

Moose Management Strategies under Changing Legal and Institutional Frameworks

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Abstract: Moose (*Alces alces*) management strategies in Lithuania, East Europe, were analyzed. The study was intended to show the (un)sustainability of the current management approach in relation to changes in hunting rules, hunting organization and development of the responsible administrative bodies. Moose population and bag dynamics were analyzed using *I* index in connected scatterplots and compound annual growth rates (CAGR). In 1962–2020, the CAGR of the moose population was 3.84%, resulting in a population size increase of nearly 10 times. The seesaw principle in moose management was confirmed, showing three periods of population decrease (1973–1977, 1989–1995, 2000–2005), and two periods of hunting bag decrease (1976–1978 and 1990–1993). All decline phases were related to legal and administrative issues in the country. Since 2006, population growth has not been controlled. Lithuania has no long-term strategy of the moose population management at any administrative level. The current management approach is not sustainable, as it has not ensured long-term stability of the moose population. The current continuous growth of population, followed by only a moderate increase in the hunting bag, is related to the possibility for owners to adopt long-term planning of the hunting plot units.

Keywords: *Alces alces*; hunting bag; population management; management strategies

1. Introduction

Almost all of Europe is populated by ungulates; their populations are expanding due to changes in land use (reforestation, abandonment of agricultural lands) [1], reintroductions, legislative changes and management approaches [2]. Of the ungulates, the moose (*Alces alces* L.) is one of the biggest and has a circumpolar species distribution [3,4]. The species inhabits tundra, taiga, boreal and temperate zones, and is found in woodland habitats, wetlands and swamps. Mosaic and second-growth forests are preferred [4]. Farmland and pastures are used when adjacent to forests [5].

In North America, the moose population is about one million individuals, while the European populations amount to nearly half a million and are still growing [4]. The largest moose populations are in Fennoscandia, mainly in Sweden and Finland, and these countries also maintain the highest hunting bags [5]. The growth of moose populations in many countries depends on land privatization and forest dynamics. However, political and economic shocks are not only the main drivers of forest change [6], but can also be the main drivers of wildlife population changes [7], including that of moose [8]. Moose is hunted in all countries within their continuous distribution, including within most of the protected areas [9]. However, there is a lack of a unified approach to the hunting [10], even in neighboring countries such as Lithuania, Latvia, Estonia and Poland [11].

In Lithuania, moose is the second largest ungulate after European bison [12]. After being abundant across the country in the 19th century, moose numbers then significantly decreased at the beginning of the 20th century. There were just 25 individuals left in 1920, and only 32 individuals in 1932. Thereafter, the population increased to over 300 in 1940, before then being decimated after WWII by poaching and wolves [13]. In 1948, only 91 moose were found during survey work. With the imposition of a hunting ban, along with afforestation of the country and carnivore control, the population then increased again, reaching 251 individuals in 1954 and 1500 individuals in 1961 [14].

Since 1962, moose numbers in Lithuania have fluctuated widely [12,14], and the moose hunting ban was ended. In this paper, we analyze population levels and bag trends since this date. We use official numbers, as expert opinions regarding population numbers, especially in the 1970s, were frequently at odds with each other, with estimates differing by a factor of two in some cases [13]. Analysis is done in the framework of the political and management changes that have occurred in the country since 1962.

The aim of this paper was to analyze the sustainability of moose management strategies in Lithuania in relation to changes in hunting rules, hunting organization and the development of the responsible administrative bodies. We consider management sustainable when several conditions are met: (1) a target moose population size has been set as the basis for long-term management, (2) management is characterized by smooth changes or stability in moose numbers, (3) the hunting bag-to-moose ratio is stable over long periods of time or fluctuates insignificantly, and (4) moose densities and quotas are equable across all 10 counties of Lithuania over the long term. If these assumptions are not met, moose management should be defined as not sustainable.

2. Materials and Methods

2.1. Study Site

The study site covers the territory of Lithuania, located in the mixed forest zone of Northern Europe, with an area of 65,300 square kilometers (Figure 1). In 2012, forest land and arable land each covered 33% of the territory, while semi-natural vegetation covered 27% of the territory [15]. In 2018, most of the land in Lithuania was agricultural (52.26%), and forests (33.2%). Built-up territories and roads covered 3.64% and 1.61% respectively. All environmental data for 2018 were obtained from the National Land Service under the Ministry of Agriculture of the Republic of Lithuania [16]. Forest cover increase between 1990 and 2018 was obtained from the CORINE [17]. The road network length is 21,238 km [18], of these 1865 km are main roads with annual average daily traffic of 3000–20,000 cars per day [19]. The population density was 31 inhabitants per square kilometer in 2011, and is currently declining [20]. Prior to the year 2000, 68 species of mammals occurred in the country, including eight species of ungulates [21]. Currently, the list is about 75 species, though there have been no additions in ungulate species [22]. There are 10 administrative counties in Lithuania, differing in area, forest percentage, habitat structure, moose numbers and bag, as well as moose population management peculiarities.

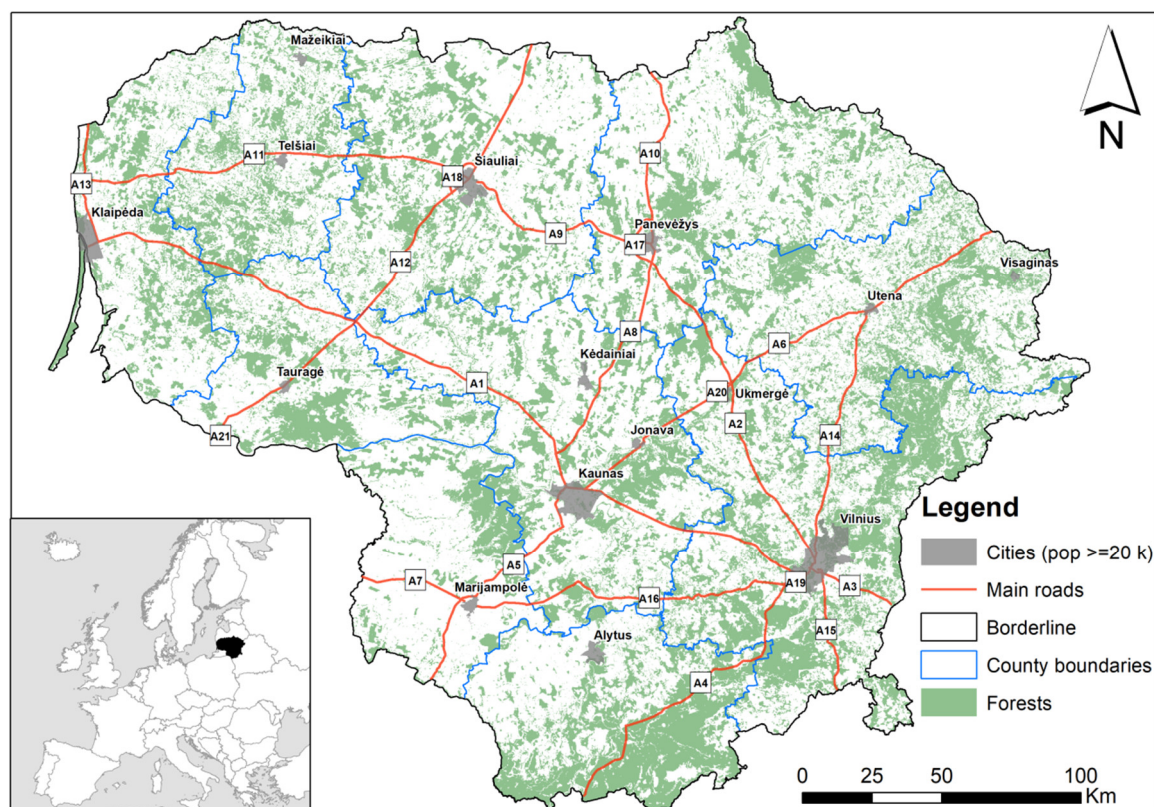


Figure 1. Study area. Forest area is shown by green color, main roads—by red lines and numbers A1–A18, county boundaries—by blue lines. Inset shows location of Lithuania.

2.2. Data on Moose Numbers, Hunting Bag, Administrative and Legal Changes Related to the Species

Data on moose numbers and hunting bag size were obtained from the official source, i.e., the Ministry of Environment of the Republic of Lithuania (data for recent years available online at [23]), and their archives. The most detailed available numbers are at the level of the administrative district, of which there are 60 in Lithuania, but the number of districts was not stable in the period 1962–2020, so we pooled data to the higher administrative level, the county.

We accept all criticism that so called “official” data may be biased. However, (i) there are no other data sources over the long term; (ii) expert evaluations have even greater and more unpredictable bias; and (iii) an increasing number of publications use these numbers (see [24,25], including for Lithuania [7,11]).

Changes in the regulations concerning moose management were collected from official sources, which are referenced in Chapter 4.1.

2.3. Data Processing and Statistics

Trends of changes in moose numbers, bag size and bag-to-population ratio were analyzed using a connected scatterplot [26,27] and compound annual growth rate analysis [28,29].

A connected scatterplot depicts a unit-free index, $I(t)$. For a given t year it is defined as

$$I(t) = (N(t) - N(t-1))/N(t) \quad (1)$$

where $N(t)$ and $N(t-1)$ are population or hunting bag sizes at the t and $t-1$ year, respectively.

As the index $I(t)$ is dimensionless, it is suitable for comparison of population sizes between species or, in our case, between counties [26]. The connected scatterplot is divided into four quadrants by indices $I(t)$ on horizontal and $I(t+1)$ on vertical axis. The first (third) quadrant is the area where both indices are positive (negative). It implies that population is under increasing (decreasing) stage. The second (fourth) quadrant is the area where $I(t) > 0$ (< 0) and $I(t+1) < 0$ (> 0). It implies that

population is moving onto the increasing (decreasing) stage at year t . Graphic representation of the $I(t)$ changes with connected scatterplot allows the defining of periods of population growth (curve in the upper right quadrant of the graph) and population decline (curve in the lower left quadrant). Average and variance of the I index, denoted as MAVI and VAR, were calculated in the standard way, using absolute values of $I(t)$. Wide fluctuations of the population size yielded large average I values. Averages are comparable between sites.

Compound annual growth rate (CAGR), re-phrased from [28], defines the population or bag size that would be required for the moose population to grow or decline, from a beginning value to an end value. This way, the number or bag values of moose are smoothed and can be used to evaluate long-term changes. The CAGR was defined as:

$$CAGR = \left(\frac{IV}{FV} \right)^{\frac{1}{n}} - 1 \quad (2)$$

where IV is the initial value and FV is the end or final value (of moose number, hunting bag or size of bag-to-population ratio) and n is the number of years [29].

All calculations were done in Excel and Statistica for Windows [30].

3. Results

We present results of moose population dynamics across Lithuania for the period 1962–2020, then switch to finer scale and analyze data for 10 counties (higher level administrative division) over a shorter period. All changes are examined in the framework of concurrent legal changes and management decisions.

3.1. Changes in Population Size and Hunting Bag at the Country Scale, 1962–2020

Moose populations in the country were not stable in the period 1962–2020—population numbers underwent two periods of significant decrease and one of milder decrease, though they also saw continual growth from 2006 (Figure 2a). These periods were characterized by differences in the compound annual growth rate, CAGR, see Table 1 and connected scatterplot (Figure 3a). Most I values in Figure 3a are less than 0.5 and are located in the first quadrant, meaning that the moose population was often under expanding conditions, though population growth was not rapid.

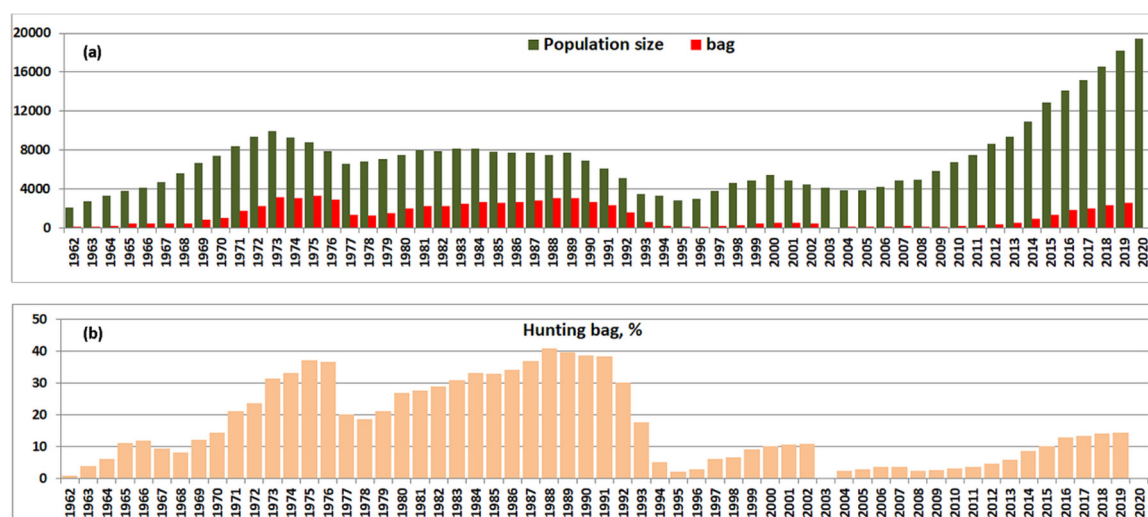


Figure 2. Moose population, hunting bag (a) and bag-to-population ratio (b) changes in Lithuania, 1962–2020.

The first population decrease, in 1973–1977, occurred along with increase in the hunting bag, which in 1975–1976 was unusually high for the country (Figure 2b). The next decline started in 1989 and was the longest during the period (with a curve in the fourth quarter, Figure 3a). The hunting

bag reached its peak in 1989 and thereafter decreased gradually for some years (Figure 2a), thus the bag-to-population ratio between 1988 and 1991 was at its highest level in the whole period (Figure 2b). A final population decrease occurred in the period 2000–2005 and was marked by a complete hunting ban in 2003 and minimum bag numbers until 2009.

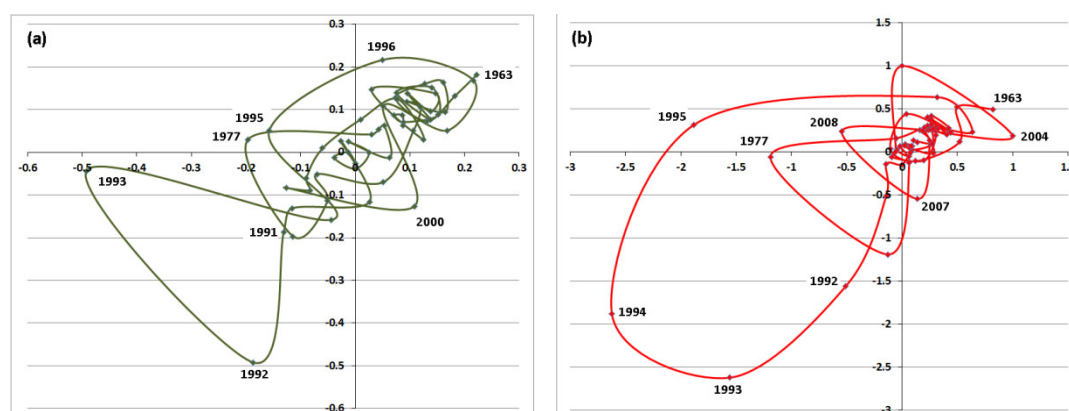


Figure 3. Connected scatterplots of moose population (a) and bag (b) changes in 1962–2020. Different scales confirm that bag changes are of a higher amplitude, and thus underwent strong regulation. The years provided are those of $I(t + 1)$.

The compound annual growth rate of the moose population after the removal of harvests in 1962–2020 was 3.84%. As a result, the population size increased by nearly 10 times (Figure 2a). The CAGR of the hunting bag in 1962–2019 was 8.96%. As changes in the bag were not strictly related to population size, this illustrates management delays.

Table 1. Compound annual growth rate (in %) of moose population, hunting bag and bag-to-population ratio in Lithuania, 1962–2020. Periods are assigned according to the most expressed changes. Arrows denote direction of change.

Period	1962–73↑	1973–77↓	1978–89→	1989–95↓	1996–2004→	2006–20↑
Population growth	13.79	−7.79	1.04	−15.27	2.84	10.56
Period	1962–1975↑	1976–1978↓	1979–1989↑	1990–1993↓	1994–2012→	2013–2019↑
Hunting bag	45.0	−24.33	6.69	−30.98	4.66	25.11
Period	1962–1976↑	1976–1978↓	1979–1989↑	1990–2008↓		2009–2019↑
Bag/pop ratio	28.43	−20.45	5.91	−14.01		17.11

The seesaw principle was confirmed in moose management. There were three periods of population decrease, two were relatively severe (1973–1977 and 1989–1995, CAGR = −7.79% and −15.27%, respectively), while the other was milder (2000–2004, CAGR = −6.63%). These fluctuations were followed by two periods of the hunting bag decrease (1976–1978 and 1990–1993, CAGR = −24.33% and −30.98%, respectively). Since 2006, population growth has not been controlled despite the higher rate of bag increase.

We found a positive relationship between changes in moose population size and changes in hunting bag (Figure 4), including in the outliers (Figure 4a), i.e., the bag ratio changes in 1977, 1994, 1995, 2004 and 2008. Note that the moose population census is conducted after the hunting season each year and the hunting bag for the next season is set after the population census. Thus, roughly speaking, the positive slope in Figure 4 implies that the population size is increasing. Our results indicated that moose numbers were, on average, steadily increasing between 1962 and 2020: this relationship is shown in Figure 4a where a population number change of one unit is accompanied by a bag size change of 2.9219 units. Outlier years are characterized by drops in the bag-to-population ratio (Figure 2b), which in fact are management failures. Removing the outliers, the results in $I(t)$ of bag become linearly related to population changes, i.e., the $I(t)$ of population numbers (Figure 4b) and the increase in determinant coefficient, R^2 . The difference between 2.9219 units and 2.4814 units

implies that the response in terms of hunting bag adjustment is too slow, resulting in drastic falls of population size and, later on, hunting bags. It is recommended to more rapidly change the bag size when the population sizes change drastically.

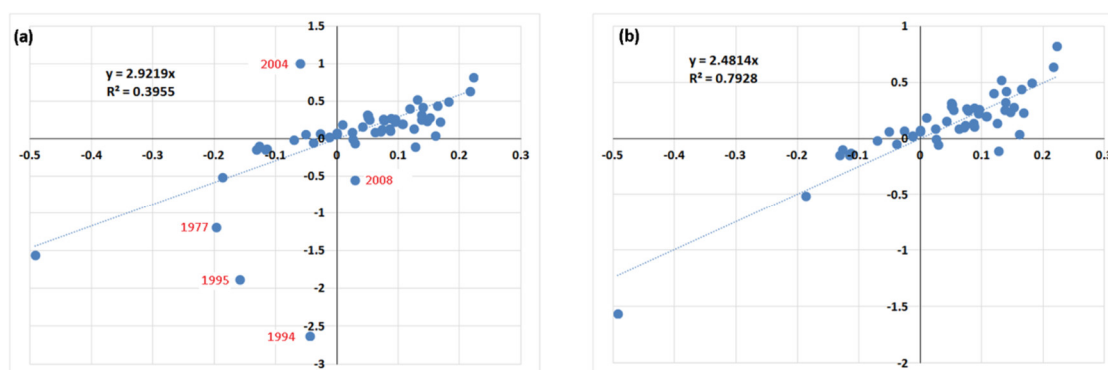


Figure 4. Changes in moose hunting bag in relation to population changes (a). $I(t)$ of hunting bag presented on the vertical and $I(t)$ of population on the horizontal axis. Outlier years are shown in red font. Removing outliers confirms linearity of relation (b).

Generalizing, if we define moose population changes in the country as moderate (except for 1989–1995; Figure 2a), then the hunting bag-to-population ratio changes are significant (Figure 2b), and bag changes are drastic (Figure 2a). These patterns were not similar across all counties (see Section 3.2).

3.2. Changes in Population Size and Hunting Bag at the County Scale, 1993–2020

Moose population dynamics and bag changes in 10 counties in 1998–2020 are presented as connected scatterplots in Figure S1 and Figure S2, respectively. Data on both population and bag sizes at the county level are available from 1993, but data are missing for some years between 1994 and 1998 and for 2020 (Table S1).

Comparing relative moose number dynamics, we did not find expressed differences in the trends of population increment among counties between 1993 and 2020. Proactive control of the hunting bag by wildlife management authorities has led to a continuous increment in the population size, most expressed since 2004–2008 (start time of increment in the counties was not the same). The trends of population growth are presented in Figure 5, with the initial numbers in 1993 equaling 100 (logarithmic scale is used). The efforts of authorities have been successful because the MAVI of $I(t)$ for the population size for each country is almost the same while the MAVI of $I(t)$ for hunting bag for each country differs substantially (Figure 6), implying that some counties take more actions (changes in hunting bags) to stabilize/increase the population size. The presented data allow us to conclude that management patterns were not similar.

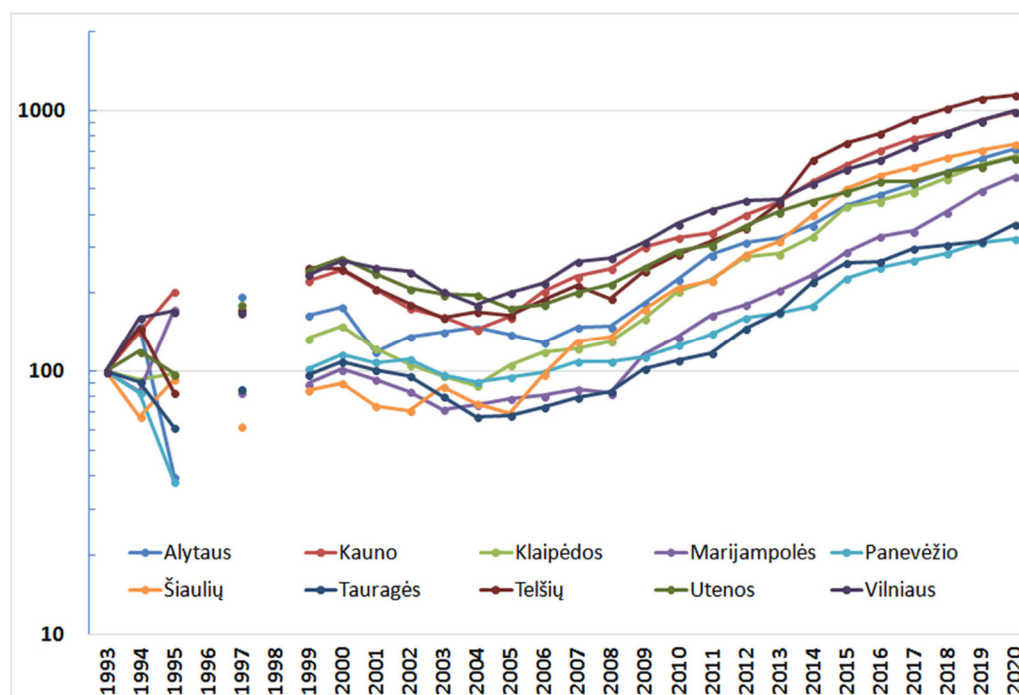


Figure 5. Trends of relative population increase in the counties of Lithuania, 1993–2020. Population sizes in 1993 were defined as 100.

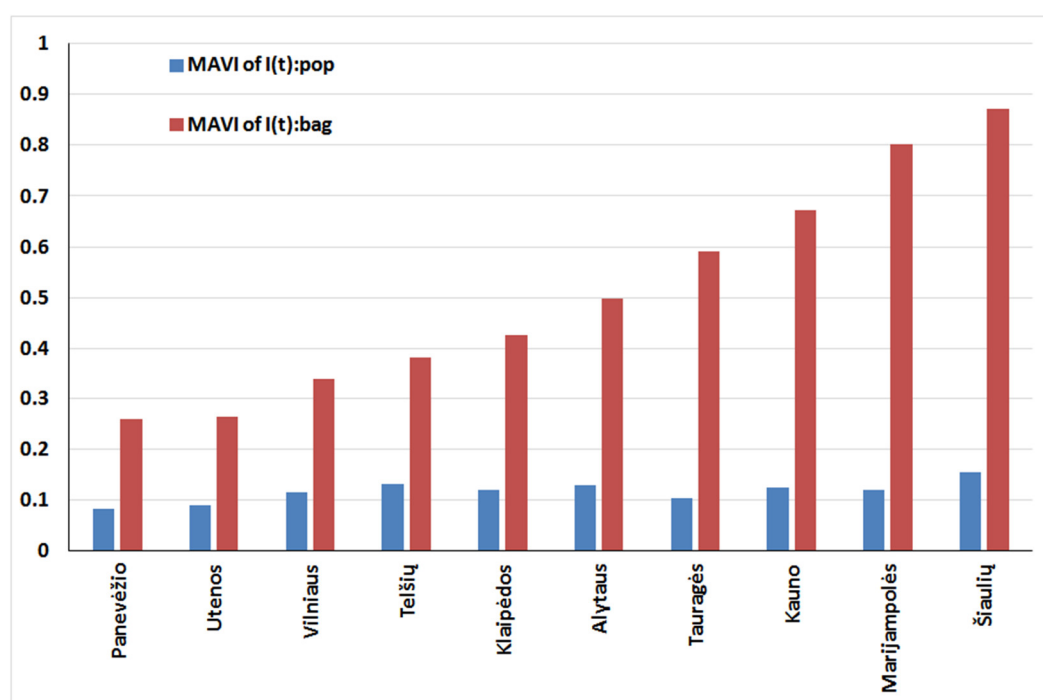


Figure 6. Comparison of the stability of population and bag size increments using the MAVI.

The initial populations were not equal among counties (for the numbers see Table S1), but despite differences in growth rates (density increase 3.12–11.07 times, CAGR 4.15–8.97), the final population sizes in 2020 still tend to be greater in the counties with larger populations in 1993. For the sake of comparison, we set the population size in 1993 as 100. From this, we can conclude the most successful county was Telšiai, with the current population size being 11.45 (=1202/105) times higher than that of 1993, while the least successful was Panevėžis county, the population here being 3.23 (=2525/783) times higher (Figure 5). Šiaulių county experienced the worst position several times

until 2005, but the size of the moose population has increased at a relatively higher rate since 2006, implying some success in moose management in the years since 2006. In fact, MAVI of $I(t)$ for hunting bag for Šiaulių county is the largest, suggesting that control of hunting bag has resulted in the observed successful increment of population in recent years.

Comparison of the densities of the population and hunting bag per unit of forested area (Tables S2 and S3), and dynamics of density changes (Table 2), showed some patterns characteristic of several counties. In the counties with highest initial moose densities in 1993 (Panevėžis and Utenos, 3.463 and 2.032 individuals per 1000 ha of forest area, respectively), the density increase rates were most moderate (3.12 and 6.13 times, respectively), with CAGR also being smallest. Vice versa, the two counties with the lowest initial moose densities (Kauno and Telšiai, 0.745 and 0.658 individuals per 1000 ha of forest area, respectively) show the highest increase rates in the 1993–2020 period, being 9.14 and 11.07 times. Their CAGR for the same period were also among the top three (Table 2). However, the fastest population density growth in the 2005–2020 period was characteristic of other counties (Klaipėdos and Šiaulių).

Table 2. Relative increase in moose density and hunting bag density (individuals per 1000 ha of forest area) in the counties of Lithuania.

County	Density, Times			Density, CAGR *			Bag, Times			Bag, CAGR		
	1 **	2	3	1	2	3	4	5	6	4	5	6
Alytaus	1.65	6.56	4.44	6.45	6.95	9.77	1.10	4.36	4.44	3.11	6.61	9.77
Kauno	2.23	9.14	6.32	10.54	8.22	12.21	1.56	6.41	6.32	16.08	8.41	12.21
Klaipėdos	1.34	6.21	7.03	3.73	6.74	12.96	1.44	6.68	7.03	12.97	8.61	12.96
Marijampolės	0.90	4.93	6.56	−1.28	5.86	12.48	1.07	5.85	6.56	2.33	7.99	12.48
Panevėžis	1.02	3.12	3.42	0.24	4.15	7.99	1.23	3.77	3.42	7.13	5.94	7.99
Šiaulių	0.84	7.04	9.37	−2.09	7.22	15.01	1.26	10.53	9.37	8.07	10.78	15.01
Tauragės	0.97	3.15	4.69	−0.36	4.18	10.15	1.06	3.44	4.69	2.04	5.52	10.15
Telšiai	2.51	11.07	6.53	12.21	8.97	12.45	1.70	7.50	6.53	19.43	9.16	12.45
Utenos	2.45	6.13	3.11	16.07	6.69	7.34	2.05	5.13	3.11	26.94	7.36	7.34
Vilniaus	2.36	9.15	5.07	11.32	8.23	10.68	1.46	5.66	5.07	13.41	7.83	10.68

* CAGR—Compound annual growth rate; ** Periods compared: 1—1993 to 2000, 2—1993 to 2020, 3—2005 to 2020, 4—1998 to 2000, 5—1998 to 2019, 6—2005 to 2019.

Relative dynamics of the hunting bag densities (number of hunted moose per 1000 ha of forest area in the county) was different from the population density changes. The two counties (Panevėžis and Utenos) with the highest density of hunting bag in 1998 were characterized with the highest animal density. Growth of the bag density in these counties for 1998–2019 were among the most moderate: CAGR was 5.94% and 7.36%, respectively (Table 2). The bag density growth in these counties for 2005–2019 was the smallest: 3.42 and 3.11 times, CAGR 7.99% and 7.34%, while the CAGR of the bag in other counties was 9.77–15.01%.

3.3. Environmental Parameters and Moose Population Dynamics

County-based environmental data are presented in Table 3. The areas of the counties remained stable in 2014–2018 (the maximum change in the three counties was in the range of 0.02% or less). Between 2014 and 2018, forest percentage in Lithuania increased from 33.4 to 33.7% [31]. Increase in the forest percentage from 1990 to 2018 was 2.6% for the entire country [17], and was best expressed in the eastern and northern counties. While wetland share was relatively constant, other factors between counties differed to a higher extent (Table 3).

Table 3. County-related environmental data and moose population densities: AREA—area, km² [32], FOR %—forest percentage from the area in 2018, FI1%—increase in forest percentage from 1990 to 2018, FI2%—increase in forest percentage from 2014 to 2018, WETL%—wetland percentage from the area, WATER%—waterbody percentage from the area, HD—human population density per km², all as for 2018. All data sources are listed in 2.1.

County	AREA	FOR%	FI1%	FI2%	WETL%	WATER%	HD
Alytaus	5418	49.5	2.8	0.4	1.13	1.94	25.5
Kauno	8086	29.7	1.7	0	0.14	2.26	69.9
Klaipėdos	5222	26.6	2.0	0.1	1.16	10.29 *	60.8
Marijampolės	4466	22	1.7	0	0.43	0.95	31.6
Panevėžis	7878	28.7	1.8	0.5	0.67	0.82	27.8
Šiauliai	8537	28.1	1.8	0.5	0.81	0.88	31.1
Tauragės	4408	33.2	2.5	0.1	0.42	1.03	21.7
Telšiai	4350	36.7	3.0	0.4	0.73	1.19	30.8
Utenos	7191	34.7	4.3	0.4	1.01	5.48	18.0
Vilniaus	9730	44.3	4.5	0.3	1.72	4.05	82.8

* Area of the Curonian Lagoon is included for Klaipėdos county.

Environmental data were analyzed for correlation with moose and hunting bag densities and indicators of their relative increase. Absolute values of moose and bag numbers were not used for correlation analysis, as they are area-dependent. All correlations but one were non-significant due to the small sample size, $n = 10$ (Table S4), however, there were some patterns.

Increase in the forest area in the 1990–2018 period was strongly and significantly correlated with the CAGR of 1993–2000 ($r = 0.74$), and positively correlated with the moose densities and moose bag densities in 2000–2015. From 2000, positive correlations of moose densities and moose bag densities were found with the increase in forest area within it in 2014–2018 ($r = 0.31$ – 0.49), the share of wetlands ($r = 0.20$ – 0.31) and the proportion of water bodies ($r = 0.21$ – 0.45), while negative correlations were found with human population density. The last figure also includes 1993, as that year saw the strongest correlations of moose densities and moose bag densities with human population density ($r = -0.41$ and -0.42) in the period of 1993–2020.

4. Discussion

Results of this study show that from the long-term perspective, despite overall growth in numbers, moose management in Lithuania was not fully sustainable, as the populations experienced three extreme decrease periods, followed by significant reductions in the hunting bag or even a ban on moose hunting. In the most recent period, moose numbers in the country have undergone a period of constant growth. The achieved density in 2020 is the greatest ever experienced. At the county level, there were differences in the pattern of density and hunting bag dynamics. In the most recent decades, the highest CAGRs were characteristic to the counties which earlier were characterized by low moose densities. The dynamics of the hunting bag in the counties was not directly related to the population densities.

We acknowledge that the dataset used is not bias-free. However, this is the only data source available for moose management decisions in the country. Evaluations of moose populations and management decisions in neighboring countries have always relied on “official” data [7,11], despite the possible influence of changes in the methods of mammal surveying, of political turmoil and of variation or absence of management decisions. As we examined the CAGR and hunting bag variations over quite long-term periods, our results and conclusions should not be sensitive to possible over- or under-estimates of population numbers.

Our results of I index in the connected scatterplots seem to be consistent with Kawata et al. (2013). Most values of I index in Figure 3a and Latvian moose in [26] are less than 0.5, this was the maximum in the initial stage of recovery (before population size reaches 1000 heads); later I values were < 0.2 . Other moose populations were not evaluated using the same methods. Moose bag changes

were more expressed, with *I* index being >1 in the periods of the most expressed management changes.

Positive correlations of the moose density and moose hunting bag density with the long-term and the short-term forest increase, share of wetlands and water bodies in the county may, in addition to a negative correlation with human population density, be interpreted as a suitably diverse habitat with less human pressure for these animals. As noticed in [13], reforested areas and mires are the main winter habitats for moose in Lithuania, and are used 1.5–11 times more than all other habitats. Forest area increase was most expressed in the northern and eastern counties, characterized with the highest moose population densities. However, based on moderate correlation coefficients, these factors are not the main regressors defining moose population dynamics. To understand the background of these patterns, legal and administrative issues of moose management and hunting should be analyzed and compared to species management in other countries.

4.1. Legal and Administrative Background of Moose Population Management in Lithuania

Arranged as a timescale, there have been a number of important legal and administrative changes related to moose population management [13,14,33–44]:

1. In 1962, moose hunting was resumed following a period during which hunting had been totally banned in order to increase moose numbers in the country. During that hunting ban, the number of moose had risen from 91 in 1948 [13] to 2100 individuals in 1962 [14].
2. 1962–1988 was the period during which ungulates were valued and protected (from poaching). Meat did not belong to hunters, it was obligatory to deliver it to state-owned meat factories and it was thereafter exported for hard currency [33]. Sums were considerable, increasing from 1.96 million rubles in 1986 to 3.01 million rubles in 1990 [31]. As a result, hunters were not interested in an increase in moose numbers or in moose hunting.
3. From 1988, institutional changes occurred in the regulation of hunting. Until 1988, quotas were set on the basis of the previous year of survey data. A decrease in numbers in 1973–1977 was conditioned by overhunting, as the bag in these years was unusually high. It was corrected by a rapid bag drop in 1977–1978 (see Figure 1). Management of wildlife was transferred to the Ministry of Forestry in 1989. This period was characterized by the highest ever bag-to-population ratio, and resulted in the largest and fastest decline in moose numbers. Overhunting was officially justified, but was later followed by a reduction in the hunting bag from 1991 to 1995, when only 58 moose were hunted [14,34].
4. After the independence of Lithuania (1990), a period of reorganization followed, with administrative and legal changes negatively affecting moose numbers. Moose overhunting was based on the norms of allowable density of ungulates [35] (Table S5). When leasing land for hunting, hunters were obliged to regulate ungulate densities. The availability of rifles to hunters, the simplified procedure of possessing guns by farmers for self-defense and the lack of hunting control all resulted in a rise in poaching levels [36].
5. Between 1990 and 1995, administrative bodies and hunting organizations underwent a period of reorganization. In 1995, regulation and control of hunting were transferred to the Ministry of Environmental Protection, this renamed the Ministry of the Environment of the Republic of Lithuania in 1988 [37]. Several documents related to moose population management were adopted, namely the Regulation for Hunting in the Republic of Lithuania (1995, last change in 2000, consolidated edition in [38]) and the Rules of Hunting in the Republic of Lithuania (1995, changes and consolidated edition at [39]).
6. In 2002, the Law on Hunting (2002, consolidated edition at [40]) established concepts of hunting, hunting plot units (order of designation and size) and selection. In our opinion, the main issue that encouraged further moose population growth was the statement that hunting plot units would be leased for terms no shorter than 10 years, thus enabling hunter organizations to seek long-term wildlife management strategies. In the hunting plot units, hunters started being able to increase ungulate populations without asking for quotas. In subsequent years, further legal changes came into force, namely Ruling of the Constitutional Court on the Law on Hunting,

2005 [41], the Description of the Order of Preparation, Coordination, Presentation to Affirmation and Affirmation Order of the Projects of Hunting Administration, 2005 [42] and the Order of Preparation, Coordination, Presentation to Affirmation and Affirmation Order of the Projects of Hunting Administration (in force from March 2005).

7. In 2012, a new edition of the Rules of Hunting in the Republic of Lithuania was published (coming into effect from 2013, last redaction 2018). According to the 2001 edition of the Rules of Hunting in the Republic of Lithuania, as of 2002, moose limits would be set upwards from the bottom by a committee in every administrative district [43]. The limit would be set by 15 April, considering the proposal, the bag of the previous season and damage done by cervids. During the season, the limit size could be re-considered. Any limit increase over 50% had to be approved by the regional Department of Environmental Protection

Prior to the implementation of these legal and organizational issues, moose numbers had grown in the period 1996–2000, but then decreased again from 2000 to 2005 despite limits in the period 1995–2002, a hunting ban in 2003 and continued hunting restraints until 2008. Further evolution of moose management came to an end with the period of continuous population growth that has occurred since 2008, accompanied by only a moderate increase in the moose hunting bag (see Figure 2, Figure 5 and Table 1). Changes in moose population have had some regional peculiarities (see Table 2). Therefore, we may conclude that the possibility for owners to plan within the hunting plot units has had a much greater impact than the temporal ban on moose hunting and temporal limitations. However, in 2020, there is no long-term strategy of moose population management, neither at the country level, nor at the lower level.

Other regulations in regard to moose hunting, such as the length of the hunting season and limitations related to the selection process, do not have tangible influences on the sustainability of species management (or, at least, have not had so far). Adult male moose may be hunted only by approved hunters-selectionists. Terms have changed over time, last changes done in 2018 [43] and 2020 [44]. Since 2020, bulls are hunted from 1 September to 31 December (the requirement for a qualification of hunter-selectionist is implemented in the Rules of Hunting in the Republic of Lithuania), while cows can be hunted from 1 October to 30 November and calves from 1 October to 31 January [44].

4.2. Moose Populations and Management Examples in Some European Countries

The best-known examples of moose population management are those in Fennoscandian countries, these characterized by high moose densities and the most heavily hunted populations in the world [10,45]. In 2000, the moose population across the region reached about 500,000 animals with an annual bag of about 200,000. The harvest maximums were observed in Sweden and Finland in the 1980s, and in Norway and a second peak in Finland in the 1990s [45]. In 2002 and 2003, Finland again experienced “an unprecedentedly high level of culling”, over 84,000 moose hunted in two consecutive years [5]. In Norway, the highest bag, over 37,000 moose, was registered in 2005 [46]. In 2017, the numbers of hunted moose were over 84,500 in Sweden, 56,600 in Finland, 31,600 in Norway, 7000 in Latvia and 6900 in Estonia [2]. Below, we briefly analyze moose management principles in these countries [5,11,13,45–78], looking for differences or similarities with moose management in Lithuania.

In Sweden, a collaborative ecosystem-based management of moose [47] aims to “achieve a high-quality moose population in balance with the grazing resources” [48], solving also conflict between hunters and other societal interests [49]. Moose management groups include landowners, hunters and reindeer husbandry representatives in some counties. Differently to Lithuania, these groups also set hunting quotas for moose [50]. Management of moose has been influenced by the re-establishment of wolves [51], hunting tourism [52] and changes in values [53]. Problems have been identified, namely “lack of funding, unclear roles and responsibilities” [54].

In Norway, hunters take an active part in the moose management process [45]. Currently, the role of local authorities in environmental management, including hunting, is being strengthened [55,56]. Management of cervids is implemented in large management areas, each of which comprises

of a number of areas, jaktvalds [57]. Each jaktvald has a steering committee and management plans. In these plans, chapters on moose population status, habitats, management goals and means of achieving these goals should be presented, and should be in balance with the goals of the municipality. Municipal goals should correspond to the county, i.e., to the broader territorial and administrative extent [58]. After approving the plan, the municipality issues permits for moose (numbers of bulls, cows and calves), which are distributed to the hunting teams by the jaktvald steering committee [57]. Such a multi-level management is specific to the country and differs from Lithuania.

In Finland, moose management aims have changed from protection and low hunting bag in the 1990s to intensive harvesting to limit population and damage to forests in the mid 1980s and the years since 2000 [59]. Differently to Lithuania, management goals are the stability of population, high reproduction rate and high harvest intensity. As the law requires a minimum of 1000 ha of integrated area for moose hunting, this has resulted in land being rented to hunting clubs [60]. With the rural society aging and members being unable to hunt moose intensively, preferences have changed to lower moose population numbers in recent decades [61]. Currently, moose management is based on monitoring results [62,63].

In Poland, following a peak of 6000 individuals in 1981, moose numbers declined due to intensive hunting and poaching, reaching just 2100 in 2000 [64]. Hunting was stopped in 2001 and thereafter the population grew to 21,323 individuals in 2017 [65]. Following this, there was an expectation of a resumption of hunting in 2018 [66], but this did not happen [67,68]. The most recent population size estimate in Poland was for 26,178 individuals in 2019 [69]. Population growth in the last decades resembles that in Lithuania, and has a similar cause, under-hunting.

In Estonia, moose number fluctuations have been observed, but are not synchronous with the other Baltic States [13,70,71]. Due to forest damage, a reduction in moose numbers was negotiated [72] and, as such, a very high moose bag-to-population ratio has been characteristic to Estonia, being over 50% in 1980, over 40% in 1990–1993 (resulting in a nearly triple decrease in numbers until 1995) and over 60% in 2019 [70]. Thus, moose management is unsustainable for the same reasons and in the same way as in Lithuania. Recent population estimates are provided by users of the hunting districts, as well as by pellet count-based monitoring since 2015 [71]. Quotas on moose are issued by the Hunting Council [73], and approved by the Environmental Board.

In Latvia, the maximum numbers of moose were recorded in 1972: 21,000 by official data and about 45,000 by expert estimation [13]. Similarly to Lithuania, reorganization after independence resulted in a moose number decrease, followed by sharp decrease in the moose hunting bag [74]. Since 2008, continuous growth has been observed until 2020, with the hunting bag closely following population tendencies from 1996 [75]. No management plans for cervids existed in Latvia prior to 2005 [11]. Now moose management in the country is supervised by the State Forest Service. Quotas are set according to estimated numbers and to damage caused to the forest [76]. However, the reliability of such estimates has recently been doubted by the State Audit [77]. Currently, various locally and temporarily introduced management manipulations with quotas and hunting permits are implemented in order to stabilize population structures and prevent conflicts with forestry [78].

Concluding, moose management in Baltic countries and Poland is not sustainable in terms of population and hunting stability and it lacks any long-term strategy.

4.3. Moose-Related Problems: Why is Management Necessary?

Recovery of populations of large mammals in Europe is beyond doubt [2,7,10,79]. As for ungulates, a lack of a common strategy for their management [7] requires unification, at least in protected territories [9,80].

Ungulates, including moose as the biggest cervid species, are important in boreal and non-boreal ecosystems. Moose have been demonstrated to be keystone species of the forests [81], but under high densities they destroy forest diversity, structure and functioning [82,83]. The impacts of browsing on the other species are mostly indirect, requiring the maintenance of favorable numbers of browsers, monitoring the size of their populations and using an adaptive management approach [84].

We did not analyze moose damage to forest regeneration and young stands, as this is a well-known issue in all countries with high numbers of animals [2,48,67,85–88]. However, high numbers of moose pose a direct threat to humans, as their large size and long legs cause injuries or lethal consequences in wildlife–vehicle collisions [89]. This also is characteristic to Lithuania, where the growth of moose populations has resulted in an increase in moose-related wildlife–vehicle collisions [90,91]. While mitigation strategies should be species-tailored [92], they are all costly. Moose management measures, such as moose hunting near roads may be another solution [89].

Moose population management is also intertwined with conservation and environmental and economic issues [93]. In the countries with moose permit systems, an increased number of permits benefits hunters, but not necessarily local inhabitants [94].

To be effective, management has to be science-based [2,93]. Moose interactions with forestry, agriculture and transport become increasingly complex [95]. For effective management, ungulates should be considered a part of the ecosystem and their management needs to be holistic [50] and sustainable; the populations of animals should be seen as renewable resources. We found that moose population growth rates may vary significantly between countries, for about 10% in British Columbia during 1996–2015 [96], but up to 30% in the Baltic countries [11,70,78]. This fact alone requires different approaches for maintaining the sustainability of moose populations.

Innovative approaches, such as hunting for fear (diverting animals from areas where they are not desirable) [97], consideration of the issues of functional heterogeneity [98] and social-ecological setting [50] are being used in the management of moose. Classified as services or disservices, “depending on the value orientation and economic position of the various stakeholders perceiving this relationship” [2], moose management may seek different scenarios. Populations could be managed towards an increase, a decrease or to a level of sustainable harvesting. Alternatively, along with monitoring of the situation, no intervention could be applied [81]. Whatever scenario will be applied in the future, Lithuania currently lacks coordinated approach, as the perspective of the moose population is undefined at the state level.

5. Conclusions

In the long term, the moose management approach in Lithuania was not sustainable, as it did not ensure the stability of the moose population, nor the relative stability of the hunting bag or a balance of moose quotas between counties in the country. All decline phases in moose numbers were related legal and administrative issues in the country. Similar situation is characteristic also to other Baltic countries.

Between 1993 and 2020, there were no big differences in the trends of population increment at the county level, probably because wildlife management authorities in Lithuania and each county have controlled bag numbers proactively, so that a continuous increment of the population size was achieved.

The observed continuous growth in moose numbers after 2008, followed by only a moderate increase in the moose hunting bag, is related to the possibility for owners to adopt long-term planning of the hunting plot units. However, Lithuania has no long-term strategy for moose population management at any administrative level.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/12/20/8482/s1, Table S1: Moose numbers (N) and hunting bag (B) size in the territories of 10 counties of Lithuania, 1993–2020, Table S2: Moose densities (individuals per 1000 ha of forest area) in the territories of 10 counties of Lithuania, 1993–2020, Table S3: Moose hunting bag densities (shot individuals per 1000 ha of forest area) in the territories of 10 counties of Lithuania, 1998–2020, Table S4: Correlation matrix between environmental data, moose densities, hunting bag densities and indicators of relative increase in moose numbers, population densities and bag densities, Table S5: Norms of allowable maximum density of ungulates in the forests of Lithuania (1995), which become Norms of recommended maximum density of ungulates in the forests of Lithuania in 2005 [35], Figure S1: Connected scatterplots of changes of moose population numbers in 1998–2020, Figure S2: Connected scatterplots of moose hunting bag changes in 1998–2020.

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