REVIEW PAPER

Dynamics and Sustainable Use of Moose (*Alces alces* L.) Population

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Abstract

The moose (*id*. European Elk) (*Alces alces* Linnaeus, 1758) is an inherent component of the forest ecosystem in Lithuania. It is an important game species harvested within its range. Without human intervention, wildlife including moose can increase in numbers up to marked overpopulation followed by disease, starvation and damage caused to forestry. Although nature has its own ways of controlling wildlife populations, these ways could be much less humane that modern hunting. Population management decisions include appropriate harvest levels, timing of hunting seasons, habitat carrying capacity and habitat management practices. We have queried publications and internet-based resources to determine the moose population dynamics and changes predicted for different habitats and conditions. The existing population management models and methodology were analysed.

Keywords: moose population, dynamics, habitats, management, modelling, sustainable use

Introduction

The moose (*idem* European or Eurasian Elk) (*Alces alces* Linnaeus 1758) is an inherent component of the forest ecosystem in Lithuania. Its geographic distribution expanded in the late Pleistocene. Some animals have dispersed from eastern Asia into North America via Bering land 14,000-11,000 years ago (Hundertmark et al. 2002). European subspecies *Alces alces* ssp. *alces* distributed throughout Scandinavia, the Baltic States, European Russia (up to the Yenissei River), Belarus, Poland and northern Ukraine. Three isolated subpopulations are found in the southern Czech Republic, and the species is occasionally recorded in Germany, Croatia, Hungary and Romania (IUNC 2016). Populations in Europe express fluctuations over a multi-year cycle (Bauer and Nygrén 1999). By 2015 statistics, population estimates for European countries is as the following: Czech Republic - maximum of 50 animals, Lithuania - 12,853, Estonia - 12,000, Latvia - 21,000 individuals, Finland - at least 120,000 individuals (60-80,000 harvested annually), Poland - 2,800 individuals and Sweden - 350,000 individuals.

Moose is an important game species harvested within its range in Europe as well as in the USA and Canada. Its commercial use as the source of the high-quality meat provides an economically viable alternative to more ecologically destructive land uses, and could help accomplish the overall goals of biodiversity conservation (Freese 2012). Throughout long time, humans have considered wildlife for consumptive, spiritual, economic, recreational and ecological reasons. Since primeval times of the subsistence hunting, it was treated as purposeful human activity. Today, moose trophy hunting has increasingly replaced traditional meat hunting in the most range. Recreational value and meat of moose are inherent components of recreational hunting that prevails in comparison with subsistence hunting that comprises only near 3% in Canada, the USA and Europe (Gill 1990). Recently, hunter in considered as a qualified proficient and manager. Without human intervention and in the absence of sufficient number of large predators, evidently, the abundance of moose can exceed the carrying capacity of their ecological niches followed by diseases, starvation, an increase in the damage caused to forestry and, moreover, they may cause serious moose-vehicle collisions (Putman 1997, Christie and Nanson 2003, Gordon et al. 2004, Langley and Mathison 2008, Apollonio et al. 2010). Although nature has its own ways of controlling moose populations, these ways could be much less humane that modern hunting. Population management decisions include appropriate harvest levels, timing of hunting seasons, habitat carrying capacity and habitat management practices. Hunters are the ultimate benefactors of these decisions. Namely hunters can help to maintain more stable and healthy wild-

life populations. Hunter activity is highly regulated and directly related to the status of moose and its habitat. The population parameters, which are at the centre of attention, are population number and dynamics, changes in sex ratio, age structure and the share of juveniles in the local population, its spatial distribution, and external biotic influences. It is necessary to know moose spatial distribution including its range, local daily movements and seasonal migration. Moose habitat is characterized by food, water, plant cover and space for thermoregulation, shelter, breeding and calf rearing.

What are species composition, habitat structure and succession stages, the amount and distribution of key species (patchiness and interspersion), and the juxtaposition of habitat types most preferred by moose? What are management strategy and tactics most acceptable to sustainable use of moose population? Unravelling these questions are the base for planning new research, modelling and sustainable use of moose population.

The recent unusual climatic anomalies induce corresponding changes and adaptations in management and are the marked challenge for moose population that caused its inadequate responses. However, until now, the population is used unreasonably; an insufficient attention is paid to moose territorial and qualitative management. Due extensive control of moose population, it increases in number and caused essential damage to forest. In the context of recent environmental changes, the previous and existing models of population management and use are odds with present situation and encourage finding ways to reduce moose damage caused to forest ecosystem and to restore and maintain the dynamic balance between moose and forest vegetation. The integrated territorial, qualitative and quantitative management of the local populations is needed. At once, it is necessary to consider species vulnerability to climate warming. Every country has its distinctive situation that should be considered because this study would help to understand the local population dynamics and find ways to manage population sustainably.

Dynamics and sustainable use of moose (Alces alces L.) population: review of the research methodology

The assessment of moose populations is the basic fundamental in applied ecology and game management. Changes in the animal population size considerably reflect changes in the environment state. To get data on the dynamics of the moose populations, it is important to assess their abundance and fluctuations over time. However, the wildlife resources would be used unreasonably as the animal census is often perfunctory. The better understanding of population dynamics requires assessing the density-dependent and density-independent factors. The population assessment is based on a) quantitative, b) qualitative and c) territorial assessment. These data are essential to determine sustainable use of moose population. For this purpose, a number of different direct and indirect methods are used. In this study, we report on the relative census of moose using indices of animal abundance (e.g. track count, pellet group count and observation). These indices can be compared over time or between areas. Absolute abundance involves actually counting animals and estimating the number or density of animals in the population. With repeated sampling over time, both relative indices and absolute estimates can be used to monitor population trends. The vital potential of animals and their possibility implementing it, displays through changes in the density of the local population. There is the index of animal living conditions. As example, we present the method of pellet group count implemented at the Institute of Forestry LAMMC. Over decade, we have performed the animal census within the monitoring network in the different natural regions. The total length of the belt transects is 147 km and the total study area is 55,654 ha. The comparative analysis of the different census methods shows their evident diūerences. Although data of the census by the hunting bag could be used for population assessment; however, this information does not show changes in populations, all the more as of the rare and sparse species and which use is forbidden or limited.

Additionally, results of such census depend on the hunting intensity and performance as the hunting effciency is not standardized. It is diūerent in the most hunting grounds, therefore, populations are incomparable by hunting bag per day. The real state of animals is also unclear. It is necessary to consider that the count of animals by secondary marks is more precise than the direct observation of animals. This is more subjective and depends on the observer, whereas the real density of the local population less relates to animal tracks. Moreover, there is an interval between the time when an animal left its track and the time when we have registered this track. All methods discussed below supplements one to another and should be combined on the study area seeking to assess also other species of wild animals, moreover, the number of predators as well as the animal distribution character. The circuit method (i.e. track counting) provides an information on the animal distribution including predators and rare non-hunted species. In this case, belt transects are extended in parallel by all forest compartment lines crossing the diūerent forest habitats. Snow tracking depends on the snow cover that becomes rather rare or short event in the last decades, moreover, this method does express neither sex ratio nor the share of young animals in the local population.

The main approved census method is the method of pellet group counting in belt transects or belt sample plots.

This is the effective and economical method that has been determined and used since third decade of the last century (Padaiga 1965, 1975, 1990, 1996, 1998, 2004, Padaiga, Marma 1979, Belova 1997, 2008, 2010, 2013, Navasaitis, Pėtelis 1998, McLaren et al. 2004; et al.). L.J. Bennett and co-authors (Bennett et al. 1940, McCain 1948) were the first who have described this method in the scientific press. In Lithuania, it is called as the McCain method. Authors have implemented this method for the white-tailed deer, wapiti and moose. Subsequently, the method has been headlined and validated in the international press (Eberhardt and Van Etten 1956, Robinette et al. 1958, Neū 1968, Bowden et al. 1969, McConnell and Smith 1970, Meehan 1973, Stormer et al. 1977, Fisher 1979, Rowland et al. 1984, White and Eberhardt 1980, Connolly 1981, Wigley and Johnson 1981, Härkönen. and Heikkilä 1999, Hill 1999, McLaren et al. 2004, Brock 2005; et al.). In Lithuania, Prof. V. Padaiga together with colleagues has adapted this method for the local deer species. They have examined the numbers of pellets produced by animals during the winter period and the duration of winter foraging. Therefore, the census technology of Lithuanian moose has been created, and coeūcients and accuracy parameters have been determined. As example, we present here the long-term dynamics of moose and other deer species (red deer *Cervus elaphus* L. and roe deer *Capreolus capreolus* L.) populations at the model territory of the Institute of Forestry LAMMC on the ground of the census data obtained by pellet-group count (Figure 1).
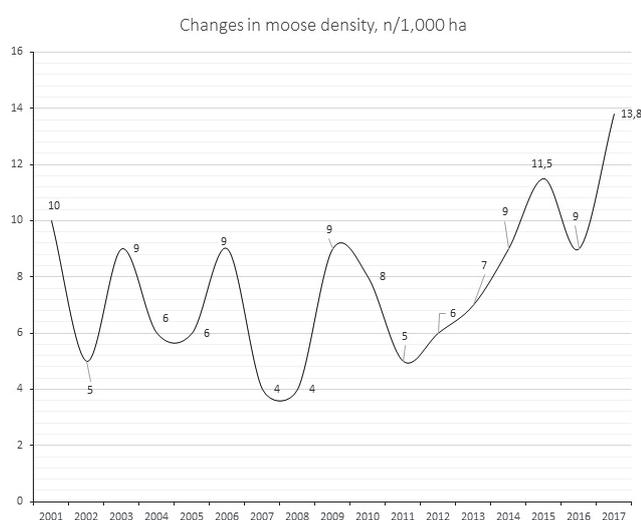
Figure 1. Long-term change in moose density, n/1,000 ha in the mixed coniferous forests of Northwestern Lithuania

This method was implemented in the different countries including Scandinavia, Germany, the Czech Republic, Poland and others. However, many still look at this method with distrust or read it by them, while for the successful use, it is necessary to perform the certain

actions that are the core of the method, and cause its precision and reliability. In this paper, we will not repeat well-known textbook knowledge after the aforesaid cited references, although these knowledge is necessary for the practical use including the time of counting (i.e. namely before the vegetation; non-vegetative period is the time that gives a lot of challenges and obstacles for animals, especially as in the last times because of the changeability of unusual weather that strongly acts conditions of animal foraging and distribution). Animals produce the di?erent number of faeces depending on the duration of non-vegetative period, respectively. The duration of the non-vegetative period reached 130-150 days (November - March). The number of faeces produced per day is typical for the certain animal species. This number is determined by the balance methods measuring the amounts of food and nutrients consumed by animals and number of excreted faeces. At the Institute of Forestry LAMMC, the comprehensive physiological and biochemical investigations were performed determining changes in the nutrient assimilation and number of faeces during the non-vegetative period complementing with the data from ūeld works (Belova 2010). The number of produced faeces directly related to the unit weight, i.e. the weight increases while the number of faeces decreases increasing the content of total ūbre. These changes are typical for the non-vegetative period because of the low moisture content in animal foods as there are no green herbaceous plants in animal feeding. The study conditions (nature, enclosure and all that), species in the animal diet, animal age and sex should be considered too (Belova 1997, 2010, 2013). In the different geographical locations, the same animal species produce the different number of pellet groups. In Western Europe, for instance, moose produces 14-21 and roe deer 14-20 groups per day, red deer 19-25 (Mitchell and McCowan 1984, Mitchell et al 1985, Dobią□ et al. 1996, Truve 2007, Theuerkauf et al. 2008). Don J. Neff (1968) has defined comprehensively defecation rates and their fluctuations in the black-tailed deer *Odocoileus h. hemionus*) (13-33/day) and white-tailed deer (*Odocoileus virginianus,*) (8-23 pellet groups per day), and has compiled the digest of defecation parameters of the different North America deer species and other ruminants. In Lithuania, moose produced 2,800 or av. 22/day (while red deer 2,085 or av. 16/day and roe deer 2,028 pellet groups or on the average 15.6/day with variation from 8 to 19) pellet groups over the non-vegetative period (Padaiga 1965, 1975, 1998, Padaiga and Marma 1979). Therefore, the number of wintered animals in the certain territory can be assessed learning of the duration of non-vegetative period, the number of pellet groups produced per day by the certain animal species, the length and area of the belt transects and the total surveyed area.

Unlike roe deer and red deer those in winter feed in the fields adjacent to forests depending on the food availability, moose is typical forest species. The error can arise because of this fact and especially in the locations with scarce small-sized stands interposed between fields, and as the non-vegetative period is changeable and unusually warm. For instance, the non-vegetative period of 2007/2008 continues 59 days, in 2013/2014 - 46 days, 2016/2017 – 66 days while one of 2008/2009 reached 151 days and 2012/2013 even 152 days. During the field works, the belt transect is divided into the 100-m units. The length is measured by foot considering that 120 steps comprise 100 metres or using GPS. The surveyed area should be not less than 0.3% of all territory (i.e. the length of belt transect should be 1 km and width 3 m) and the perfect area 1.2% (i.e. the length and width of belt transect is 4 km and 3 m per 100 ha, respectively). The number of moose that spend their winter in the certain sample location, is calculated by the widely known formula: $M = (S \times N_m / s_t)/2,800$ (Padaiga 1996, Belova 2005, 2010, 2013), where M is the number of animals that spend winter in the certain location; S is the total forest area of the sample location, hectares; N_m is the total number of counted pellet groups, s_t is the total area of the line transect, hectares. The density of moose is calculated as the number of animals, which have spent winter in the certain location, per 1,000 ha. Using this method, it is necessary to consider the ratio between areas of the census transect belt and the total territory. On the ground of the comparative analysis, the accuracies of the different census methods have been motivated and reasoned. The error of the circuit method is ± 20-25%, while one of the pellet group count method reached ±10%. Moreover, mentioned method allows us to assess the age and sex structure of the local populations, to determine the main winter habitats of moose. The identification of animal age and sex is based on the prevailed shape and size of pellets in the pellet group.

Although the method does not show the time that animal spends in the certain habitat but it indicates habitat preference. However, the method is nothing less than panacea in the animal census. It is recommended to combine several census methods. The method should be combined with the sample plot method, radiotelemetry, as well as it is implemented in the animal monitoring. For practical use, we recommend to combine the circuit method (at the end of hunting season and given the snow cover) and the method of pellet group count supplementing this data with data of widely used observations as well as the thermal imaging cameras. Thermal imaging cameras are widely used worldwide for hunting and research. These devices are applied to determine the size of wildlife populations, to localize animals and their habitats, to analyse the influence of environmental factors on animal

behaviour and for other purposes (Garner et al. 1995, Lavers et al. 2005, Cilulko et al. 2013). However, determining population number, the ratio of the number of identified individuals to the actual population of the examined species in a given area remains unknown, as the extent of measurement error cannot be reliably estimated in surveys (Garner et al. 1995). Thermal cameras allow seeing through complete darkness detecting body heat around what the camera lens sees. Cameras are also equally effective in bright sunlight. Many animal species can easily remain hidden during the daytime, so this technology proves extremely effective when out in the field. These devices are very helpful under different weather conditions as are able to be used to see through the area in thick fog or in rain, snow, in extreme sunlight and other weather conditions because they aren't affected by visible light. Unfortunately, animal behaviour as their response to changing environmental factors cannot be predicted, and researchers cannot control the outcome of thermographic measurements. The distance, at which animal can be clearly discerned, is also limited. It can be measured accurately only from a distance of several meters. In this case, the measurement error caused by limited atmospheric permeability and infrared radiation from the observed object are minimal (Minkina 2004). Thick vegetation and other objects between the observed animal and thermal imaging cameras also are the obstacle of measurement results.

More available and widespread devices are triggered trail cameras that are used for moose and other wildlife research to study their activity and behaviour (Foster and Humphrey 1995, Main and Richardson 2002) or to estimate population size (Jacobson et al. 1997, Sweitzer et al. 2000, Roberts et al. 2006) and for other wildlife studies. It is an advantage of camera traps to work independently of observers and storage data within battery lifespan. Triggered trail cameras (often is entitled as "camera traps") are more efūcient. Cameras incorporate the digital technology, resulting in the prolonged battery life and photo storage capabilities. Trail cameras automatically take images of animals passing in front of the camera. The weatherproof protective shell allows mounting the device to a tree stem or other posts. There are many models of camera traps. The most cameras are digital, having storage media as compact ūash or secure digital card, visible or invisible ūash, power supply, and a trigger mechanism. Digital camera traps record the photographs and video digitally onto a memory card. Camera traps can be passive (heat in motion sensor) or active (infrared beam established across a potential animal path). In the passive system, the camera is equipped with a heat in motion sensor. It triggers the camera, when e.g. moose with a temperature different to the ambient temperature moves through the sensor field of detection.

Passive systems may not trigger if the animal's body temperature and ambient temperature are similar. Direct sunlight, sunwarmed vegetation, and sometimes even high ambient temperatures may cause false triggers with this system. In an active system, an infrared beam is actively established across the potential travel path of the animal e.g. moose. When this infrared beam is broken, the camera is triggered. This system provides flexibility in setup when the height of the beam can be adjusted for the certain species (Dreibelbis et al. 2009, Damm 2010, Ancrenaz et al. 2012, Meek et al. 2014). However, it is triggered by anything breaking the infrared beam, including vegetation, rain or large insects. Since the trigger comprises separate units as emitter and receiver, the device is heavier and more complicated to transport, and also requires two supports, one extra to fix the trigger units. Sampling effort is expressed as the number of trap days accumulated by a camera-trap. To determine moose spatial distribution, camera-traps are installed at the several spatial levels from landscape to local habitat. The information of the certain habitats should be used, including habitat characteristics, distances to settlements, roads, forest infrastructure elements etc., to determine effect of these factors on the target species distribution. Surely, use of camera traps also meet with problems, e.g. large amounts of data lead to problems with storage, backup, sharing and image processing (Harris et al. 2010, Hamel et al. 2013, Newey et al. 2015). Some occupancy models are used, which account imperfect detection, e.g. false absence. McKenzie et al. (2006) has discussed these models that reduce count data of photographs to a binary (1/0) format describing the detection or non-detection of the target species at sampling sites during repeated visits (Ancrenaz et al. 2012). These models help to detect species, which are likely to vary, depending on the species and/or sample site. The most refined measure for wildlife monitoring is abundance or density (i.e. animal number per unit area). There is a problem of imperfect detection as during the count of individuals, it is difficult to distinguish one from another. Simultaneously, photo records provide information on how many times that species was recorded in the certain site. However, unless it is possible to assign records to distinct individuals, such information cannot be used to actually determine abundance.

Aerial surveys help to provide data for estimation of population size, density, composition, habitat use and for sustainable management (Nielson et al. 2006, Lenarz 2009, Wibke et al. 2010, Oehlers et al. 2012, Kantar and Cumberland 2013, Andreozzi et al. 2016). Aerial survey is considered as one of the most accurate and useful to study moose population (Anderson and Lindzey 1996). Snow conditions have a major influence on visibility of moose during the aerial surveys: satisfactory snow conditions must exist throughout the survey area and throughout the survey period. Other important requirement is a low cover of vegetation. Sighting conditions could be good, fair, and poor based upon degree of overcast, precipitation, and lighting conditions. The visibility also depends on the type of aircraft and experience of observers (Oehlers et al. 2012). As example, helicopters can cause deviations from animal behaviour, which can complicate detection and observation probability. Surely, properly applied statistical methods can correct inherent biases in aerial surveys (Lubow and Ransom 2016). Moreover, aerial survey or capture-recapture methods require additional labour and financial expenditures. The observation method (visual) (the accuracy varies from 30 to ~150- 200%) is an important as it allows us to determine the locations of animal gathering, shelters and other in the diūerent seasons. If possible, the modern remote methods are used (e.g. radiotelemetry, passive animal control etc.).

Radiotelemetry is widely used to obtain data on moose distribution and habitat use. In Fennoscandia, the first results of moose telemetry studies were published in the 1980s (Sandegren et al. 1985, Cederlund et al. 1987, Cederlund and Okarma 1988, Sweanor and Sandegren 1988, Nikula 2017). In this case, information from a transmitter is gone on the air to a receiver. Conventional transmitters consist of an antenna, a power source and a transmitter unit. The two most common are whip antennas and loop antennas. Whip antennas produce more uniform signal over a greater distance than do loop ones; however, it should be masked between layers of a collar for protection against breakage by animals, then the loop ones are more suitable, although the signal spreads more slowly than from the whip ones. The main power sources are lithium and silver batteries and solar cells. Duration of battery life is directly proportional to pulse period and inversely proportional to pulse width and signal strength (Lessard 1989, Anon. 1998). Despite solar batteries are long-lived and powered by sunlight, these are unsuitable for species under vegetation cover or for nocturnal ones. For wide-ranging species as moose, long-range, short-life tags are most preferable. The range and life of a transmitter is dependent on the size of the battery, which in its turn depends on the size of study animal and the method of transmitter attachment (Anon 1998). The two-stage transmitters are most suitable (Kenward 1987) for moose. Recently, the specialized transmitters are most used, including ARGOS Platform Terminal Transmitters that differ from the VHF transmitters in that they emit a much more complex and larger transmission which is repeated at longer intervals and received by an ARGOS satellite (Burger 1989). Transmitters are programmed to collect and compile data and then transmit it at specified times when the satellite orbit takes it overhead, but they do not transmit the location of animals as this is done by

the satellite. Next widespread and preferable specialized transmitter is GPS (Global Positioning System). It receives and triangulates signals from at least 3 of 26 possible satellites, then transmits the position of animal to the user. The accuracy of GPS location systems may vary with the density of the forest canopy (Rempel et al. 1995, Ericsson et al. 2015). Receivers take in the signal picked up by the antenna, to which they are connected by a coaxial cable, amplify it, and make it audible to the user. Receiver antennas are hand-held or mounted on a vehicle roof, or other means of locomotion. The most commonly used hand-held antennas are the Yagi and the 'H' antennas. A Yagis has 2 to 5 elements, and each additional director element increases the distance from which the antenna can pick up a signal. The advantages of radio-tracking are its relatively low cost, reasonable accuracy for most purposes and long life. GPS tracking is based on a radio receiver in an animal's collar. The receiver picks up signals from a special set of satellites and uses an attached computer to calculate and store the animal's locations periodically on a given time. GPS tracking is highly accurate and suited to studies where intensive and frequent data are needed. GPS tracking may not require frequent field visits (Mech 2002, Hebblewhite and Haydon 2010). GPS tracking collars rely on battery power to function. The battery powers the GPS unit itself along with related electronic components which store data. As rule, a battery in a typical GPS collar could last about a year. However, animals must be recaptured for replacement of battery for longer research. Despite GPS technology reduces human resources costs in comparison with VHF when locations are manually obtained, GPS collar costs are substantially greater than average costs for VHF collars. GPS collar costs increase depending on collar features, battery size, longevity, data access via satellite communication and additional contract to transfer data. If the terrain is unfavourable to GPS signals, the unit takes longer to establish a location, leading to shorter battery life. Longer-lasting batteries would necessarily weigh more, adding cost and weight to the unit. It affects sample size required for research in comparison with VHF unit number (Mech 2002, Lindberg and Walker 2007, Hebblewhite and Haydon 2010). M. Hebblewhite and D.T. Haydon (2010) underlined that the trade-off between cost and sample size of GPS telemetry studies lead to inappropriate use of this technology by drawing ecologists into accepting lower sample sizes than would be possible using VHF units. Moreover, other disadvantage of this technology is collar failure. Here is also a problem in the inadequacy of the information on animal movements, their behaviour and their environment. However, GPS telemetry allows obtaining precise spatial and temporal location data on moose movements in short time intervals to a degree larger than in case of VHF telemetry or camera trapping. Reduction of the human resources required collecting VHF-based location data on species and, simultaneously, human-induced collection bias should be considered.

Separate use of the radiotelemetry does not reŭect the habitat preference. As it was emphasized above, to collect more appropriate spatial and temporal scale information on the distribution, dynamics and behaviour of moose, the combination of GPS advances, cameras, remote sensing (e.g. MODIS) and usual belt transect methods is needed.

Dynamics and sustainable use of moose (Alces alces L.) population: modelling and management issues

The population dynamics of moose expresses the population sizes and the factors that could cause its maintenance, decline, or increase through time and space including ecological and human-related processes e.g. hunting. Models are an important tool to predict future distribution and abundance of moose populations, and to assess limiting density-dependent and density-independent factors that may affect habitat use, distribution and abundance of animals. These models are concerned with changes not only in the moose population size, but also in its age and sex structure, Models help to reduce bias in parameters of density relationships that appeared due to errors in census counts (Gross 1969, Walters and Gross 1972, Sylvén et al. 1979, Rolley and Keith 1980, Ryman et al. Luoma et.al. 2001, Weisberg et al. 2002, Dennis et al. 2006, Abadi et al. 2012, Zipkin et al. 2014, Doak et al. 2016). Moose population models, including conceptual ones, diagrams, or mathematical equations, usually, contain ecological parameters of age, gender, mortality rates, reproductive rates, and number of animals. Moreover, models reflect relationship between these parameters and forestry (e.g. browsing of pine plantations and debarking of the main forest species caused by moose) and moose harvest management. Recent advances in digital technology make possible spatial modelling of the moose location pattern related to the extent and habitat parameters, using the tools of statistical modelling and geographical information systems (GIS) as it was mentioned above.

Despite moose inhabits a wide range of coniferous and deciduous forest habitats, from the northern forest biomes as tundra and taiga, southwards through boreal to temperate zones, it prefers dam habitats close to water bodies and adapted to cold environments (Karns 2007) while is intolerant to high temperatures. The current period is distinguished by an unavoidable and unprecedented climate change (COM/2013/0216 final). Climate change becomes one of the most pervasive threats to the Earth today. Annual average temperature has increased by 0.4 - 0.8 °C over the last century (IPCC 2001), and Europe has

warmed by 0.8 °C (Beniston and Tol 1998). Through the times, climate changes have occurred at a comparatively slow rate, therefore, forest ecosystems and their components have been able to adapt with corresponding changes in ecosystems themselves. The primary limiting factor for moose is climatic factor as high temperatures (Kelsall and Telfer 1974, Renecker and Hudson 1986) and thermal variability (Belova 2012). The upper critical temperatures of moose are –5 °C in winter and 14-20 °C in summer (Renecker and Hudson 1986, Schwab and Pitt 1991, Lowe 2009, Lowe et al. 2010, Belova 2012, Broders et al. 2012, Rempel 2012, McCann et al. 2013). However, moose can adapt to climate changes using their physiological and behavioural mechanisms to reduce thermal stress (Belova 2012, 2013). During the vegetation period, from May to October, moose prefer forest edges, wet deciduous stands, marshes and bogs and even stay in the small groves and shrubs. In winter animals select habitats with higher food supply (e.g. forests with pine and aspen plantations, clear-cuts and wetlands) (Prūsaitė, J. 1988, Miller and Litvaitis 1992, Heikkilä and Härkönen 1996, Belova 2013). Moose daily movements within their habitats comprise up to 5 km, annual short-distance as seasonal migration from summer to winter habitats is about 20-30 km and up to 50 km e.g. in Lithuania (Baleišis et al. 2003, Belova 2013), up to 179 km in North America, 100 km in Norway (Andersen et al. 2010) and 300 km in northeastern Europe (Hundertmark 1997, LeResche 1974, Pulliainen 1974). In Minnesota and North Dakota, the long-distance migrations of 1,511 and 367 km were observed (Hoffman et al. 2006). When heat-stressed, animals search for habitats that provide cooling and shade (Schwab and Pitt 1991, Belova 2012). Although before decades a usual movement to the winter habitats has ended until mid-November in Lithuania, changes in winter duration caused later coming to winter habitats (from mid-November to mid-December) (Belova 2013, 2015). Home range size of males is larger than females. The individual territory of males (bulls) reaches 5,500 ha and one of female group is 500-1,000 ha (Baleisis et al. 2003). They do not defence such territories excluding moose cows with calves that do not tolerate neighbours close to their territory. Home range size of female moose without calves is larger than females with calves (Cederlund and Sand 1994, van Beest et al. 2011, Balogh 2012). The size of female home ranges is 500-740 ha (Cederlund et al. 1987; Cederlund and Okarma 1988; Cederlund and Sand 1994), while one of males is 750-1,800 ha (Cederlund and Sand 1994; Olsson et al. 2011). Seasonal home range size is largest during winter for both reproductive categories (Balogh 2012). During the mating, female and bull keep the territory ca. 100-200 ha. In North America, home range size of moose varies between 360 and 9,200 ha (Hundertmark 1997). Therefore, winter moose habitats have increased substantially not only due to changes in food supply but also in re-

sponse to warming (Tape et al. 2016). It indicates a significance of the thermal suitability for moose population models including HSI models (habitat suitability index). C.G. Haase and H.B. Underwood (2013) have incorporated an index of thermal suitability into a moose models for assessing their habitats. Authors have included the operative temperature (T_e) as the thermal index that integrates the combined effects of ambient temperature, total absorbed radiation, and wind velocity on the thermal environment. Moose habitat suitability is a function of food supply and thermal cover (*Ardea Biological Consulting* 2004) (i.e. vegetative condition with greater than 70% canopy closure and 12.19 metres in height that ameliorate weather affects habitat requirements, according to *Glossary of Energy Terms* 2016). The parameter of the thermal cover is a certain habitat variable that allows assessing a current suitability of moose habitat and as good tool to predict future suitability under climate-warming scenario (Allen et al. 1987, Koitzsch 2002, Haase and Underwood 2013). Demarchi and Bunnell (1993, 1995) provided a range of crown closure classes required for moose based on summer ambient temperatures. They suggest that moose will select forests with crown closures greater than 66% when temperatures are greater than 25 °C. In Lithuania, during the changeable and atypical periods, the moose gathered in the old-growth forests. The climate warming determines less influence of moose on the main tree species in the forest plantations in the littoral pine forests owing to the sensibility of moose to the thermal factor. Only during the colder time animals occur in the older >10-year-old pine plantations. Animal distribution in the mixed spruce forest varied from one in the littoral forests. Although animals mostly occurred in the 61-70-year-old stands in the periods 2001-2005, further they far more preferred 8-10-year-old plantations (mostly females) and older >10-year-old young stands (mostly males) (Belova 2012). The warming effect of the sea in the littoral zone is stronger (up to 3 °C) than in the more continental eastern and southern parts of Lithuania. In the continental pure pine forests, animals have distributed unevenly grouping mainly in the sites of the optimal foraging as plantations of the earliest succession series. Being previously observed mainly in the old-growth stands, the moose had shifted to the forest plantations. Females and juveniles occur mainly in the pine plantations of the 1st succession stage while males gathered in the middle-aged stands (foraging in the patches under natural regeneration, stand stocking 0.5-0.6). Moose gathering causes stronger impact on the woody vegetation. The positive relation is revealed between changes in the weather temperatures and damaged area ($r = 0.57$). The moose damage rate increases rapidly when the population density exceeded 3 individuals /1,000 ha. Moose impact on woody forest vegetation shows an increasing trend under conditions of recent and further climate changes

(Belova, 2008, 2013). By feeding, moose belongs to the "browsers" (Edenius 1991, Belova 2013) (concentrate selectors, after Hofmann 1989, i.e. animals that select diets containing at least 75% tree and shrub stems, shoots and foliage, dicot foliage and fruits). Moose demonstrate to be keystone species, as the elimination of species, leading to a lack of consumption of some phytomass, results in unsustainability of ecosystems due to interrupted compensatory growth. It shows necessity of sustainable management of their populations territorially, quantitatively (reducing or increasing their number) and qualitatively (seeking for the optimal sex and age structure of populations). Research and conservation attention needs to be focused not only on global warming and each of other stressors by themselves but also on the synergism of several pressures (Belova 2010) that together are likely to prove to be the greatest challenge to animal and plant conservation. Climate warming and anomalies are stressors for many species while moose and roe deer show much sensitivity that evidently reflect through their foraging and an increase in damage caused to forest. It is necessary to include habitat characteristics (e.g. forest category, stand composition, age, forest site type, crown closure, canopy value based on forest type and crown closure) and food consumption parameters into the models.

Moose represent a primary resource for recreational hunting. A negligible reduction of moose due to natural predators (near 5%, Lithuania, and until 50% depending on the food supply and availability of the certain prey species), poaching and limited use (e.g. hunting licenses and season duration), has a stimulatory effect on population increment, and moose population increase within species range despite climate changes. The population growth positively affected by food supply, suitable changes in forest management implementing opportune reforestation and mosaic effects in forest habitats, sufficient amount of shelter habitats and protection of wetlands. Management of moose population on the ground of Malawi principles (CBD, Lilongwe, Malawi, 26-28 January 1998, Downes 1999, Maltby 2000) emphasized need of implementation at the lowest appropriate level. It is less suitable for moose due their seasonal movements. Therefore, one forest owners/holders count damage caused by moose and while other ones can manage wintering population as in the last decade, the seasonal migration is late because of longer vegetative warmer period (Belova, 2006, 2008, 2013, 2015). Appropriate changes in hunting season terms and distribution of licenses for moose between hunting units allow hunters to manage local population on the ground of its density (permissible and ecological), qualitative structure (optimizing and maintaining sex ratio and the share of juveniles in the local population) and damage caused to forestry. Proper management requires consideration of the moose ecol-

ogy. Moose population could be managed towards its increase (a); decrease (b); harvesting it sustainably (c) and leaving it to itself but supervise it (d). Population dynamic theory shows that calves less affect future growth of population than cows calving for the first time (Stearns 1992). An increase in the share of young animals in the harvest will increase the proportion of adults and productive animals in the winter population (Padaiga 1996). Namely age-selective harvest strategy results in a significantly faster overall population growth rate, helps to optimise hunting opportunities, meat or trophy animals. Hunting effects could be pronounced in license harvesting and if the population size and structure are regulated by hunting. Such strategy is used in Lithuania, e.g. the higher share of young animals in the harvest and the rate of population increase by changing the relation between adult males (bulls) and adult females (cows) in the harvest. Optimisation of trophy males implies their age-selective harvesting. The increase in calf harvest (meat production) and protection of adult (reproductive) females results in the increase of age in the local population. In such cases, the decrease in calf carcass weight shows that food supply is insufficient or there is an effect of density-dependent factors. It helps to manage population. To assess hunting sustainability, in recent decades the demographic models are developed. Population trends or its rate of changes are estimated from its abundance over time using indices as e.g. the density as animal number per unit area comparing demographic parameters of the different territories (Weinbaum et al. 2013).

There are numerous population and habitat characteristics and the potential interactions between above-mentioned climate change impacts as increases or decreases in temperature, precipitation, and timing of weather events, phenology, extreme weather events, and spatial extent of these impacts. The complexity of potential impacts of climate change on populations and habitat demand additional monitoring, surveys, and research. To detect climate change impacts, ongoing monitoring and surveys must be conducted to ascertain the effect of those impacts.

New models are needed to predict impacts of future climate changes on the environment (Dale et al. 2000) and moose population. These models should build upon monitoring data collected regarding the relationship between climate and disturbances. It should include methods to observe effects of both climate and disturbances on moose. Experiments that explore these relationships must be conducted, and resulting data should be built into models (Dale et al. 2000). Monitoring is the most useful and needed today. The scale of monitoring is primary. Monitoring data should be gathered on the identified distributions and habitat characteristics (Lucier et al. 2006). There is a need to implement adaptive manage-

ment by conducting long-term monitoring of responses of moose habitats to climatic change along altitudinal and latitudinal gradients (Arvai et al. 2006, Shugart et al. 2003). These evaluations should be enhanced by using computer models that include not only the changes in a habitat type at a point in time but also changes in space (Shugart et al. 2003). This process would also benefit by mapping areas to account for habitat movement in response to climate change by developing better process-based models of environmental factors controlling species ranges (Lucier et al. 2006).

There is a need to recognize that global change will be a factor in future wildlife conservation (Inkley et al. 2004) and to be prepared to adapt to diverse conditions by employing rigorous and effective monitoring and adaptive management principles**.**

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