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Editorial

Ecology, Diversity, Conservation and Management of Ungulates

Friedrich Reimoser [1,2,*] and Ursula Nopp-Mayr [1]

[1] Department of Integrative Biology and Biodiversity Research, Institute of Wildlife Biology and Game Management, University of Natural Resources and Life Sciences, 1180 Vienna, Austria; ursula.nopp-mayr@boku.ac.at

[2] Research Institute of Wildlife Ecology, Department of Interdisciplinary Life Sciences, University of Veterinary Medicine, 1160 Vienna, Austria

* Correspondence: friedrich.reimoser@vetmeduni.ac.at

Wild ungulates are important drivers of the dynamics of many terrestrial ecosystems and impact biodiversity at different system levels. Studies on ungulate species and their ecological interactions with forestry, agriculture, and other land-use activities in different landscapes may particularly relate to the following topics: ungulates and their habitats—ecological dependencies, interactions in different ecosystems, e.g., [1–6]; effects of ungulates on forest composition and structure in different forest communities, e.g., [1,7–11]; wildlife ungulates as pests in forestry and agriculture, as well as in disease transmission, e.g., [3,10,12]; methods for studying the ecological effects of ungulates, e.g., [13–15]; ungulates and their predators—interactions and predator–ungulate–plant cascades, e.g., [16,17]; management of ungulates—sustainability, biodiversity, and human–wildlife conflict, e.g., [3,4,18–20]; the conservation of ungulates and habitats, and their genetic diversity, e.g., [2,13,18,21].

This Special Issue provides an overview of the current research results on ungulate species and the interactions between ungulates and their habitats. In total, ten papers were finally accepted for inclusion in this Special Issue: two reviews and eight original research articles. Six papers cover topics relevant to ungulate–plant relationships, with two papers on the relationships between ungulates and other animal species; one paper focuses on population structures for sustainable management (red deer), and another one considers genetic topics (wild boar).

Kárpáti and Náhlik reviewed the findings on the impact of the European mouflon (*Ovis gmelini musimon*) on vegetation as a dependence of the allochthonous nature of the species. They reviewed the forest damage attributed to mouflons, considering interspecies competition with other large herbivores such as red deer and chamois. Climate change has forced the mouflon to use its space differently when seeking shelter in southern habitats; consequently, the increased trampling and foraging pressures suggest new challenges in managing its impact. The study results showed that the long-term effects of this species on herbaceous plant communities, such as rock grasslands, are still unclear. The results set directions for future research on long-term experiments regarding density impact, coexistence with red deer or chamois, and warming-climate-driven behavioral change.

Pfeffer et al. investigated browsing damage on Scots pine (*Pinus sylvestris*) considering the direct and indirect effects of landscape characteristics, as well as moose and deer populations. Focusing on Sweden, they found that increasing amounts of pine forests, preferred deciduous trees, and young forests had positive and direct effects on moose densities and thereby indirectly contributed to increased browsing damage. The density of smaller deer species had no direct effect on browsing damage on pine. The authors highlighted that the choice of statistical method may alter the understanding of driving forces.

Tarvydas and Belova examined the effect of wild boar (*Sus scrofa*) on forests and agricultural lands, as well as population management in Lithuania. This study focused on the current condition of the wild boar population at the country level, the species' activity

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in forests and adjacent agricultural lands, the problem of damage caused to agriculture and forestry by wild boar, and methods for the management of the wild boar population.

Nopp-Mayr et al. explored impacts of ungulate herbivory on the diversity of woody plant species (trees and shrubs) based on a long-term study in a montane forest ecosystem in Austria. Incidence data for woody plant species in exclosure and control plots were aggregated. The diversity of top-height individuals and structural diversity, expressed using height classes, were two diversity aspects that differed between exclosures and control plots. Other diversity estimates of woody plant species showed huge variation without significant differences between plots. Height growth was significantly suppressed by ungulate herbivory. The effects of ungulate herbivores in forest ecosystems are highly complex and context-dependent and thus are not reducible to simple top-down forces. Long-term surveys provided data that reflect the "ultimate" effects of herbivory interacting with other drivers of community dynamics.

Angst and Kupferschmid assessed impacts of browsing in Swiss beech forests and the importance of tree responses after browsing. Browsing was particularly frequent in climate-adapted species. Winter browsing was more frequent than summer browsing, which significantly reduced height growth. Former damage along the main stem further reduced upgrowth. Browsing shifted the height increase ratio in favor of *Fagus sylvatica*. Many winter-browsed saplings of *Abies alba*, *Fagus sylvatica*, *Acer pseudoplatanus*, *Fraxinus excelsior*, and *Prunus avium* had no new leader shoot by the end of the next growing season, i.e., browsing had a long-lasting impact. For estimating browsing impact, delays in the response after browsing must be assessed.

Griesberger et al. investigated the spatial distribution of hunting and its potential effect on the browsing impact of roe deer (*Capreolus capreolus*) on forest vegetation. In addition to direct mortality, the nonlethal effects of hunting activities were found to further affect the spatial habitat selection of this species. Accordingly, the spatial distribution of hunting locations could influence the impact of game on forest vegetation. An avoidance of forests by hunters was found in regions with low forest cover and intolerable browsing impact. When hunters in certain regions, however, used forests according to their availability, the impact of game on forest vegetation was tolerable. Careful consideration of hunting locations might be an additional approach to reduce browsing intensity by roe deer, at least in regions with low forest cover.

Teffo et al. reviewed recent findings on the impact of ungulates on reptiles. Most studies were conducted in the Americas and Australia. The proportions of studies were balanced for wild ungulates and livestock. Wild boar (*Sus scrofa*) was found to be the most problematic species for reptiles, whereas the reptiles that suffered the harshest impacts were Squamates (i.e., lizards and snakes). Ungulate activities may directly harm reptiles (consuming or killing them) or indirectly affect them by modifying their habitats or destroying their hideouts. Some beneficial effects were also noted, e.g., of moderate livestock grazing or when wild ungulates were prey for large reptiles. Published livestock impacts were mainly indirect and mostly negatively linked to overgrazing. They concluded that the densities of ungulates must be managed and monitored to minimize their negative impacts on reptile species.

Miller et al. obtained new insights from a long-term study of the efficacy of killing large carnivores to enhance moose harvests. They analyzed harvest data from nearly four decades of brown bears (*Ursus arctos*), black bears (*U. americanus*), gray wolves (*Canis lupus*), and moose (*Alces alces*) in Alaska. They rejected their hypothesis that harvest of predators positively correlated with moose harvests. They recommended that predator reductions designed to improve hunter harvests of moose be conducted within a research framework that permits the improved interpretation of results and the implementation of an adaptive-management approach to achieve management objectives.

Martín-Fernández et al. presented a method for obtaining sustainable population structures for the management of red deer. This methodology allows managers to numerically justify how to control population growth to preserve biodiversity and sustainability.

Böheim et al. investigated the signals of pig ancestry in wild boar (*Sus scrofa*) from Austria, with respect to current hybridization or incomplete gene pool differentiation and historical introgressions. Pig ancestry in wild boar stems from incomplete gene pool differentiation during domestication and/or historical introgressions, when free-ranging pig farming was common. Individual introgression levels were lower in wild boar from periurban habitats, possibly reflecting the largely historical absence of local pig farms. Moreover, a marginal precipitation effect, but no temperature effect, on introgression was observed.

The contributions collected in this Special Issue revealed several research gaps.

Long-term studies: The long-term impacts of ungulates on plant communities and other animal species are often unclear. Therefore, to estimate the ultimate effect of ungulates, postimpact response delays must be assessed within the ecosystems. Sustainability considerations and comprehensive perspectives for an integrative management of ungulates and their habitats at the landscape scale are areas where the current literature is inadequate.

Forest–ungulate interactions: The effects of ungulates in forest ecosystems are highly complex and context-dependent and thus not reducible to simple top-down forces. The results provide directions for future research on long-term investigations relating to ungulate-density impact the coexistence of different ungulate species, and to warming-climate-driven behavioral change. Furthermore, studies are lacking in the area of evaluation research to investigate the benefits of ungulates in ecological, economic, and sociocultural aspects.

Methodology: Methods should be improved for objectively assessing the long-term effects of certain densities of different ungulate species on the development of vegetation composition, on other animal species, and on overall biodiversity. The choice of statistical method can change the understanding about the driving forces. Therefore, comparisons of different statistical methods are necessary using the same data material.

Experiments: Further experiments with the control and monitoring of certain ungulate densities are encouraged to better interpret both their negative and positive effects on the diversity of plants and animals, particularly for nonmammalian species such as reptiles and insects. A case study showed that the careful consideration of hunting locations could be an additional approach to reducing the browsing intensity of ungulates; further experiments under different conditions are required. Management models should be developed.

Meta-analyses: More systematic reviews are needed of case studies with meta-analyses to better understand the context dependence of various findings from the specific investigations.

Recommendations for integrated ungulate-forest management include the following:

- See the forest ecosystem, including its animals, holistically.
- Recognize the importance of the silvicultural system as a habitat factor.
- Include ungulate game as a site factor in forest management.
- Recognize the importance of the silvicultural system as a game-damage factor.
- Clearly define management targets to be able to recognize 'damage'.
- In assessing damage, take the compensatory mortality of trees into account.
- Promote close-to-nature silviculture.
- Coordinate habitat and ungulate management.
- Support more interdisciplinary research into forest–ungulate–human interactions.

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