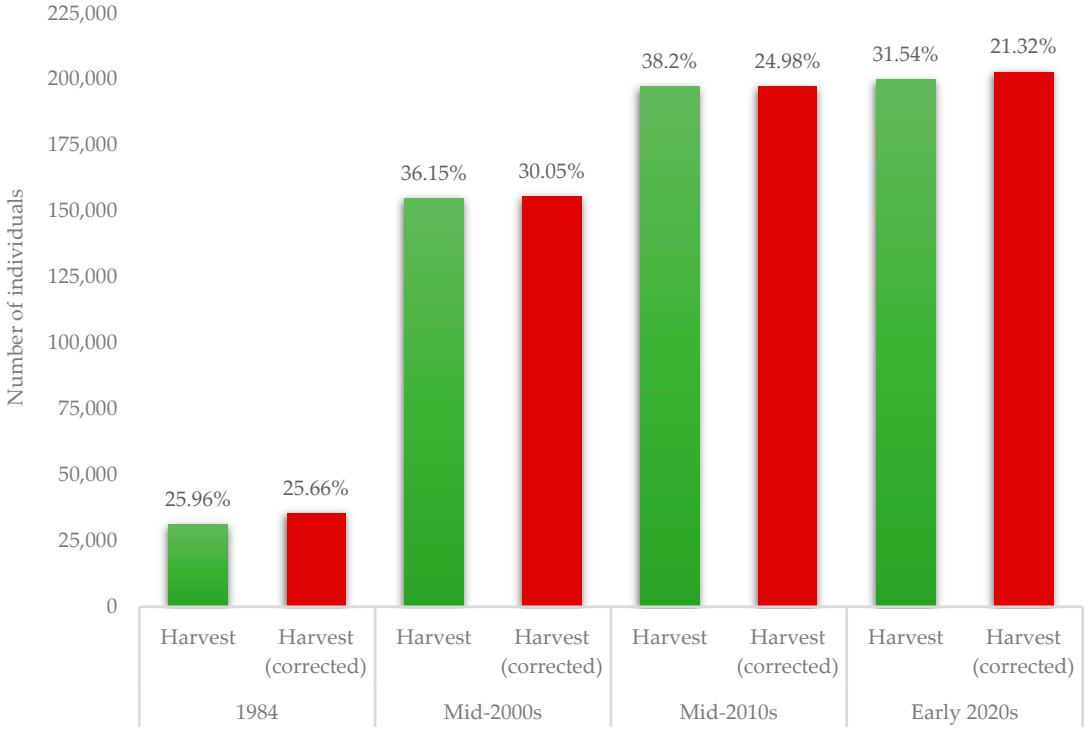


Figure 2. Total harvest and harvest rates of fallow deer in Europe with corrections for 1984, the mid-2000s, mid-2010s, and early 2020s. Legend: original data (green), corrected numbers (red).

The overall harvest rate increased from 25.96% in 1984 to 31.54% in 2020; however, corrected numbers actually indicated a decline from 25.66% in 1984 to 21.32% in 2020. This could have been attributed to the increase in population size. The harvest rate was the highest in the mid-2010s at 38.2% when considering the non-corrected numbers a. However, the corrected numbers showed the highest harvest rate in the mid-2000s with 30.05%.

3.1. Period from 1984–2000s

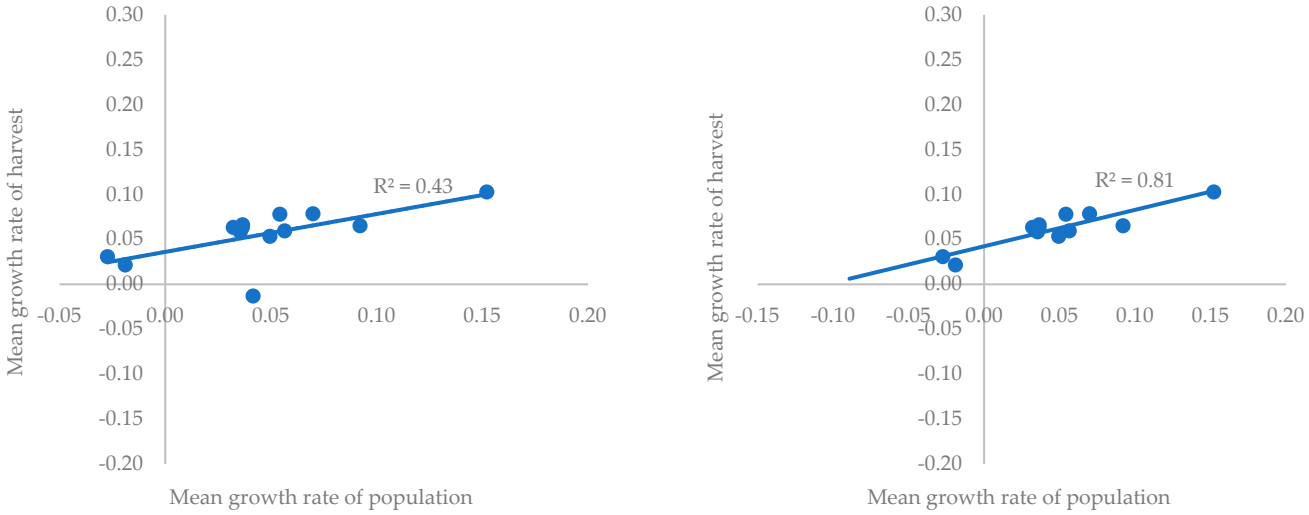
In the period from 1984 to the mid-2000s, fallow deer numbers increased in all countries except for Denmark and Romania. The harvest increased in all countries for this period as well, with only a slight decrease in harvest numbers in the Netherlands; however, this could have been due to a smaller hunting effort. The average growth factor for this period was 9.32 for population size and 3.82 for the harvest, with a relatively strong correlation of $R^2 = 0.68$ (Table 2). The strong correlation indicates that the larger the population growth of the countries, the larger the harvest growth between the two time periods.

Table 2. Mean growth factor for population size and harvest of fallow deer in Europe, the coefficient of determination (R^2), and *p*-values for the six periods along with the number of countries that had population and harvest data (*N*).

Time Period	Mean Growth Factor		R^2 *	*p*-Value	*N*	
	Population (*x*)	Harvest (*y*)			Population (*x*)	Harvest (*y*)
1984–2000s	9.32	3.82	0.68	0.0006	20	13
1984–2010s	5.89	7.71	0.58	0.0025	18	16
1984–2020s	9.27	10.85	0.36	0.0113	13	14
2000s–2010s	1.97	3.48	0.21	0.0655	20	23
2000s–2020s	3.97	5.52	0.85	0.0000	15	19
2010s–2020s	1.51	1.49	0.06	0.4893	13	19

* Determination coefficient between growth factor of population and growth factor of harvest of all countries, which is presented with the trendline when plotted.

According to the regression analysis of the growth rates, there was a rather weak correlation between the mean growth rate of the population size and harvest for this period (Figure 3). When creating the regression analyses, only non-corrected data were used. However, population sizes were often underestimated, or harvest rates were unusually low compared with the population size, and this created outliers in the dataset. Therefore, when the outlier countries (the Netherlands and Spain) during this period were removed, a much stronger relationship could be observed. This indicates that with a stronger population increase, the hunting pressure increases, and therefore, the harvest as well.



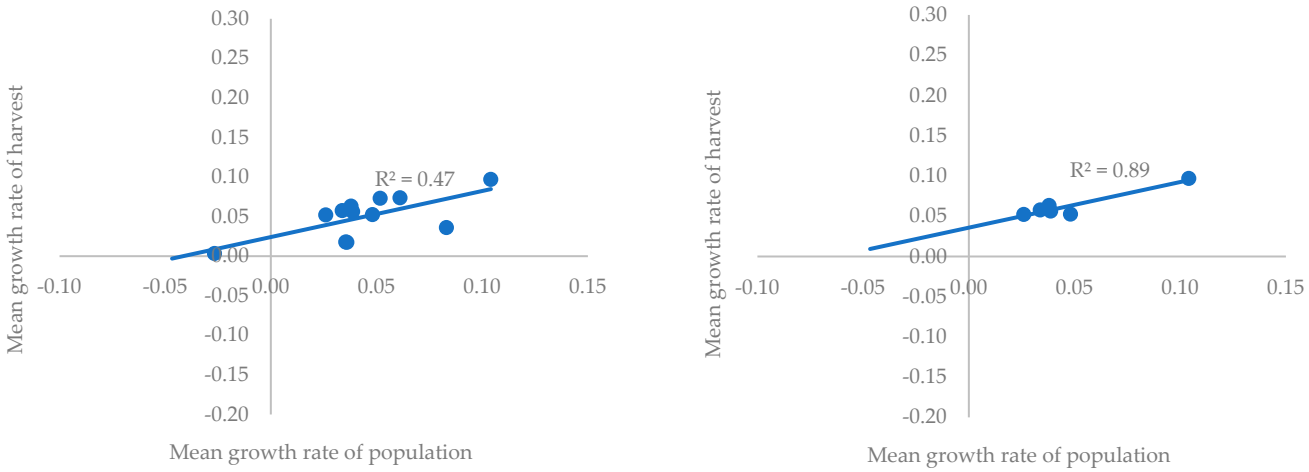
(**a**) (**b**)

Figure 3. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between 1984 and the mid-2000s: (**a**) all countries; (**b**) outliers removed (i.e., the Netherlands and Spain).

3.2. Period from 1984–2010s

From 1984 to the mid-2010s, the population size decreased only in Greece and Romania; there was no decrease in harvest. The average growth factor was lower compared with the previous, shorter period for the population (5.89), but was higher for the harvest (7.71).

A similar weak correlation could be seen between the average growth rate of the population size and harvest (Figure 4). However, if the Netherlands, Finland, and Serbia were removed as outliers, then a more realistic correlation could be observed, and was the strongest compared with the other periods. The outliers were removed due to a very low harvest compared with the population size.



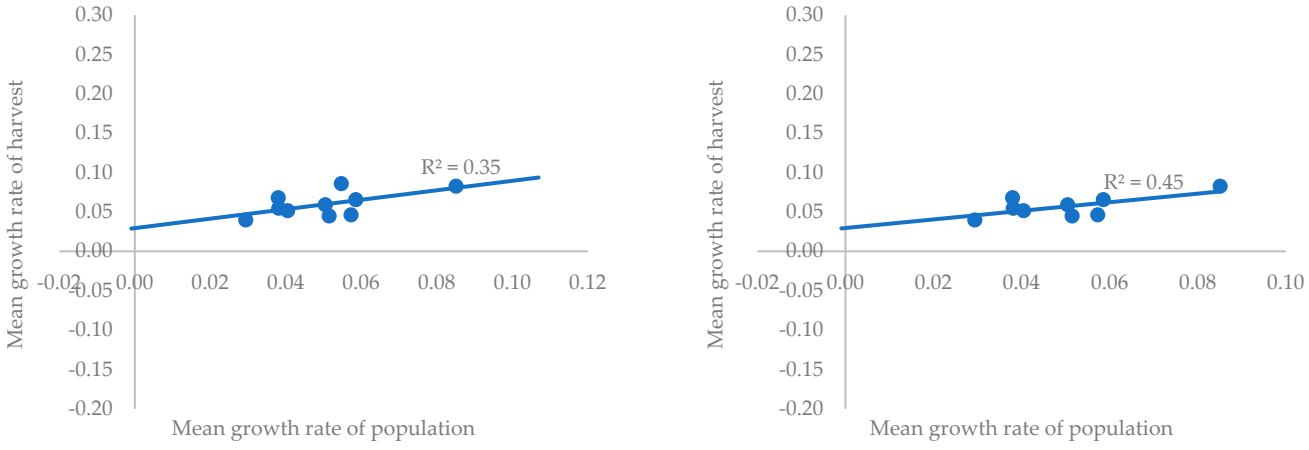
(**a**) (**b**)

Figure 4. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between 1984 and the mid-2010s" (**a**) all countries; (**b**) outliers removed (i.e., the Netherlands, Finland, and Serbia).

3.3. Period from 1984–2020s

During the longest period from 1984 to the early 2020s, the fallow deer increased to a large extent in all countries with an average growth factor of 9.27; there was only a slight decrease in Ukraine (0.98). Moreover, there was no decrease in harvest numbers during this period. Fallow deer harvest numbers actually had the highest increase during this period, compared with the other periods, with an average growth factor of 10.85.

Despite the high average growth factors, there was a weak correlation between the annual growth rate of the population size and harvest, even when the outliers were removed (Slovakia and Lithuania) (Figure 5). This could indicate that there was no conscious effort made to increase the hunting pressure on fallow deer as the population was increasing or the populations were drastically underestimated. The outlier Slovakia was removed due to the latter reason; the outlier Lithuania was removed due to its extremely high population growth factor (42.3).



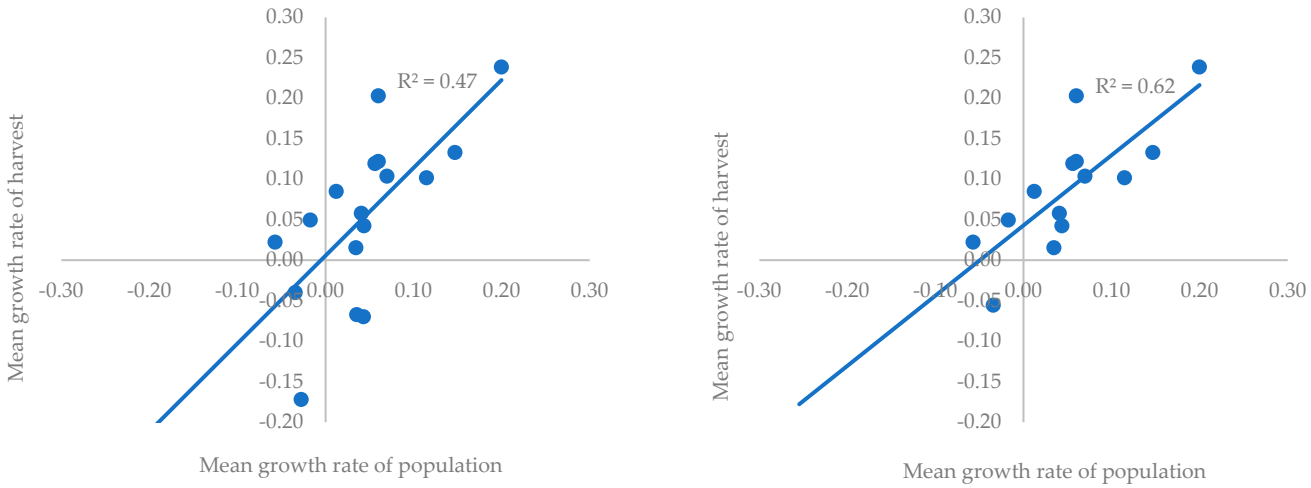
(**a**) (**b**)

Figure 5. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between 1984 and the mid-2020s: (**a**) all countries; (**b**) outliers removed (i.e., Slovakia and Lithuania).

3.4. Period from 2000s–2010s

During a period of approximately ten years, from 2005/2006 to 2015/2016, the fallow deer population and harvest numbers increased, but to a smaller extent. This is also indicated by the low average growth factors (1.97 for population; 3.48 for harvest). The population size decreased in the highest number of countries during this period, namely in Belgium, Germany, Greece, Italy, Romania, Ukraine, and the UK. Harvest numbers decreased in Finland, Italy, Romania, and Serbia.

Similar to previous periods, a weak correlation could be found between the average growth rates of the population and harvest numbers (Figure 6). When outliers were removed (Romania, Finland, and Serbia), there was a slightly stronger relationship. The outliers were all countries that had shown a decrease in harvest numbers, which suggests that an increase in population size did not coincide with an increase in harvest.



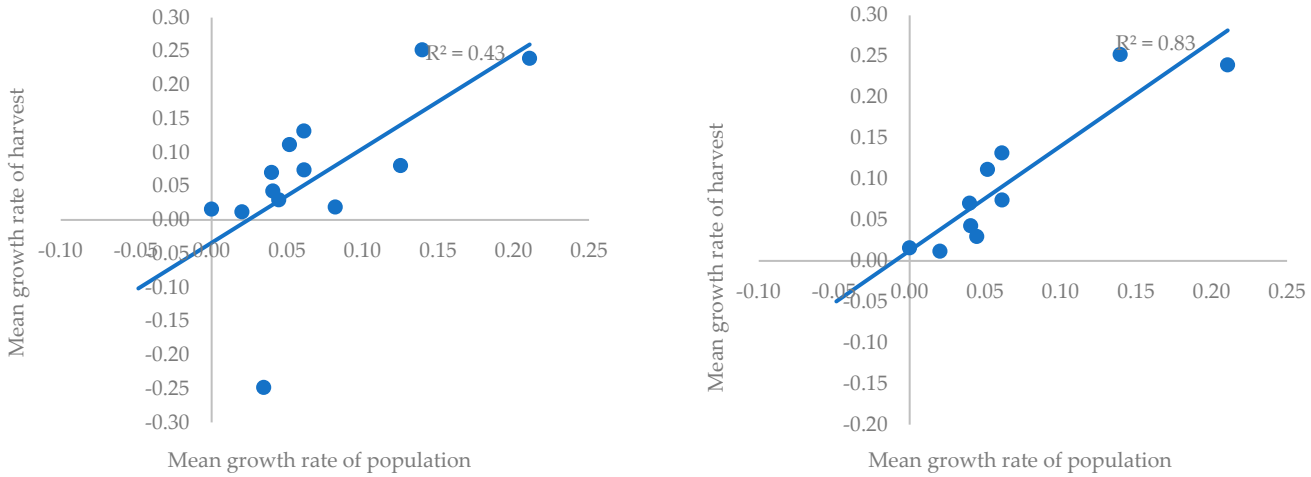
(**a**) (**b**)

Figure 6. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between the mid-2000s and the mid-2010s: (**a**) all countries; (**b**) outliers removed (i.e., Romania, Finland, and Serbia).

3.5. Period from 2000s–2020s

From 2005 to 2020, fallow deer numbers increased in all countries except for Ukraine. Harvest numbers decreased only in Sweden and the UK. The average growth factors were quite low compared with the other periods, with 3.97 for the population and 5.52 for the harvest.

The relationship between the average growth rate of the population and harvest showed a weak correlation; however, removing the outliers (Finland, Demark and the UK) led to a strong correlation (Figure 7). The outliers were removed due to the low harvest compared with population size, especially for the UK because harvest data was only available from Scotland.

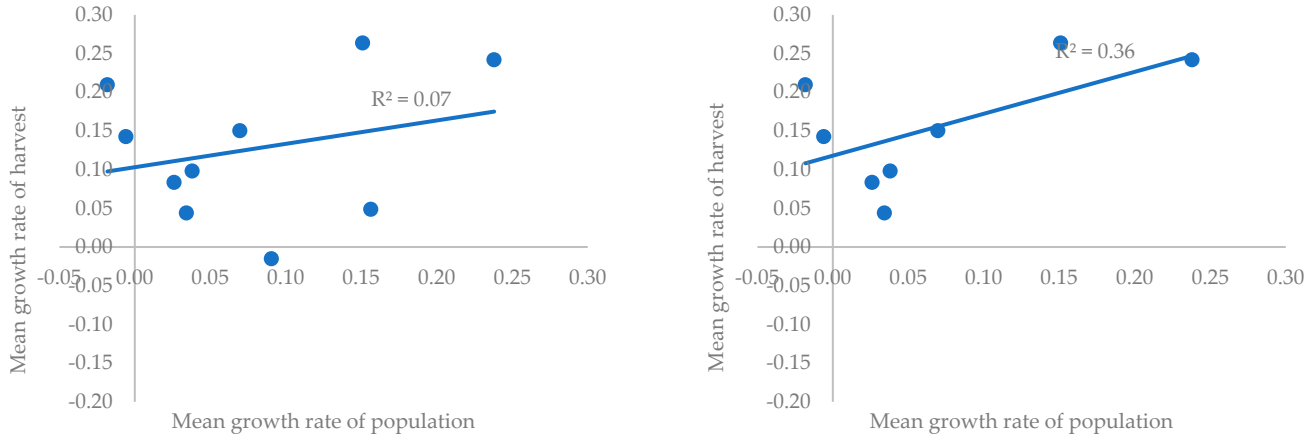


(**a**) (**b**)

Figure 7. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between the mid-2000s and the mid-2020s: (**a**) all countries; (**b**) outliers removed (i.e., Finland, Denmark and the UK).

3.6. Period from 2010s–2020s

During the shortest period from 2015/2016 to 2020/2021, the fallow deer population showed the least amount of growth and the weakest correlations (Figure 8). The population size decreased in Serbia and Ukraine, and the harvest showed a decrease in Portugal, Sweden, and the UK. The average growth factors were the lowest during this period, with 1.51 for the population size and 1.49 for the harvest.



(**a**) (**b**)

Figure 8. Relationship between the growth rate of harvest and the growth rate of population size of fallow deer between the mid-2010s and the mid-2020s: (**a**) all countries; (**b**) outliers removed (i.e., the UK and Denmark).

The removed outliers were the UK and Demark, due to their very low harvest numbers compared with population size. For the UK, this was because harvest data was only available from Scotland.

Altogether, based on the population data, the largest decrease was seen in Romania, where the population decreased in three out of the six periods. This was also the case for roe deer and red deer and could be attributed to unreliable data, high levels of poaching, or unstable political circumstances that resulted in weakened game management [14,15].

Political and economic changes influence wildlife population management scenarios and have been documented for countries in Eastern Europe [62]. The decrease in harvest numbers during the different periods was limited to only a few countries; however, there were different countries decreasing in each period. The exceptions to this were Sweden and the UK, where a decrease could be seen over two periods. The decrease in Sweden could have been due to an increase in large predators (grey wolf (*Canis lupus*) and, to a lesser extent, the Eurasian lynx (*Lynx lynx*), resulting in less hunting [63]; the decrease in the UK was due to harvest numbers only being available from Scotland in 2015/2016 and 2018/2019.

4. Discussion

The fallow deer population has increased from over 100,000 to almost 650,000 over the last four decades. However, the corrected (and more probable) numbers show a larger increase, with an overall larger population size: from almost 140,000 to almost one million. The harvest has stayed relatively the same since the mid-2010s, at approximately 200,000, both for corrected and non-corrected numbers. There was a weak correlation between the average growth rate of the population and the harvest. However, when outliers were removed, a much stronger relationship could be seen for the periods 1984–2000s, 1984–2010s, and the mid-2000s–mid-2020s. The outliers were usually countries that had an unusually low harvest compared with the estimated population size. The weak correlations could indicate that, despite the population increase, no efforts were made to harvest more fallow deer, or they could indicate the weakness of data in several European countries. On the other hand, the strong correlations (after outlier removal) show that an increase in population does lead to a larger hunting bag. Similarly, the population growth factor was the strongest between 1984–2000s and 1984–2020s, with almost a ten-fold increase. The growth factor of harvests was the largest between 1984–2010s and 1984–2020s, with an almost eight-fold increase and eleven-fold increase, respectively. This shows that the fallow deer population has significantly increased since the early 1980s.

According to the latest status report of the IUCN, fallow deer are present in 37 European countries [64]. Moreover, the species has been introduced outside of Europe, and can be found in the United States, Argentina, Chile, Peru, Uruguay, South Africa, Australia, New Zealand, the islands in the Fijian group, the Lesser Antilles, and the Pacific coast of Canada [65]. In this study, data was found for 27 countries. However, in the missing 10 countries, fallow deer either had very low numbers or were only kept in enclosures. Therefore, this lack of information would not have significantly impacted the overall populations of (wild) fallow deer.

Moreover, the large difference between corrected and non-corrected population data was due to the underestimation of population sizes. Additionally, fallow deer is a typical farm animal and frequently kept in enclosures and in the majority of the countries, it was not indicated whether the numbers represented deer in captivity or from the wild. Therefore, it could be that the overall population of wild fallow deer was smaller than indicated if deer in enclosures were included in the overall population size. Furthermore, the method of population census (direct or indirect) was not indicated, which could result in inconsistent results between the countries. However, these differences would also be present in the harvest data. Although hunting bags can be less biased, there are national and local differences in hunting effort, which depend on the selection of harvesting locations, harvest strategy, and hunting seasons [66]. Thus, these variations in population censuses and hunting bags could explain the large differences between countries. Despite these differences, increasing trends could clearly be discerned.

Compared with the roe deer and red deer, the fallow deer population increased to a higher extent than expected. Between 1984 and the mid-2000s, both the roe deer and red deer population increased 1.5-fold [14,15], whereas the fallow deer population increased 3.6-fold. Furthermore, the roe deer harvest increased 1.6-fold and the red deer harvest increased 1.7-fold, whereas the fallow deer hunting bag increased 5-fold. This difference

could be due to a preference of hunters for roe deer and red deer, which results in stronger management of these species. In fact, the share of game meat is the highest for red deer and roe deer [67–69]. These cervids are also considered the most overabundant, according to the scientific literature [70]. Although fallow deer are also known for their ability to reach high densities [71], the stronger population increase compared with the roe and red deer shows that the fallow deer managed to increase their population more despite the higher hunting pressure. The fallow deer had smaller numbers at the beginning of its expansion, which explains the stronger support of managers and hunters for its increase. Consequently, the stronger increase resulted in a higher harvest compared with the roe and red deer. In addition, the fallow deer are able to survive with lower-quality resources [72]. This is a consequence of its long history living in human-dominated areas (hunting gardens, parks, etc.) [1]. Therefore, their adaptation to human-dominated landscapes could be more successful as a result of a higher number of suitable habitats for foraging and cover [73].

The increase in cervids in the last few decades, including fallow deer, can be attributed to multiple factors. The most obvious reasons are an increase in forage in forested areas and the reduction in hunting and natural predators throughout the twentieth century [74]. However, the latter is starting to reverse as wolves, brown bears (*Ursus arctos*), Eurasian lynx, and wolverines (*Gulo gulo*) are expanding into countries from which they disappeared at the beginning of the twentieth century [75]. In the future, this could result in declining deer populations in areas with high densities of large carnivores, as in the case of Poland [76] and Scandinavia [77].

As of now, it is essential to have consistent, reliable data collection and monitoring programs in place to tackle local overabundance [78], efficiently manage the increasing population, and close knowledge gaps regarding its worldwide distribution. If the current trend continues, negative impacts such as damage to forestry and agriculture, disease transmission, or vehicle collisions could increase [6–9,73]. Therefore, fallow deer populations need to be managed on a local level first, based on clearly set objectives, in cooperation with stakeholders. It is essential to emphasise the management of fallow deer based on adaptive harvest management (flexible and responsive) to reduce the population increase, and consequently, potential negative impacts [79]. However, positive impacts like the provision of recreation and game meat should not be overlooked, but instead utilised in a sustainable manner [67–69,73]. Thus, full responsibility should be taken for the appropriate and integrated management of the species of fallow deer [73] in a way that ensures sustainability.

Author Contributions: Conceptualization, S.C.; methodology, S.C.; validation, H.B. and S.C.; formal analysis, H.B. and S.C.; investigation, H.B.; data curation, H.B.; writing—original draft preparation, H.B.; writing—review and editing, S.C.; visualization, H.B.; supervision, S.C.; project administration, H.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Research, Development and Innovation Office within the framework of the National Laboratory for Health Security programme (RRF-2.3.1-21-2022-00006).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analysed in this study. This data can be found here: Austria: https://www.statistik.at/web_en/statistics/Economy/agriculture_and_forestry/livestock_animal_production/hunting/029432.html (accessed on 8 August 2022); Belgium (Flanders): https://grofwildjacht.inbo.be/ (accessed on 8 August 2022); Czech Republic: https://www.czso.cz/csu/czso/home?p_p_id=3&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&_3_struts_action=%2Fsearch%2Fsearch&_3_redirect=%2Fc%2Fportal%2Flayout%3Fp_l_id%3D20137706%26p_v_l_s_g_id%3D0&_3_keywords=hunting+&_3_groupId=0&x=0&y=0 (accessed on 8 August 2022); Denmark: https://fauna.au.dk/jagt-og-vildtforvaltning/vildtudbytte/udbyttet-online-siden-1941/soejlediagram (accessed on 8 August 2022); Finland: http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__06%20Kala%20ja%20riista__02%20Rakenne%20ja%20tuotanto__16%20Metsastys/?tablelist=

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Acknowledgments: The authors express their gratitude to all whom have provided them with unpublished data to support this study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Fallow deer population and harvest data collected from European countries for 1984, the mid-2000s, mid-2010s, and early 2020s with calculated harvest rates. Corrected numbers are highlighted in yellow.

	NON-CORRECTED			CORRECTED		
	1984					
Country	*Population*	*Harvest*	*Harvest rate*	*Population (correction)*	*(correction)*	*Harvest rate (correction)*
Austria	370	102	27.57	370	102	27.57
Belgium	163	26	15.95	163	26	15.95
Bulgaria	2800			2800	840	30.00
Croatia						
Czech Republic	9574	2511	26.23	9574	2511	26.23
Denmark	10,000	1644	16.44	10,000	1644	16.44
Finland	300	40	13.33	300	40	13.33
France	600	167	27.83	600	167	27.83
Germany	48,000	18,958	39.50	63,193	18,958	30.00
Greece	200			200		0.00
Hungary	9760	2380	24.39	9760	2380	24.39
Ireland	3000			3000	900	30.00
Italy	6150			6150	1845	30.00
Lithuania	220			220	66	30.00
Luxembourg	23	6	26.09	23	6	26.09
Macedonia						
Moldova						
Netherlands	500	418	83.60	1393	418	30.01
Norway	40			40	12	30.00
Poland	4000	948	23.70	4000	948	23.70
Portugal	200			200	60	30.00
Romania	10,000	500	5.00	10,000	500	5.00
Serbia	365	57	15.62	365	57	15.62
Slovakia	3126	826	26.42	3126	826	26.42
Slovenia						
Spain	1000					
Sweden	4500	1930	42.89	6433	1930	30.00
Ukraine	1331			1331	399	29.98
United Kingdom	1100	548	49.82	1827	548	29.99
Yugoslavia	2941	164	5.58	2941	164	5.58
Total	**52,263**	**31,225**	**59.75**	**54,816**	**16,389**	**29.90**
Mean			**27.64**			**23.36**
Median			**26.09**			**27.57**

Figure A1. Fallow deer population and harvest data collected from European countries for 1984 with calculated harvest rates. Corrected numbers are highlighted in yellow.

	NON-CORRECTED			CORRECTED		
	Mid-2000s					
Country	*Population*	*Harvest*	*Harvest rate*	*Population (correction)*	*(correction)*	*Harvest rate (correction)*
Austria	1500	489	32.60	1500	489	32.60
Belgium	267	65	24.34	267	65	24.34
Bulgaria	3748	48	1.28	3748	48	1.28
Croatia	1200	230	19.17	1200	230	19.17
Czech Republic	20,667	10,049	48.62	33,497	10,049	30.00
Denmark	5800	3130	53.97	10,433	3130	30.00
Finland	590	151	25.59	590	151	25.59
France	1980	925	46.72	3083	925	30.00
Germany	150,000	52,186	34.79	150,000	52,186	34.79
Greece	600			600		0.00
Hungary	21,791	8903	40,86	29,677	8903	30.00
Ireland	10,000	2000	20.00	10,000	2000	20.00
Italy	20,996	4424	21.07	20,996	4424	21.07
Lithuania	487	14	2.87	487	14	2.87
Luxembourg		63		210	63	30.00
Macedonia						
Moldova	2300			2300	690	30.00
Netherlands	1150	309	26.87	1150	309	26.87
Norway						
Poland	13,115	3300	25.16	13,115	3300	25.16
Portugal	3000	130	4.33	3000	130	4.33
Romania	5900	930	15.76	5900	930	15.76
Serbia	770	194	25.19	770	194	25.19
Slovakia	8425	2529	30.02	8425	2529	30.02
Slovenia	300	140	46.67	467	140	29.98
Spain						
Sweden						
Ukraine	2692	107	3.97	2692	107	3.97
United Kingdom	152,000	64,600	42.50	215,333	64,600	30.00
Total	**429,278**	**154,916**	**36.09**	**519,440**	**155,606**	**29.96**
Mean			**26.93**			**22.12**
Median			**25.39**			**25.59**

Figure A2. Fallow deer population and harvest data collected from European countries for the mid-2000s with calculated harvest rates. Corrected numbers are highlighted in yellow.

	NON-CORRECTED			CORRECTED		
	Mid-2010s					
Country	*Population*	*Harvest*	*Harvest rate*	*Population (correction)*	*(correction)*	*Harvest rate (correction)*
Austria		805		2683	805	30.00
Belgium	450	138	30.67	450	138	30.67
Bulgaria	8159	1005	12.32	8159	1005	12.32
Croatia	2469	879	35.60	2930	879	30.00
Czech Republic	31,099	18,968	60.99	63,227	18,968	30.00
Denmark	23,000	7826	34.03	23,000	7826	34.03
Finland	949	70	7.38	949	70	7.38
France	2702	1062	39.30	3540	1062	30.00
Germany	80,000	65,176	81.47	217,253	65,176	30.00
Greece	47			47		0.00
Hungary	33,742	13,601	40.31	45,337	13,601	30.00
Ireland						
Italy	17,697	3770	21.30	17,697	3770	21.30
Lithuania	3590	193	5.38	3590	193	5.38
Luxembourg		170		567	170	29.98
Macedonia	141	1	0.71	141	1	0.71
Moldova						
Netherlands	7766	1329	17.11	7766	1329	17.11
Norway						
Poland	28,282	9302	32.89	28,282	9302	32.89
Portugal		489		1630	489	30.00
Romania	5283	555	10.51	5283	555	10.51
Serbia	1098	99	9.02	1098	99	9.02
Slovakia	14,771	7405	50.13	24,683	7405	30.00
Slovenia		228		760	228	30.00
Spain		22,651		75,503	22,651	30.00
Sweden	125,935	38,860	30.86	125,935	38,860	30.86
Ukraine	1339	49	3.66	1339	49	3.66
United Kingdom	128,000	2677	2.09	128,000	2677	2.09
Total	**516,519**	**197,308**	**38.20**	**789,849**	**197,308**	**24.98**
Mean			**26.29**			**21.07**
Median			**25.98**			**30.00**

Figure A3. Fallow deer population and harvest data collected from European countries for the mid-2010s with calculated harvest rates. Corrected numbers are highlighted in yellow.

	NON-CORRECTED			CORRECTED		
	Early 2020s					
Country	*Population*	*Harvest*	*Harvest rate*	*Population (correction)*	*(correction)*	*Harvest rate (correction)*
Austria		980		3267	980	30.00
Belgium		72		240	72	30.00
Bulgaria	9761			9761	2928	30.00
Croatia	2740	1228	44.82	4093	1228	30.00
Czech Republic	39,058	30,982	79.32	103,273	30,982	30.00
Denmark	42,975	10,490	24.41	42,975	10,490	24.41
Finland	2018	201	9.96	2018	201	9.96
France	3694	1401	37.93	4670	1401	30.00
Germany	150,000	66,236	44.16	220,787	66,236	30.00
Greece						
Hungary	40,035	16,940	42.31	56,467	16,940	30.00
Ireland						
Italy						
Lithuania	9299	508	5.46	9299	508	5.46
Luxembourg		197		657	197	29.98
Macedonia	102	2	1.96	102	2	1.96
Moldova						
Netherlands	10,712	8189	76.45	27,297	8189	30.00
Norway						
Poland	34,936	10,049	28.76	34,936	10,049	28.76
Portugal		176		587	176	29.98
Romania						
Serbia	1021	229	22.43	1021	229	22.43
Slovakia	22,424	18,245	81.36	60,817	18,245	30.00
Slovenia		297		990	297	30.00
Spain		24,707		82,357	24,707	30.00
Sweden		6182		20,607	6182	30.00
Ukraine	1300	100	7.69	1300	100	7.69
United Kingdom	264,000	2557	0.97	264,000	2557	0.97
Total	**634,075**	**199,968**	**31.54**	**951,521**	**202,896**	**21.32**
Mean			**33.87**			**23.98**
Median			**28.76**			**30.00**

Figure A4. Fallow deer population and harvest data collected from European countries for the early 2020s with calculated harvest rates. Corrected numbers are highlighted in yellow.

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