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Increase in the moose (*Alces alces* L. 1758) population size in Poland: causes and consequences

KATARZYNA DZIKI-MICHALSKA, KATARZYNA TAJCHMAN, MONIKA BUDZYŃSKA
Faculty of Biology, Animal Science and Bioeconomy, University of Life Sciences in Lublin

Abstract: *Increase in the moose* (Alces alces *L. 1758*) *population size in Poland: causes and consequences.* The aim of the study was to characterise the determinants of the moose (*Alces alces*) population size in Poland, taking into account the methods for assessment thereof as well as animals' habitat preference and behaviour, and to identify problems associated with the increased population size in this species. The study presents threats posed by the overpopulation in these animals not only to their living habitat but also to the species itself. The process of habituation, which results in changes in the behaviour of free-living animals, may play an important role. It is advisable that steps should be taken to maintain healthy populations of moose on the one hand and mitigate the adverse effects of overpopulation in this species on the other hand. There is a need for a reliable method for making inventories of the species and resumption of the regulation of moose density by culling.

Key words: *Alces alces*, population size, behaviour, damage, collisions

INTRODUCTION

In recent years, there has been increased interest in the largest representative of the deer family (*Cervidae*), i.e. the moose (*Alces alces*). The moratorium (year-round protection) on harvesting the species has been in force since 2001 (Journal of Laws 2001 No 43, item 488). In the autumn of 2017, it seemed that the moratorium would be withdrawn and moose culling would be reinstituted. However, the decision was halted by the Minister of the Environment (Nasiadka 2018, Ratkiewicz 2018, Wawrzyniak 2018). Continuous research is being conducted to determine whether the current moose population size is sufficient to resume culling. Annual hunting plans must be established for the management of ungulates. Appropriate hunting management helps to maintain good health status of animal populations and to minimise the damage caused by animals not only in forest ecosystems but also in agricultural crops. Currently, the highest abundance of this species is noted in the provinces of the eastern part of Poland, i.e. Podlaskie, Warmińsko-Mazurskie, Mazowieckie, and Lubelskie Provinces (GUS 2013–2017) – the figure. The highest growth rates in moose populations were recorded over the last several years, i.e. from several thousand individuals at the beginning of 2001 to tens of thousands in 2017. It is possible that the moose population size is overestimated, as the inventory based on drive counts does

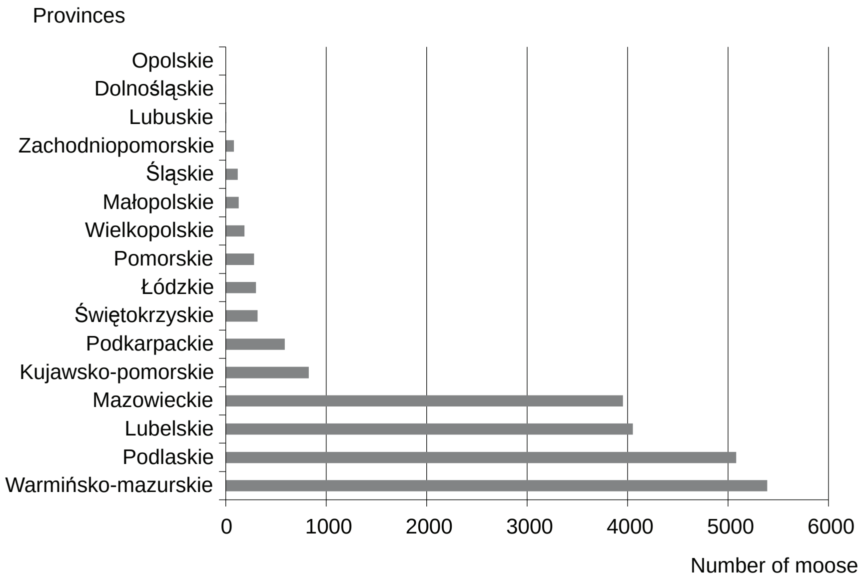

FIGURE. The number of moose in the areas of particular provinces in Poland in 2017 (GUS 2017)

not give reliable results. Other inventory methods (snow-track, year-round observations) are also burdened by a risk of inaccuracy (Bobek et al. 2013).

The aim of the study was to characterise the determinants of the moose (*Alces alces*) population size, taking into account the methods for assessment thereof as well as animals' habitat preference and selected behaviour traits, and to identify problems associated with the increased population size of this species.

DETERMINANTS OF THE MOOSE POPULATION GROWTH

As shown by the data of the Statistics Poland (GUS), the moose population size over the last 16 years has grown from approximately 2,000 to 21,323 animals in 2017 (GUS 2013–2017). There are several determinants of the increase in the moose population size in Polish forests. These mainly include the better availability of the feed base for this species. Forest habitats are fertile and the average age of tree stands increases. The enlargement of the undergrowth and understory areas and their reduced compactness are important as well (Sokół 2009). Another factor is very often introduction of agricultural monocultures, in particular maize, which provides not only high-energy forage but also protection during the feeding time. Climate change resulting in mild winters and easy access to food is another determinant. From year to year, the animals' fitness is better, which is directly reflected in the higher reproductive success. Changes in the behaviour of these animals are an important factor as well. Moose can more frequently be encountered close to cultivated fields and areas inhabited by humans (Bobek et al. 2013). Undoubtedly, this may be influenced by the progressing process of synurbisation. Conflict-free encounters of animals with humans have become more frequent in forest areas, leading directly to habituation in these species. This physiological process resulting in a gradual reduction and disappearance of the response to a repetitive stimulus (in particular a monotonous stimulus that does not involve significant consequences for the organism) causes changes in the behaviour of wild animals (Poucet et al. 1986). The habituation process has fundamental biological importance, as it leads to disregarding stimuli that are not important for the animal and is a reflection of certain economics of behaviour (Thorpe 1963). In nature, animals usually avoid an unknown stimulus. Yet, individuals who do not have natural enemies and have frequent contact with humans are characterised by reduced escape distance and lower timidity levels (Sadowski 2012, Hansen and Aanes 2015). These changes in the behaviour have also been observed in moose, which may be associated with the expansiveness and presence of this species in areas of human activity. Do such changes in the moose behaviour not pose threats to the species and humans?

In recent years, there has been a rise in the number of hunting districts inhabited by the moose. At the turn of the 20th and 21st centuries, the number of the largest representative cervids was approximately 400 individuals (approx. 8–9% of all districts), and this number increased to 1,500 in 2015 (32% of all districts). Hence, the area occupied by moose was growing bigger four times (Panek and Budny 2015), which confirms the high expansiveness of this species. The highest density of moose was recorded in eastern and north-eastern Poland, where 9–12 individuals per 1,000 ha of forest were noted. Additionally, after a several-year break, a constant presence of representatives of this species was observed in the western part of the country, e.g. in Gorzów (2012) and Zielona Góra (2014) districts (Panek and Budny 2015).

The moratorium, which is in force at present, has resulted in a dynamic growth in the population of these animals also in the Kampinos Primeval Forest. The moose density in this area has increased from 6 to 12 animals per 1,000 ha of forest area. Since 2007, the number of moose in this region has been constant and is currently estimated at approximately 300–400 individuals (Nasiadka et al. 2015). It seems that this number exceeds the carrying capacity of the environment. One of the main causes of the high density of moose in the Kampinos Forest is the high increase in the size of this population mainly associated with the dominance of females and the substantial percentage of females starting reproduction (Nasiadka et al. 2015). As shown by investigations conducted in Estonia (Tõnisson and Randveer 2003), the optimal moose density should not exceed 5 animals per 1,000 ha of forest and swamp areas; in terms of the ecology and biology of the species, the optimal density level should not be higher than 7–8 individuals per 1,000 ha. Given the similar parameter values in permanent occurrence ranges, it can be assumed that the density of the Polish population should range from 1.2 individuals per 1,000 ha to 10 individuals per 1,000 ha of forest and swamp areas (Ratkiewicz 2011). Overpopulation has an adverse effect not only on the ecosystems colonised by the animals but also on the animals themselves. High densities promote competition for feed and living space (Szukiel 1972).

The rapid increase in the population size are also caused by the relatively high incidence of twin pregnancies in this species (Sokół 2009). As demonstrated in the investigations conducted by Gębczyńska and Raczyński (1989) in the Biebrza valley, twins accounted for 12.4% of all calves, which was a relatively low value in comparison with other investigations. Investigations conducted on the Princess Royal Island (Canada) showed that the lowest numbers of twins were born during the peak of the moose population size (Peterson 1977). It was also found that the sex of the calves was depended on by the father's age (Saether et al. 2004). In Poland, it was shown that the ratio of females to males was at 100 : 80. This was a result of selective culling targeted at harvesting bulls that were valuable for their trophy (Gębczyńska and Raczyński 1989).

Showed that selective harvest has the potential to affect offspring sex ratio, timing of birth, reproduction, survival rate, age structure, and body weight (Milner et al. 2007). In Sweden focused on increasing the adult age structure to improve the quality of the moose population at large. Two common restrictions are protecting individual bulls based on the size of the antler (Schwartz et al. 1992), or alternatively, protecting cows based on the presence of calves (Balciauskas 2002). Simulated selective harvest strategies of moose in Sweden using antler size and protection of cows with calves to assess the impact of these strategies on population age structure and potential harvest efficiency (proportion of allowed shooting opportunities). The post-hunt, adult bull to cow ratio was held constant throughout the simulations, but age structure of the bull cohort was allowed to vary. The simulation showed that protecting bulls with small antler reduced the average bull age in the post-hunt population, whereas protecting bulls with averages yielded a higher average age (Kalén 2018). Swedish research showed also, only 33 and 55% of the bulls in the population were eligible for harvest with small and average antlers, respectively. For cows, the post-hunt, average age was unaffected. However, restrictions protecting reproductive cows reduced harvest efficiency of calves, making it more difficult to reach calf harvest quotas. Kalén (2018) suggested that antler size and cow hunting restrictions be abandoned in favour of sex-differentiated harvest quotas.

In Poland, extensive research is currently being carried out to determine the exact abundance of this species, its density, realized increment, age and gender structures etc., so as to be able to develop a management rate for population of the largest cervid in the future. As specified by the adopted principles of population and individual selection of game animals in Poland (2015), the sex ratio in moose populations should be from 1.2 to 2.0 (number of females per 1 male). A historical study carried out by Peterson (1977) demonstrated that the sex structure in this species should be balanced. It should be between 1 : 1 and 1 : 15 in favour of cows. Data obtained from the Regional Directorate of State Forests in Lublin for the period from 1 April 2017 to 31 March 2027 indicate, that the sex structure in the Lublin region is 1 : 35 (unpublished data). Structural instability increases the number of cows pregnant and consequently leads to an increase in the number of moose. All these factors increase the reproductive success of moose and lead to a rapid increase in the population size. However, the changes in the behaviour of moose and the density exceeding the carrying capacity of the habitat suggest that harvesting of the species should be resumed.

METHODS FOR ASSESSMENT OF THE MOOSE POPULATION SIZE

There is a probability of overestimation of the population size in this largest representative of cervids, which can be ascribed to the methods used for calculation. Most probably, the differences between the results yielded by different methods (drive counts, aerial surveys, and distance-sampling) are associated with the cluster distributions of moose and the non-randomness in the choice of the area for the drive counts (Sobociński 2018). Monitoring in the case of a specific species (spatio-temporal assessment of density changes) is sufficient. However, in the case of game animals, it should be substantially expanded, as the aim of hunting management is not only to analyse and trace changes occurring in populations but also to determine the sex and age structure by adjustment of the level of animal harvesting (Krausman and Cain 2002, Tajchman and Drozd 2018). The current assessment of the moose population size raises considerable controversy since the method of drive counts is based on merely 10–20% of the hunting district area, while the methodology recommends minimum 30% (Chmielewski and Maślanko 2014). Additionally, the boundaries of the districts are determined "artificially" and are not based on natural structures. The suitability of the habitat for moose may be substantially diversified in each sector, while the results of the entire hunting district are averaged with no regard to the recommendations mentioned above (Chmielewski and Maślanko 2014). The data are probably overestimated by approximately 46% in relation to the results reported by other researchers (Bobek et al. 2001). The method of block counts proposed by Bobek et al. (2013) confirms this thesis. Furthermore, it was proved by the analysis of the results of an inventory carried out by the employees of hunting associations in the "Polesie Zachodnie" Biosphere Reserve in February 2012 (Chmielewski and Maślanko 2014). There is therefore a need to develop and adjust inventory methods to the biology and behaviour of moose.

Commonly used methods should be complemented with direct observations of e.g. data collected by volunteers and hunters or foresters (hunting data collection) (Ericsson and Wallin 1999, Kindberg et al. 2009) and with aerial surveys. Despite their efficiency, the latter method is not often used, as it generates relatively large costs. Moreover, the aerial survey method should be complemented with the use of infrared detectors and low drone flights, which would considerably increase detection of animals (Cilulko et al. 2013, Pagacz and Witczuk 2016). Documented direct observations are particularly highly valued in the case of the largest cervid species. Data collected by hunters and foresters can be regarded as one of the most reliable sources of information on the moose population structure and size (Ericsson and Wallin 1999). In Scandinavia, where moose inhabit very large areas, this is the only effective and economically viable method (Nygren and Pesonen 1993). Another approach yielding satisfactory results is the use of photo-traps. The method provides information that would be given by the other more tedious procedures after many years. Photo-traps save time and limit the number of staff required for this methodology; concurrently, they provide reliable and methodically irrefutable information. Data collected in this way are used primarily for the design and implementation of active protection procedures (Olszewski 2016).

THREATS POSED BY THE INCREASE IN THE MOOSE POPULATION SIZE

The problems associated with the increase in the moose population in Poland include damage to forests caused by these animals, traffic collisions, encroachment into urbanised areas, and spread of parasitic invasions. A growing problem observed from year to year is the increasing amount of damage in forest ecosystems. Damage to coppices, older tree stands, and forest crops induced by forest mammals was estimated in 2014, in the Kampinos National Park. The total damage area covered 172.79 ha, whereas the devastation caused only by moose foraging covered an area of 65.92 ha (Tyburski and Przybylski 2016). During the estimation, critical damage was taken into account, i.e. damage to the main shoot, trampled seedlings, broken, pulled out, or dug out young trees, and trunks debarked along over 1/3 of the perimeter. Seedlings are mainly chewed by such cervids as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), moose (*Alces alces*), and fallow deer (*Dama dama*) (Szukiel and Borowski 2000). Some investigations have demonstrated that fencing crops with a mesh is the most effective method of protection against animals (Baran 2007). However, the multitude of preventive methods (biological, chemical, mechanical, and biological-mechanical approaches) does not prevent further degradation of ecosystems but rather contributes to concentration of animals in a small area. In the natural conditions of European forests, it is difficult to maintain cervid populations at a level that will prevent the significant impact of the foraging of these animals on restoration and preservation of forests (Szukiel 1991). The moose has long legs and a long lip adapted to reaching plants at a height of up to 2 m. In contrast to other game species, it cannot feed on low vegetation, as its short neck prevents reaching for this feed. Depending on the season, the moose eats 30–50 kg of vegetation per day in summer and approximately 12 kg in winter (Sokół 2009). At a high density of these animals, it is difficult to restore vegetation in Polish forests. Sustainable ecosystems and forest stands in reserves are not resistant to the activity of ungulates. Hence, forest degradation cannot be prevented with this type of forest management and this cervid density (Mayer 1975). Two-year investigations conducted in the Białowieża National Park demonstrated that herbivorous ungulates had a negative effect on forest restoration (Kweczlich and Miścicki 2004). There is no doubt that large herbivorous mammals can significantly modify the structure and species composition of tree stands (Côté et al. 2004). Forest restoration is considerably more effective after minimisation of the pressure of large herbivores (Putman et al. 1989). The relationship between the degree of damage to trees and cervid density has been highlighted as well. It has also been shown that the percentage of trees damaged by moose decreased at a simultaneous increase in pine density from 2,000 to 11,000 per 1 ha (Lyly and Saksa 1992).

Due to the excess density of moose in their natural habitat and the declining food base, the animals are forced to migrations in search for better living environments (Dzięciołowski and Pielowski 1993). The moose's migration range is large. Investigations conducted by Mauer (1998) demonstrate the longest migration at a distance of 392 km recorded in Canada. A similar result, i.e. 320 km, was reported by Sangren and Sweanor (1998) from Sweden. In turn, the longest distance reported by Gasaway et al. (1983) in Alaska was 280 km. The long migrations are associated with the increasing number of collisions with this species (Tajchman et al. 2017). As shown by the Kampinos National Park documentation, between 2013 and 2017 there were 24–33 of traffic incidents caused by the presence of cervids, which accounted for 35% of all falls of these animals within the protected area (unpublished data). In the Lubelskie Province, there were 2,122 accidents involving cervids in 2011–2013, including 78 collisions with moose (Tajchman et al. 2017). It should be emphasised that although the accidents accounted for merely 7% of all recorded collisions, road events involving moose are usually fatal to the human participants and the animals. This is related mainly to the great body size of the largest representative of cervids.

The intensification in the number of traffic events involving animals is closely related to the development of road infrastructure, which often crosses their migration corridors. The uncontrolled increase in the moose population size will be associated with an multiplied in the number of collisions involving the species. Methods that are employed to prevent this situation are not always effective. There has been a case of moose's intrusion on the road despite the safety mesh fencing with fatal consequences for the driver (Targosiński 2015). The capture method used for relocation of animals is often accompanied by stress that can result in animal falls. Therefore, pharmacological immobilisation is gaining popularity and will be applied increasingly (Krzysiak et al. 2014). Yet, this method generates high costs; hence the question whether maintenance of adequate density adapted to the area of animal occurrence would be a simpler way.

Another serious threat posed by moose overpopulation and migrations is the spread of parasitic invasions. Multiplication of *Alces alces* population can enhance the risk of transmission of this type of diseases onto other ruminant species (Filip et al. 2017). Moose can be carriers of common parasites of not only other wild animals but also grazing livestock. Parasitic infestations in moose are characterised by high incidence, which has not been detected in other wild ruminants. Parasitic diseases in moose are caused by e.g. coccidia (*Eimeria catubrina*), flukes (*Paramphistomum cervi*), *Moniezia* tapeworms, and nematodes (*Ashworthius sidemi*) (Filip et al. 2017).

SUMMARY

One of the main causes of the persistence of the high number of moose is the substantial growth in their population size. This is mainly promoted by the high percentage of cows that start reproduction every year. The large number of twin pregnancies in this species is an equally important factor. The disturbance in the sex ratio also contributes to the enhanced reproductive success. Conditions prevailing in moose' habitats promote increased reproduction rates as well. The moose, which prefers forest and swamp habitats, is provided with excellent conditions for reproduction, as these habitats are located in close vicinity of arable fields offering high-energy food and, additionally, shelter during foraging. The diversity of social groups confirms the plasticity of moose behaviour. These animals adapt well to changing environmental conditions. Furthermore, as a consequence of the ban on culling imposed in 2001, moose are not disturbed and may change their behaviour. Even the presence of wolves in their habitats is not sufficient to regulate the population size of the largest cervid. This was confirmed in investigations conducted by Gaspar et al. (2018) in the Gorczański National Park, which demonstrated that ungulates: red deer (*Cervus elaphus*), roe deer (*Capreolus*), and wild boar (*Sus scrofa*), accounted for 48% of the food base for wolves (*Canis lupus*), with the red deer representing 64%. Similarly, research carried out in the Bieszczady Mountains (Śmietana and Klimek 1993) indicated deer to be the main food of wolves. Nevertheless, the selection of prey by wolves is flexible, as it is influenced by many factors (Okarma 1995). Noteworthy, wolf's foraging success often does not exceed 20% (Mech and Peterson 2003). Additionally, multiyear field observations have demonstrated that the impact of wolves on the cervid population is in the range of merely 5–10% (Kamiński et al. 2011).

The increase in the moose population size is regarded as a positive phenomenon although some concern is raised as well. Undoubtedly, the largest representative of the cervid family contributes to the increased damage in forests and agricultural crops. There is disturbing information about changes in the moose behaviour as well as the fact that it outcompetes the deer in its natural habitat. The media report on collisions with moose more increasingly. Furthermore, the overpopulation contributes to the spread of parasitic infections, which are extremely dangerous and may lead to falls of a large number of animals (Burliński et al. 2011).

The management of the resources of wild animals should involve activities that will help to preserve a healthy moose population in Poland on the one hand and contribute to limitation of the adverse effects of the growth in the population size of these animals on the other hand. The proposals aimed at the preservation and management of moose populations include partial protection of the species for a period of several years or sustainable management in areas

with the highest population density (Ratkiewicz 2011). The latter proposal suggests continuation of the moose status as a game species and reinstitution of culling in north-eastern and eastern Poland. Importantly, the regulation of moose density by culling has to be preceded by a reliable assessment of the size and structure of the species population as well as the actual increase in the population size.

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Streszczenie: *Wzrost liczebności populacji łosia* (Alces alces *L. 1758*) *w Polsce: przyczyny i konsekwencje.* Celem pracy była charakterystyka czynników warunkujących liczebność populacji łosia (*Alces alces*) w Polsce z uwzględnieniem metod jej oceny oraz preferencji siedliskowych i wybranych cech behawioru zwierząt, jak również wskazanie problemów towarzyszących zwiększeniu populacji tego gatunku. W pracy przedstawiono zagrożenia wynikające z przegęszczenia populacji łosia dla środowiska, w którym bytuje, ale również dla opisanego gatunku. Znaczenie może mieć również proces habituacji, którego konsekwencją są zmiany w behawiorze zwierząt wolno żyjących. Istotne jest wprowadzenie działań, które z jednej strony będą w stanie utrzymać zdrową populację łosia, a z drugiej umożliwią zmniejszenie niekorzystnych konsekwencji wzrostu liczebności tego gatunku. Istnieje potrzeba wypracowania wiarygodnej metody inwentaryzacji tego gatunku, a następnie wznowienia regulowania zagęszczenia łosia drogą odstrzału łowieckiego.

Słowa kluczowe: *Alces alces*, liczebność, behawior, szkody, kolizje

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Authors' address:
Katarzyna Dziki-Michalska
Zakład Hodowli Zwierząt Dzikich
Katedra Etologii i Dobrostanu Zwierząt
Uniwersytet Przyrodniczy w Lublinie
ul. Akademicka 13, 20-950 Lublin
Poland
e-mail: katarzyna.michalska@up.lublin.pl