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Using Corine Land Cover to predict habitats occupied by moose *Alces alces*

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Abstract: *Using Corine Land Cover to predict habitats occupied by moose Alces alces.* The aim of the study is to assess the possibility of predicting the habitats occupied by moose on the basis of Corine Land Cover. The second aim was to assess whether the impact of the structure of land cover on the population density of moose can change over time with an increase in population numbers. The data for analysis was the number of moose in 293 hunting districts assessed each year in spring in Podlaskie Voivodship. The data covered ten years from 2010 to 2019. The boundaries of each hunting district were compared to the Corine Land Cover layer, and the share of each type of coverage was calculated. The impact of cover types on moose numbers was analyzed in generalized linear models. The moose population showed a distinct increase of population numbers over the last 10 years in the Podlaskie Voivodship. In all the analyzed years, four cover types explained the distribution of moose. The numbers of moose decreased along with the increasing share of arable lands, but was positively related to the presence of inland marshes and share of deciduous forest. In 2010 and 2011, additionally two cover types explained the distribution of moose in the models, similarly in 2019. Obtained results show that the current range of moose in the Podlasie Voivodeship allows the reliable prediction of its numbers on the basis of Corine Land Cover. Impact of some cover types has changed with time.

Key words: *Alces alces*, density, cover types, Corine Land Cover, hunting districts

INTRODUCTION

The size of the moose population is highly variable over last 200 years due to the fact that this species is exploited, but then it recovers. By the mid-nineteenth century, this species was extinct throughout Central and Western Europe; in Poland, it remained only in the forests near Rajgrod (Raczyński and Ratkiewicz, 2011). According to Dzięciołowski and Pielowski (1993), the size of the moose population increased several times during the interwar period, but then there was a drastic decline during World War II (Raczyński 2006). In 1952, this species was under protection, which brought an increase in population numbers (Świsłocka 2014); since 1967, it has been included again in the list of game species. Another decline in the population size resulted in the introduction of a moratorium on the hunting of moose in 2001. Since then, a significant increase in the population size of this species has been recorded, especially in the northeastern part of Poland (including the Biebrza Valley) (Raczyński 2006, Ratkiewicz 2011, Wawrzyniak 2016), which is home to

70% of the Polish population (Świsłocka 2014). At present, the western border of the moose range runs through Poland (Ważna et al. 2014).

The increase in the moose population is associated with its impact on the environment and the human economy. In the area of the Regional Directorate of State Forests in Białystok, moose was responsible for about 30% of significant damage to forests in 2011, and 36% in 2015. In young forest stands, moose browse trees and cause around 60% of all significant damage to them (Ratkiewicz 2011, Wawrzyniak 2016). Animals of this species chew pine shoots on plantations, which affects the trees' growth and shape. In older stands, moose strip bark off trees. Despite the use of various forest-protection measures (including chemical and mechanical protection of trees), the amount of damage is constantly increasing. Moreover, according to Wawrzyniak (2016) the natural forest protection measures used so far are no longer effective. In 2015, in four Regional Directorates of State Forests (Białystok, Olsztyn, Lublin, Warsaw), the value of the damage caused by this species amounted to EUR 3.4 million (Wawrzyniak 2016).

The effect of the increasing number of moose is that they move to new habitats that are not always optimal for this species; nevertheless, the distribution of moose on a regional scale varies, even in the main moose refuge in the Podlaskie Voivodship (Wawrzyniak 2016). Understanding the colonizing mechanisms and factors that limit the presence of moose is necessary for the proper management of this species and to determine optimal population size. The aim of the study is to assess the possibility of predicting the habitats occupied of moose on the basis of Corine Land Cover (https://land.copernicus.eu). The second aim was to assess whether the impact of the structure of land cover on the population density of moose can change over time with an increase in population numbers.

MATERIAL AND METHODS

The data for analysis was provided by the Polish Hunting Association Research Station in Czempiń. The number of animals in each hunting district was assessed each year in spring by counting the moose population in hunting districts in Podlaskie Voivodship on the area of. The analyzed area covered 20,187 km^2 (http://www.gios.gov.pl). The data covered four years: 2010–2011 and 2018–2019. Moose numbers in each hunting district were combined with the boundaries of the districts in shapefile format. In total, we analyzed data from 293 hunting districts (Fig. 1).

The boundaries of each hunting district were compared to the Corine Land Cover layer, and the percentage share of each type of coverage was calculated. For the further analysis, we used cover types that occurred in at least 10% of the districts. Cover types that occurred in less than 30% of the districts were transformed to a grouping (categorical) variable (with the presence or absence of this cover type) to avoid zero-inflated variables. Two cover types were transformed into categorical variables: "Industrial or commercial units" and "Inland marshes". In total, we analyzed 12 cover types: 1) broad-leaved

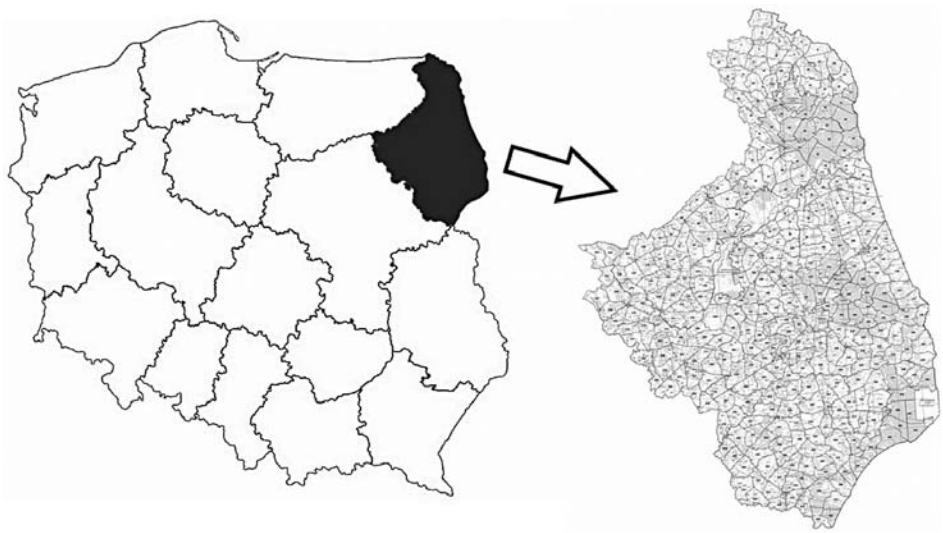

FIG. 1. Study area with marked hunting districts
Source: https://fotoomnia.pl and http://www.gminalomza.pl

forest, 2) complex cultivation patterns, 3) coniferous forest, 4) discontinuous urban fabric, 5) industrial or commercial units, 6) inland marshes, 7) land principally occupied by agriculture, with significant areas of natural vegetation, 8) mixed forest, 9) non-irrigated arable land, 10) pastures; 11) transitional woodland-shrubs; 12) water bodies.

The impact of cover types on moose numbers was analyzed in generalized linear models because the dependent variable (moose numbers in each hunting district) was not normally distributed. Using Akaike criterion information (AIC), we compared various distributions to find the best-fitting model. Finally, we used tweedy distribution with the log link function. To select set of variables in each model we compared various model types and a null model to achieve the best-fit model using AIC in a backward elimination procedure. In this procedure, we started by including all 12 variables in the model and evaluated the change of the AIC value after removing the variables. The model with the lowest AIC value was selected. We also used a pairwise comparison with Bonferroni adjustment of groups in factors that were statistically significant in the model.

RESULTS AND DISCUSSION

The moose population showed a distinct increase of population numbers over the last 10 years (2010–2019) in the Podlaskie Voivodship. The population was estimated to be 2,277 individuals in 2010. Since then the population has more than doubled and there were 5,047 individuals in 2019 (Fig. 2). At the same time, the proportion of hunting districts occupied by moose increased from 76% to around 95% (Fig. 3).

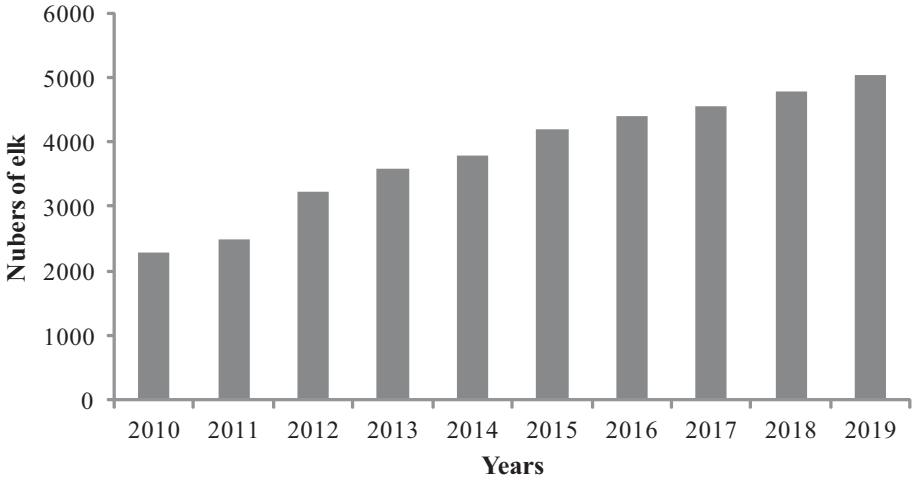

FIG. 2. Moose population numbers in 2010–2019 in Podlaskie Voivodeship (analyzed hunting districts)
Source: Polish Hunting Association Research Station in Czempiń.

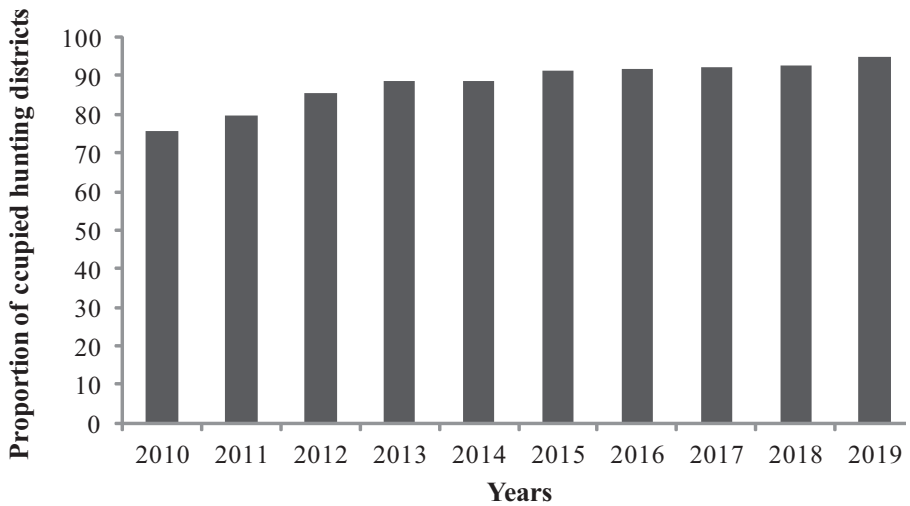

FIG. 3. Proportion of hunting districts occupied by moose in 2010–2019 in Podlaskie Voivodeship (analyzed hunting districts)

Source: Polish Hunting Association Research Station in Czempiń.

In all the analyzed years, four cover types explained the distribution of moose (Table 1). Moose numbers were positively related to the presence of inland marshes (negative B-value to the lack of Inland marshes; F_Inland marshes = 0). The numbers of this species also decreased along with the increasing share of arable lands expressed by two cover types: "land principally occupied by agriculture, with significant areas of natural veg-

TABLE 1. Effects of generalized linear models of moose numbers and land cover (from Corinne Land Cover) in years, 2010–11 and 2018-2019; *B*-values of each cover type are shown in the table. Each row presents model effects for one year; * = statistically significant.

Source	2010	2011	2018	2019
[F_Industrial or commercial units = 0]				0.334*
[F_Inland marshes = 0]	–0.445*	–0.487*	–0.410*	–0.433*
Broad-leaved forest	5.464*	4.411*	2.830*	2.521*
Land principally occupied by agriculture, with significant areas of natural vegetation	–3.131*	–3.649*	–2.111*	–1.476
Non-irrigated arable land	–2.605*	–2.547*	–1.797*	–1.803*
Pastures	1.217*	1.104*	0.730	
Transitional woodland-shrubs	–7.203*			
Complex cultivation patterns				–3.879*
Water bodies				
model statistics				
$\chi 2$	149.46	158.47	133.14	136.60
df	6	6	5	6
p	<0.001*	<0.001*	<0.001*	<0.001*

etation" and "non-irrigated arable land" (negative B-values in all cases). Moose numbers were positively related to the share of broad-leaved forest (positive B values in all cases). B coefficient of other forest types were not statistically significant and variables were excluded during the backward elimination procedure. In 2010 and 2011, two cover types were significant in the models: moose numbers were positively related to the share of "pastures" (B = 1.217 for 2010 and B = 1.104 for 2011) and negatively to "transitional woodland shrubs"(B = –7.203 for 2010 and B = –5.239 for 2011); however, B coefficient of these cover types were not significant in the following years. In 2019, which was the last year of analysis, moose numbers were negatively related to the presence of "industrial or commercial units" (positive B value to the lack of Industrial or commercial units; F_ Industrial or commercial units = 0) and "complex cultivation patterns" (B = –3.879).

The obtained results show that Corine Land Cover can predict habitats occupied by moose in specific hunting districts. The presence of moose was positively related to the presence of inland marshes and the proportion of deciduous forests in all the studied years. Moose mainly prefers swamps, vast forests, peat bogs and willow-birch thickets (Gębczyńska and Raczyński 1984, Heikkilä et al. 1996, Raczyński 2006, Sokół 2009, Ratkiewicz 2011). Its diet consists of deciduous trees such as birch, which are browsed all year round, but also willow and aspen (Morow 1976, Hjeljord et al. 1990, Heikkilä et al. 1996). Poole and Stuart-Smith, 2005). These tree species are characteristic of swampy deciduous forests and explain the positive relation between the occurrence of moose and the higher proportion of deciduous for-

ests. In the Biebrza National Park (the main moose refuge), as much as 30% of the area is covered by alder stands, and 29% mixed boggy forest (https://www.biebrza.org.pl/47,lasy).

In winter, after the first frost and snowfall, moose usually move to pine forests, mainly the younger age classes (Gębczyńska and Raczyński 1984, Gębczyńska and Raczyński 1997). However, coniferous forests did not represent a significant variable in any of the models, even though pine needles and shoots are one of the main components of the moose diet in winter (Morow 1976, Heikkilä and Härkönen 1993, Sokół 2009, Ratkiewicz 2011). In our opinion, this was an effect of the common presence of this cover type. Coniferous forest is dominant in the study area and does not limit the numbers of moose.

The moose makes long migrations, often to areas that were not previously inhabited by this species, thus resulting in the gradual extension of its range (Raczyński 2006). This may be the reason for the decrease in the negative relation between moose numbers and arable land (for non irrigated arable land: B= –2.605, B= –2.547 for 2010 and 2011 respectively, and B = –1.797, B = –1.803). Moose use arable land because it offers easy access to high-energy food (Flis 2018, Dziki-Michalska et al. 2019). In our results, however, moose avoided arable lands with and without a significant share of natural vegetation. Over the studied years, a negative relation was demonstrated between moose numbers and the proportion of two types of cover that represent arable lands: "land principally occupied by agriculture, with significant areas of natural vegetation" and "non-irrigated arable land". In the last year of the study, the "complex cultivation patterns" cover type also limited the occurrence of moose. However, forest is the main habitat for moose, and arable lands offer only supplementary food. A hunting district with a significant share of this type of coverage will therefore have less habitat capacity for this species. However, the lower B-values in 2018 and 2019 indicate overpopulation of moos in this region and occupation of suboptimal habitats.

In 2010–2011, moose numbers were positively impacted by the presence of pastures and negatively by "transitional woodland shrubs". Moose was not as widespread during the given years and reached the highest density in the Biebrza valley (Ratkiewicz 2011, Świsłocka 2014). Domestic livestock pastures are concentrated mainly around Biebrza National Park, even in the hunting districts. Hence, the greater importance of this cover type was the result of a clear predominance of moose in this region. Successional plant communities, represented here by "transitional woodland shrubs", are the food base for moose, particularly in the early stages of growth (Morow 1976, Gębczyńska and Raczyński 1984, Raczyński 2006). However, unlike pastures, the "transitional woodland shrubs" cover type was dispersed in other regions, and its share in the vicinity of the main moose refuge was insignificant. In 2019, industrial or commercial units had a negative impact on the number of moose. The results, therefore, indicate that the moose spread extends to suburban areas where this type of coverage usually occurs. This also indicates that moose tend to occupy

suboptimal habitats as result of the overpopulation.

CONCLUSIONS

It can be concluded that the current range of moose in the Podlasie Voivodeship allows the reliable prediction habitats occupied by moose on the basis of Corine Land Cover. As shown, analysis of moose occurrence in 2010–2011 could lead to erroneous assessments of the importance of individual habitats due to the concentration of the population around the main refuge. We have shown 1) a positive relation between numbers of moose and inland marshes or deciduous forests, and 2) a negative relation between numbers of moose and arable lands or industrial commercial units. However the significance of the last group indicate that moose tend to occupy suboptimal habitats as result of the overpopulation in Podlasie Voivodeship.

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Streszczenie: *Wykorzystanie Corine Land Cover* do przewidywania środowisk zasiedlanych przez łosia *Alces alces*. Celem pracy była ocena możliwości przewidywania środowisk zasiedlanych przez łosia na podstawie Corine Land Cover. Drugim celem była ocena, czy wpływ struktury pokrycia terenu na zagęszczenie populacji łosia może zmieniać się w czasie wraz ze wzrostem liczebności tego gatunku. Materiał do analizy stanowiły dane o wiosennej liczebności łosi w obwodach łowieckich województwa podlaskiego. Dane obejmowały 10 lat od 2010 do 2019 roku. Granice każdego obwodu łowieckiego porównano z warstwą Corine Land Cover i obliczono procentowy udział każdego rodzaju pokrycia terenu. Wpływ rodzajów pokrycia terenu na liczebność łosi przeanalizowano w uogólnionych modelach liniowych. Populacja łosi wykazała wyraźny wzrost liczebności w ciągu ostatnich 10 lat w województwie podlaskim. We wszystkich analizowanych latach cztery typy pokrycia terenu objaśniały rozmieszczenie łosia. Liczebność łosi malała wraz z udziałem pól uprawnych, ale była pozytywnie powiązana z obecnością bagien i mokradeł śródlądowych oraz udziałem lasów liściastych. W latach 2010-2011 dwa inne typy pokrycia objaśniały występowanie łosia, podobnie w roku 2019. Uzyskane wyniki pokazują, że obecne występowanie łosi w województwie podlaskim pozwala na wiarygodne prognozowanie jego liczby na podstawie Corine Land Cover. Wpływ niektórych typów pokrycia uległ zmianie w czasie.

Słowa kluczowe: *Alces alces*, zagęszczenie, typ pokrycia, Corine Land Cover, obwody łowieckie

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