HUNTING AS A METHOD OF MANAGEMENT OF WOLF (*CANIS LUPUS*) POPULATION

[1]KATARZYNA WIELGÓRSKA, [2]JOANNA GRUSZCZYŃSKA, [3]BEATA GRZEGRZÓŁKA, [4]ANNA KARLAK

[1,2,3]Department of Animal Genetics and Conservation, Institute of Animal Sciences
[3,4]Scientific Association of Experimental and Laboratory Animals
Warsaw University of Life Sciences - SGGW
E-mail: [1]katarzyna_wielgorska@sggw.edu.pl, [2]joanna_gruszczynska@sggw.edu.pl, [3]beata_grzegrzolka@sggw.edu.pl, [4]ankarlak@gmail.com

Abstract -
Growing population of wolves, that are strictly protected species in Poland, causes discussion about necessity of hunting those predators. The main reason to change their status to game species is to reduce their number and reduce losses in livestock and wild ungulates caused by them. Postulants of wolf hunting indicate that only legal hunt will provide a stable level of wolf population, increase the acceptance of their presence by hunters and farmers and decrease poaching. However, according to scientific studies, wolf hunt may cause a lot of threats to the population of those predators. Our goal was to estimate if hunting is actually a good method of wolf population management.

Keywords - Wolf Hunting, Population Management, Poaching

I. INTRODUCTION

Wolf (*Canis lupus*) is a species that evokes extreme emotions. The increase of the population after taking it under protection in Poland in 1998, causes discussion about the need to reduce number of wolves by consider them as a game species and provide opportunity of legal hunt, as it is possible in other countries (like Ukraine or Slovakia). In Poland wolf, after decades of persecution, is strictly protected species since 1998 [1]. It is also protected by Directive 92/43/EEC (Habitat Directive) [2] since Poland joined the European Union in 2004. In Poland, directive protects the wolf on annexes: II (needing habitat conservation) and IV (taking in the wild and exploitation is subject to management restrictions) [3]. In Polish legislation, it is possible to shoot a wolf only with the consent of the General Director for Environmental Protection and only in relation to individuals posing a significant threat to humans or causing significant damage to the inventory [1]. Consent for shooting an individual is issued when there are no alternatives, it is not detrimental to the conservation of wolf population in good condition, and in the case of wolves attacking inventory - inventory protection measures and methods have proved ineffective.

Before 1998 wolves mainly appeared in the northeast and southeast of the country and were absent west of the Vistula [4]. Since they became strictly protected species in 1998, the population has been recovering, and by 2012 had recolonised most of the large forests in western Poland [5]. Currently, country population number is estimated around 2000 individuals [6] and that is the number that some people consider too much for Poland.

Supporters of hunt often suggest that shooting is necessary to effective population management, especially in case of excessive increase of population. Additional factor that indicates necessity of treating wolf as game species, is aversion of some social groups and reduction of poaching in favour of legal hunting. Another argument to consider wolf as a game species is that it would also affect the involvement of hunters in monitoring this species.

However, in case of wolf, there are many factors that indicates, that a regular hunt can cause serious threat to all population. In this paper we present results of analysis of available scientific literature and reports from different countries and evaluation of hunting as a method of wolf population management.

II. MATERIAL AND METHODS

In this paper we review different approaches of wolf population management that are used around the world and compare them to scientific literature. We analysed advantages and disadvantages of hunting as a method of population management, based on scientific literature available on Scopus, Research Gate and Google Scholar.

III. RESULTS

An analysis of the scientific literature shows that legal wolf hunting not only does not significantly reduce the phenomenon of poaching or a smaller number of damages caused by wolves but can negatively affect the population of the species. The following are the results of a review of the literature on wolf hunting and the impact of this method of population control on aspects indicated by postulators of restoring the species to the list of game species.

POACHING. The key aspect to consider when analysing human impact on the wolf population is the

fact that wolf mortality as a result of human activities is additive [7,8], which means, that hunt does not reduce natural mortality of wolves, but in an important way is added to it. Metanalysis of data from North America [8] showed, that in places where hunting wolves is legal, mortality of a species is the sum of individuals killed by human (by hunting, poaching or roadkill) and individuals dead by natural causes (injuries, hunger and diseases). In that case both, legal hunt and poaching, cannot be treated as compensatory mortality.

In the case of wolves, poaching, which in many places is the biggest problem of species protection [9], is a process independent of the legality of hunting - research indicates that legalization of hunting does not eliminate this phenomenon, although some cases show that possibly can decreases it. In Spain, north of the Duero River, where wolf shooting is legal, poaching accounts for up to 50% of reported cases of dead wolves. In the rest of Spain, where the species is protected, almost 100% of detected cases of dead individuals are the result of poaching [10]. It should be emphasized, however, that there is no research indicating clearly that legalization of hunting reduces the number of cases of poaching on wolves [11].

INVENTORY DAMAGE. The postulate of registration wolves as a game species most often appears in the context of the killing farm animals (mainly sheep and cattle) by these predators.

In 2018, the number of reported damages caused by wolves in the whole country was 865 and the value of compensations paid by the State Treasury was 1155000 PLN, which constituted only 5% of the damage caused by all protected species [12]. For comparison, the value of compensations for damage caused by game species (wild boar, red deer, roe deer) in season 2018/2019 was 6164110 PLN [13]. Damages caused by game species costs over 50 times more than those made by wolves.

Some studies suggest that grey wolves select wild prey when it is available, even when livestock is present at higher density and prey on livestock especially when there are no fencing or other protection of livestock [14]. However, leaving animals unattended could significantly increase livestock depredation. What is important is that preventing measures are crucial in areas occupied by wolves and may decrease damage caused by wolves [15, 16], without eliminating them.

What is worth noting, is that in countries where wolf hunting is legal, the number of damages in livestock does not always decrease but may also increase [17] and decreasing is observed when the predator population exceeds 25% [18]. However, mortality rates on this level are unsustainable over the long period of time.

In addition, when an individual from a breeding pair is shot, it can result in a decrease in the effectiveness of getting food. Few membered groups and young individuals, deprived of the support of more experienced wolves, are usually unable to hunt for larger prey (red deer, moose) and more often hunt for easier and smaller victims such as roe deer [19] or farm animals [18]. Farm animals are simply easier prey, and therefore weakened. Young groups can thus obtain the food necessary for survival, which results in an increase in damage to the inventory.

It is also interesting that even intensively conducted hunting will not cause that wolves will be eliminated from a given area where they cause numerous damages. Research shows that areas inhabited by wolves that are subjected to hunting pressure, even after eliminating all individuals, will mostly be settled by wolves from neighbouring areas [20, 21].

HYBRIDIZATION. Another problem, that previous studies of the wolf population indicate, is the crossbreeding with dogs. Hybridization, along with poaching, is one of the most serious problems in conservation biology [22] and a real threat to the wolf population. Hybridization usually occurs when a female wolf crossbreed with a male dog [23], usually due to the absence of a male wolf during the mating season [24, 25]. The absence of a male wolf may be the result of the female appearing in a new, uninhabited area or the partner's death in the pre-heat period (as a result of hunting, poaching or road collision). Hybrids of dog bitch with male wolf are very rare [23].

Although hunting is not a direct cause of hybridization, the intense hunting pressure (especially during mating season) in combination with numerous free-ranging domestic dogs in most of the European countries [26, 23, 27], increases the risk of hybridization [23]. Due to the most frequent crossbreeding between female wolf and male dog, pups are more often born in the wild and can breed with wolves, threatening genetic purity of this species [23]. Hybridization cases are still considered rare in most of the areas when wolves occur, yet they can be particularly problematic in isolated, fragmented and endangered populations [28].

UNGULATES AND FORESTRY. An often-raised argument about the need to regulate wolf populations through hunting is also the impact of predators on wild ungulates. Hunters and farmers postulate to include the wolf in the list of game species, due to the damage this predator causes in hunting and livestock [48].

An important issue in the discussion about the role of the wolf in the ecosystem is the fact that the main prey of wolves are red deer, roe deer, wild boar and beaver [29, 30, 31], which all are species that are causing damage to agriculture and forestry. Therefore, wolves are limiting populations of ungulates and by that positively influencing the issues related to compensations that must be paid for damages in agriculture and forestry. In addition, the

presence of wolves in forest complexes reduces the number of wandering dogs and cats [29, 30] that have a negative impact on local fauna [26].
Wolves, unlike humans, above all eliminate mainly individuals that are weaker [32], often sick and thereby contributing to the reduction of epizootic diseases [33]. Selection of prey by wolves affects the age-sex structure of the ungulate population and keeps the population in good condition. It should be emphasized, that despite a significant increase in the number of wolves in Poland in recent years, the number of ungulates did not decrease, but increased [13].
It is also important that the introduction of regular wolf hunting does not significantly reduce the number of ungulates killed by wolves. Studies have shown [34] that a pair of wolves kill the same number of victims as a family group of 6 individuals, with the difference that a pair lose a significant portion of prey to small predators and scavengers (foxes, mustelids, badgers) and birds (bald eagles, ravens) [35, 36, 37].

DIFFICULTIES IN SELECTIVE HUNTING. In discussions about the sense and effectiveness of wolf hunting, the argument about elimination of problematic individuals is often raised. However, it should be remembered, that wolves lack clearly marked sexual dimorphism [38], which practically makes it impossible to distinguish a male from a female in the field. In addition, juveniles can reach parental height as early as two years of age [39], and therefore selection by age is also very difficult.
Due to the specifics of the species' biology, shooting individuals with uncertainty about their gender and age may have a negative impact on the entire local population. Wolves are social animals, most frequently living in family groups [39,40]. The family group usually consists of a breeding pair and their offspring [1, 39]. Individuals that are not dispersing, stay with their parents and help looking after the pups in subsequent years [20]. Because there are several adult wolves in the family group, it is very difficult to recognize breeding pair from other adults during hunting. Therefore, in the case of wolves, unlike wild ungulates, it is almost impossible to shoot individuals of a particular age or sex group.

The above factors are very important during discussion about hunting as a method of wolf population management. Hunting without certainty about role of the individual in family group, can cause disorders of the social structure, which is based on close relationship between individuals (39) and often ensure cooperation and survival of whole pack. Shooting may result in the attachment of unrelated individuals, which can adversely affect group coherence and adaptation, while the goal should be maintaining kin relationships in socially structured populations, which is evolutionarily important and can have positive effects on fitness [40].
On the contrary, study conducted in Białowieża Primeval Forest [41] showed that the two well-sampled Belarussian packs adopted unrelated single wolves that might be long-distance dispersers, which may lead to a conclusion that packs reduced by hunting to few wolves or only a pair are probably more tolerant of adopting unrelated wolves in order to rear pups and survive.
The cohesion and sustainability of a family group is also greatly influenced by the shooting of a breeding pair or one of the parents. Studies on part of the American population have shown that the loss of one of the breeding individuals leads to the breakup of the family group in 38% of cases, and the loss of both individuals from the breeding pair results in the breakup of up to 85% of the family groups [20]. In addition, 56% of the groups had successful reproduction in the following year after a loss of one parent and only 9% after the loss of both individuals from the breeding pair. The loss of parental pair has great impact for the survival of young ones [7].
Nonbreeding adults have also important role in the family group, helping to raise pups [39] and by that leading to the pack survive, therefore their loss can also be dangerous.
Pups surviving index is up to 92% in family groups where auxiliaries were present, while groups without adult helpers, this indicator decrease to 64% [20].

SIZE AND POPULATION STRUCTURE. In areas where wolf hunting is legal and regular, the family groups of these predators are usually smaller - most often they are pairs or groups of 3 individuals [8]. The size of the group is correlated with the size of the territory - a small group is unable to maintain an extensive territory, resulting in a greater number of family groups and thus a greater number of litters [8, 42, 43].
In places where the hunting is very intense, the number of pups in the litter increases and the number of females in the litter is higher (over 7 puppies per litter compared to 5 puppies per litter in places of less intense hunting and higher predator density [43]. The proportion of females in the litter in high-density populations is 50%, while in low-density populations this parameter increases to 70%.
A side effect of intense hunting pressure is also the risk of inbreeding. In a situation where one of the breeding individuals is killed during the breeding season, the other individual from the parent pair may mate with a closely related individual, which adversely affects the genetic structure of the population and may lead to genetic defects [22, 41, 44]. Therefore, some scientists postulate that wolf hunt shouldn't be allowed during mating season and rearing young ones [38].
The intensive wolves hunting, due to its additive nature in general species mortality, also adversely affects the range of occurrence of the species. When source populations are subjected to intense hunting

pressure, the process of dispersion of young adults into new, uninhabited areas may be slowed down or even stopped [45]. As a result, the range of the species occurrence is limited, despite existing favorable areas not inhabited by wolves. In Poland, this was the case when the wolf was a game species and only occurred in the Carpathian Mountains and the eastern part of the country [5, 46]. A few years after the species was protected in 1998, wolves from the eastern part of the country [45] began to recolonize areas west of the Vistula River [5], which abounds in habitats suitable for this species [46].

What should be emphasized, is that the edges of the species range, even recreational hunting may have similar effect to the wolf population as intentional eradication. Therefore, every case of legal hunt cannot be implemented without further analysis of population viability and connectivity with other subpopulations [45].

IV. CONCLUSION

Wolves are animals that have evolved under a kin-based social framework. Studies suggest, that somehow there is an influence of kin-based group structure on fitness [47]. Social organization of wolf packs is crucial for effective resource use (i.e. knowledge of prey distribution and ability to kill prey) [19] or survival of pups [20]). Other crucial factor, that can influence the group is breeder loss, which can result dissolution of family group, abandonment of territory and smaller pack size [20, 47]. Minimizing the anthropogenic impact on social structure in populations such as wolves, that form highly related groups could lead to improve overall fitness of the population, by allowing natural selection [47].

Hunting, although seems as a good idea when it is necessary to deal with individuals that cause damage, is actually hard to conduct without damage to the population. Lack of clearly marked sexual dimorphism makes selective killing, focused on eliminating a specific individual practically impossible. Moreover, it is hard to shoot individuals of a certain age or sex category, which leads to killing individuals without explicit selection.

Another problem, that seems to be ignored in discussion of hunts, is migration. Areas, where wolves are hunted, eventually will be settled by other wolves from nearby habitats (e.g. young wolves during dispersion). Therefore, maybe better idea would be to conduct a proper monitoring of population and increase funding to livestock breeders to protect their animals.

Wolf hunting is very complex and emotional topic. However, to properly approach it, we should take under consideration other methods of population management. It should be cleared, that hunting sometimes is the only way, but in the case of wolf maybe it should be the last way to deal with the problematic individuals or too numerous populations. Wolves are one of the species, that are conflicted with humans, but we cannot underestimate their important role as a part of the ecosystem. The focus in case of this predator should be how to conciliate interests of various social groups (foresters, hunters, breeders) and predator, that is very important in sustainable ecosystem.

REFERENCES

[1] Mysłajek R.W., Nowak S. 2014. Handbook of best practices for the protection of wolf, lynx and brown bear [Podręcznik najlepszych praktyk ochrony wilka, rysia i niedźwiedzia brunatnego]. Centrum Koordynacji Projektów Środowiskowych, Warszawa [in Polish].

[2] EC. 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora. Official Journal of the European Communities L 206/7. 1992:7–50.

[3] Linnell J, Salvatori V, Boitani L. Guidelines for population level management plans for large carnivores in Europe. A Large Carnivore Initiative for Europe report prepared for the European Commission (contract 070501/2005/424162/MAR/B2)2008. http://ec.europa.eu/environment/nature/conservation/species/carnivores/pdf/guidelines_for_population_level_management.pdf.

[4] Okarma H. Status and management of the wolf in Poland. Biological Conservation. 1993; 66(3): 153–8.

[5] Nowak S, Mysłajek RW. Wolf recovery and population dynamics in Western Poland, 2001–2012. Mammal Research. 2016; 61(2):83–98.

[6] Central Statistical Office. Environment. Warsaw: Central Statistical Office; 2018. https://stat.gov.pl/wyszukiwarka/szukaj.html?query=zwierzę#!/ochrona_srodowiska-2018.pdf.

[7] Borg B.L., Brainerd S.M., Meier T.J., Prugh L.R. 2014. Impacts of breeder loss on social structure, reproduction and population growth in a social canid. Journal of Animal Ecology 84: 177–187.

[8] Creel S., Rotella J.J. 2010. Meta-analysis of relationships between human offtake, total mortality and population dynamics of grey wolves (Canis lupus). PLoS ONE 5(9): e12918.

[9] Liberg, O., Chapron, G., Wabakken, P., Pedersen, H. C., Hobbs, N. T., & Sand, H. (2012). Shoot, shovel and shut up: cryptic poaching slows restoration of a large carnivore in Europe. Proceedings of the Royal Society B: Biological Sciences, 279: 910-915. doi:10.1098/rspb.2011.1275.

[10] Reinhardt, I.; Kluth, G.; Nowak, S.; Mysłajek, R.W. A Review of Wolf Management in Poland and Germany with Recommendations for Future Transboundary Collaboration; Bundesamt fur Naturschutz: Bonn, Germany, 2013.

[11] Browne-Nuñez C., Treves A., MacFarland D., Voyles Z., Turng C. 2015. Tolerance of wolves in Wisconsin: A mixed-methods examination of policy effects on attitudes and behavioural inclinations. Biological Conservation 189: 59–71.

[12] Romanowski J. 2019. Damages caused by wolves and ways to prevent them. Discussion forum „About wolf", Sękocin Stary. General Directorate for Environmental Protection [unpublished].

[13] Central Statistical Office. Statistical Yearbook of Forestry. Warsaw: Central Statistical Office; 2019. https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-lesnictwa-2019,13,2.html

[14] Janeiro-Otero A., Newsome T.M., Van Eeden L.M., Ripple W.J., Dormann C.F. 2020. Grey wolf (Canis lupus) predation on livestock in relations to prey. Biological Conservation 243: 108433.

[15] Echegaray, J., il , C., 2010. Non-invasive monitoring of wolves at the edge of their distribution and the cost of their conservation. Animal Conservation. 13: 157–161.
[16] Agarwala, M., Kumar, S., Treves, A., Naughton-Treves, L., 2010. Paying for wolves in Solapur, India and Wisconsin, USA: comparing compensation rules and practice to understand the goals and politics of wolf conservation. Biological. Conservation 143 (12): 2945–2955.
[17] Mannil P., Kont R. (red.). 2012. Action plan for conservation and management of large carnivores (wolf Canis lupus, lynx Lynx lynx, brown bear Ursus arctos) in Estonia 2012-2021. Estonian Game 12. Estonian Theriological Society, Tartu.
[18] Wielgus RB, Peebles KA (2014) Effects of Wolf Mortality on Livestock Depredations. PLoS ONE 9(12): e113505. doi:10.1371/journal.pone. 0113505.
[19] Sand H, Wikenros C, Wabakken P, Liberg O (2006) Effects of hunting on group size snow depth and age on the success of wolves hunting moose. Animal Behaviour 72: 781–789.
[20] Brainerd S.M., Andrén H., Bangs E.E., Bradley E.H., Fontainee J.A., Hall W., Iliopoulos Y., Jimenez M.D., Jozwiak E.A., Liberg O., Mack C.M., Meier T.J., Niemeyer C.C., Pedersen H.C., Sand H., Schultz R.N., Smith D.W., Wabakken P., Wydeven A.P. 2008. Effects of breeder loss on wolves. Journal of Wildlife Management 72: 89–98.
[21] Kutal M., áňa M., Suchomel J., Chapron G., López-Bao J.V. 2016. Trans-boundary edge effects in the Western Carpathians: the influence of hunting on large carnivore occupancy. PLoS ONE 11(12): e0168292.
[22] Liberg O., Aronson A., Sand H., Wabakken P., Maartmann E., Svensson L., Akesson M. 2012. Monitoring of wolves in Scandinavia. Hystrix 23: 29–34.
[23] Hindrikson M., Männil P., Ozolins J., Krzywinski A., Saarma U. 2012. Bucking the trend in wolf-dog hybridization: first evidence from Europe of hybridization between female dogs and male wolves. PLoS ONE 7(10): e46465.
[24] Iacolina M, Scandura M, Gazzola A, Cappai N, Capitani C. (2010) Y-chromosome microsatellite variation in Italian wolves: a contribution to thestudy of wolf-dog hybridization patterns. Mammal Biology 75: 341–347.
[25] Godinho R, Llaneza L, Blanco JC, Lopes S, Alvares F, et al. (2011) Genetic evidence for multiple events of hybridization between wolves and domestic dogsin the Iberian Peninsula. Molecular Ecology 20: 5154–5166.
[26] Krauze-Gryz D., Gryz J. 2014. Free-ranging domestic dogs (Canis familiaris) in Central Poland: density, penetration range and diet composition. Polish Journal of Ecology 62: 183–193.
[27] Wierzbowska, I.A., Hędrzak M., Popczyk B., Okarma H., Crooks K. R. 2016. Predation of wildlife by free-ranging domestic dogs in Polish hunting grounds and potential competition with the grey wolf. Biological Conservation. 201: 1–9.
[28] Torres R.T., Ferreira E., Rocha R.G., Fonseca C. (2017). Hybridization between wolf and domestic dog: First evidence from an endangered population in central Portugal. Mammalian Biology, 86, 70-74.
[29] Jędrzejewski W., Niedziałkowska M., Hayward M. W., Goszczyński J., Jędrzejewska B., Borowik T., Bartoń K.A., Nowak S., Harmuszkiewicz J., Juszczyk A., Kałamarz T., Kloch A., Koniuch J., Kotiuk K., Mysłajek R.W., Nędzyńska M., Olczyk A., Teleon M., Wojtulewicz M. 2012. Prey choice and diet of wolves related to ungulate communities and wolf subpopulations in Poland. Journal of Mammalogy 93: 1480–1492. DOI 10.1644/10-MAMM-A-132.1.
[30] Nowak S., Mysłajek R.W., Kłosińska A., Gabryś G. 2011. Diet and prey selection of wolves Canis lupus recolonising Western and Central Poland. Mammalian Biology 76: 709–715. DOI 10.1016/j.mambio.2011.06.007.
[31] Mysłajek R., Romański M., Nowak S., Tołkacz K. 2018. Composition of the wolf's Canis lupus L. diet in the Wigry National Park. Forest Research Papers. 79. 10.2478/frp-2018-0013.
[32] Sand H, Wikenros HC, Ahlqvist P, Strømseth TH, Wabakken P. Comparing body condition of moose (Alces alces) selected by wolves (Canis lupus) and human hunters: consequences for the extent of compensatory mortality. Canadian Journal of Zoology. 2012; 903: 403–412.
[33] Orłowska B., Augustynowicz-Kopeć E., Krajewska M., Zabost A., Welz M., Kaczor S., Anusz K. 2017. Mycobacterium caprae transmission to free-living grey wolves (Canis lupus) in the Bieszczady Mountains in Southern Poland. European Journal of Wildlife Reserach (2017) 63: 21. doi:10.1007/s10344-017-1079-4.
[34] Jędrzejewski W., Schmidt K., Theuerkauf J., Jędrzejewska B., Selva N., Zub K., Szymura L. 2002. Kill rates and predation by wolves on ungulate populations in Białowieża Primeval Forest (Poland). Ecology 83: 1341-1356.
[35] Wilmers C.C., Crabtree R.L., Smith D.W., Murphy K.M., Getz W.M. 2003. Trophic facilitation by introduced top predators: grey wolf subsidies to scavengers in Yellowstone National Park. Journal of Animal Ecology 72: 909–916.
[36] Vucetich J.A., Peterson R., Waite T.A. 2004. Raven scavenging favours group foraging in wolves. Animal Behaviour 67: 1117–1126.
[37] Kaczensky P., Hayes R.D., Promberger C. 2005. Effect of raven Corvus corax scavenging on the kill rates of wolf Canis lupus packs. Wildlife Biology 11: 101–108.
[38] Okarma H. 2015. Wolf. Kraków, H2O.
[39] Mech L.D., Boitani L. 2003. Wolves. Behavior, ecology, and conservation. University of Chicago Press, Chicago-London: 35–103.
[40] Rutledge L.Y., Patterson B.R., Mills K.J., Loveless K.M., Murray D.L., White B.N. 2010. Protection from harvesting restores the natural social structure of eastern wolf packs. Biological Conservation 143: 332–339.
[41] Jędrzejewski, W., Branicki, W., eit, C. 2005) Genetic diversity and relatedness within packs in an intensely hunted population of wolves Canis lupus. Acta Theriologica 50::3–22. https://doi.org/10.1007/BF03192614.
[42] Jędrzejewska B., Jędrzejewski W., Bunevich A.N., Miłkowski L., Okarma H. 1996. Population dynamics of wolves Canis lupus in Białowieża Primeval Forest (Poland and Belarus) in relation to hunting by humans, 1847-1993. Mammal Review 26: 103–126.
[43] Sidorovich V.E., Stolyarov V.P., Vorobei N.N., Ivanova N. ., Jędrzejewska B. 2007. Litter size, sex ratio, and age structure of gray wolves, Canis lupus, in relation to population fluctuations in northern Belarus. Canadian Journal of Zoology 85: 295–300.
[44] Räikkönen J., Vucetich J.A., Vucetich L.M., Peterson R.O., Nelson M.P. 2013. What the inbred Scandinavian wolf population tells us about the nature of conservation. PLoS ONE 8(6): e67218.
[45] Nowak, S. & Mysłajek, R. W. 2017. Response of the wolf (Canis lupus Linnaeus, 1758) population to various management regimes at the edge of its distribution range in Western Poland, 1951–2012. Applied Ecology and Enviornmental Research 15(3): 187–203, https://doi.org/10.15666/ aeer/1503_187203.
[46] Jędrzejewski W., Jędrzejewska B., Zawadzka B., Borowik T., Nowak S., Mysłajek R.W. 2008. Habitat suitability model for Polish wolves Canis lupus based on long-term national census. Animal Conservation 11: 377–390.
[47] Rutledge, L.Y., Patterson, B.R., Mills, K.J., Loveless, K., Murray, D.L., White, B.N. 2010. Protection from harvesting restores the natural social structure of eastern wolf packs. Biological Conservation 143 (2010) 332–339.
[48] Ministry of Environment, unpublished data (2016). Application KRIR/MR/W/1339/2016.

★★★