Wild Red Deer Benefit the Conservation of European Semi-Natural Open Habitats

F. Riesch
University of Göttingen, Germany

Bettina Tonn
University of Göttingen, Germany

Marcus Meißner
Institut für Wildbiologie Göttingen und Dresden e. V., Germany

Sven Herzog
Institut für Wildbiologie Göttingen und Dresden e. V., Germany

Niko Balkenhol
University of Göttingen, Germany

See next page for additional authors

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F. Riesch, Bettina Tonn, Marcus Meißner, Sven Herzog, Niko Balkenhol, and J. Isselstein

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Riesch, F.*†; Bettina Tonn*, Marcus Meißner‡, Sven Herzog‡§, Niko Balkenhol¶, Isselstein J.*†.
* Grassland Science, Department for Crop Sciences, University of Goettingen, Von-Siebold-Str. 8, 37075 Goettingen, Germany; † Centre of Biodiversity and Sustainable Land Use, University of Goettingen, Büsgenweg 1, 37077 Goettingen, Germany; ‡ Institut für Wildbiologie Göttingen and Dresden e.V.; §Wildlife Ecology and Management, Technische Universität Dresden; ¶ Wildlife Sciences, Faculty of Forest Sciences and Forest Ecology, University of Goettingen

Key words: conservation management; heathland; exclusion experiment; mowing; wildlife grazing

Abstract
Traditional land use practices have shaped European landscapes for millennia. Agricultural intensification and declining popularity of pastoral farming in the past century have resulted in a tremendous loss of extensively used open landscapes and associated biodiversity. Today, conservation management needs to prevent secondary succession of many open habitats. Large or inaccessible target areas unsuitable for conventional conservation measures might benefit from grazing by wild herbivores, which do not require fencing nor regular welfare monitoring. In a military training area in Germany, we studied the quantitative and qualitative effects of wild red deer in two protected open habitat types (lowland hay meadows and European dry heaths) based on grazing exclusion experiments over three years. Using movable exclusion cages, we showed that the amount of biomass annually removed by red deer was similar to the forage removal in livestock-based conservation grazing systems. Mown grasslands were particularly attractive to red deer owing to enhanced productivity and forage quality, suggesting that red deer grazing activities can be influenced by mowing. In addition, we compared the vegetation development in grasslands and heathlands with and without red deer grazing using open and permanently fenced plots. Grassland plant diversity decreased in fenced plots. In both habitat types, different structural vegetation characteristics, e.g. increasing sward and litter height, indicated successional developments when red deer grazing was excluded. Our results substantiate that allowing red deer access to open landscapes could not only alleviate potential conflicts with forestry, but can also promote open vegetation structure and diversity, thus providing a valuable contribution to the conservation management of semi-natural habitats.

Introduction
The cultural landscapes of Europe have been created through many centuries of traditional land use such as pastoral farming (Poschlod et al. 2009). Many plant and animal species of high conservation importance depend on these heterogeneous semi-natural open landscapes. Widespread agricultural intensification, indoor housing of livestock and abandonment of low-productive sites have, however, resulted in a tremendous loss of extensively used open landscapes and their associated biodiversity (Wesche et al. 2012). Maintaining protected semi-natural open habitat types today therefore often requires conservation management measures such as grazing, mowing or burning to keep up biomass removal levels necessary for preventing secondary succession (MacDougall and Turkington 2007, Tälle et al. 2016, Valkó et al. 2018).

Implementing conservation management is a major challenge when the target area is large or difficult to access. This is especially so for military training areas, which often feature high biodiversity including many threatened and endangered species (Warren et al. 2007, Riesch et al. 2018). In contrast to livestock that require fencing and regular monitoring of health and wellbeing, wild herbivores do not require frequent human presence in the target area and could thus usefully complement available strategies for conservation management of semi-natural open habitat types.

We studied in a three-year field experiment if grazing by the most widespread autochthonous large herbivore species in Central Europe, the red deer (*Cervus elaphus*), contributes to maintaining the vegetation structure and diversity of different semi-natural open habitat types protected under the European Habitats Directive.

Methods
Our study area was the US Army Garrison Grafenwöhr Training Area (GTA) in Germany (49°40′56″ N, 11°47′20″ E) extending over 230 km^2 made up of 60% forest and 40% open land (Raab et al. 2019). Long-time (1981–2010) annual averages of temperature and precipitation are 8.3 ± 0.04°C and 701 ± 4 mm. GTA is characterized by a large population of wild red deer. Owing to an adapted hunting regime, which has been applied for several decades, the animals regularly forage in open land areas (Richter et al. 2020).

We established our grazing experiment in grasslands (EU Habitats Directive Annex I habitat type 6510 lowland hay meadows) and heathlands (4030 European dry heaths) with five sampling sites (each c. 1 ha in grasslands and c. 0.5 ha in heathlands) per habitat type. Grassland sampling sites were split into treatment areas that were either burnt or mown once per year or remained untreated. We installed one open and one fenced plot (ca. 15×15 m, 10×30 cm mesh size) per treatment totalling 15 plot pairs in grasslands. In heathlands, we examined only untreated areas on two sites with one and three sites with two plot pairs. We assessed the standing biomass combining rising-plate meter measurements of the compressed sward height (CSH) and calibration cuts (Correll et al. 2003) and estimated the cover of bare soil at five annual sampling dates in 2015–2017. Movable exclusion cages (one per open plot) allowed measuring the above-ground net primary productivity (ANPP) and forage removal by red deer for growth periods between succeeding sampling dates (McNaughton et al. 1996). In 2014, before the beginning of the experiment, we visually assessed the relative biomass contribution of each vascular plant species to the total above-ground plant dry matter biomass on a 5×5 m relevé per plot. We repeated this survey in 2018 after three years of red deer exclusion. Additionally, in 2018, we measured the maximum height of fallen litter and counted the total number of individuals of woody species per plot. More detailed information on the study is presented in Riesch et al. (2019, 2020).

Results

Forage removal by red deer

Annual forage removal by red deer amounted to 35%, 44% and 48% of the ANPP in burnt, mown and untreated grasslands (Fig. 1a). In the mown treatment, however, red deer forage removal actually accounted for 79% of the residual fraction of ANPP that was not removed by mowing (average yield 204 g/m^2). In heathlands, forage removal by red deer amounted to 59% of the ANPP. The daily rates of red deer forage removal were 58% higher in mown (averaging 0.71 g m^{-2} d^{-1}) than in burnt (0.45 g m^{-2} d^{-1}) areas and intermediate in untreated grasslands. Forage removal rates peaked in spring and early summer from April to June at 1.1 to 1.9 g m^{-2} d^{-1}. In heathlands, forage removal rates differed significantly from zero only in October–April with 0.4 g m^{-2} d^{-1} on average.

Red deer grazing effects on vegetation structure and diversity

The exclusion of red deer resulted in increasing CSH in fenced compared to open plots in both habitat types. At the end of the third study year, the CSH in fenced grassland plots was on average 5.0 cm higher than in the open plots, while the difference in heathlands amounted to 3.5 cm. Moreover, in heathlands, the area covered by bare soil in the fenced plots decreased continuously from 2016 onwards (Fig. 1b). In 2017, the bare soil cover in fenced plots was 50% lower than in 2015. The estimated contribution of the main species *Calluna vulgaris* to the total above-ground biomass showed a reverse development (Riesch et al. 2020).

Before the start of the red deer exclusion experiment, grasslands plant species richness did not differ, averaging 47 species per 25 m^2 across all treatments and plots (Fig. 1c). In 2018, species richness was significantly lower and showed a marginal difference between plots with a higher number of species in the open than in the fenced plots. Besides, in 2018, the average species richness was significantly higher in the mown than in the other grassland treatments. In heathlands, plant species richness was lower in 2018 than in 2014 (14 vs. 11 species per relevé), but there was no difference between open and fenced plots. The height of the litter layer measured in April 2018, approximately 30 months after installation of the exclusion fences, was higher in the fenced than in the open plots in both grasslands and heathlands (Fig. 1d).

Discussion

We measured substantial forage removal by wild red deer. Theoretically, the overall average annual red deer forage removal corresponded to grazing by 0.54 and 0.45 standard animal units (requiring 8.8 kg dry matter forage per day at maintenance level, Allen et al. 2011) per ha in grasslands and heathlands. Hence, free-ranging red deer can remove similar amounts of forage as livestock in conservation grazing schemes (e.g. a stocking rate of 0.5 animal units ha^{-1}year^{-1} is recommended extensive grazing of neutral grasslands (Crofts and Jefferson 1999).

We found that red deer forage removal increased with increasing grassland productivity and forage quality (Riesch et al. 2019), i.e. was high in spring and early summer when forage productivity and quality were high. This is in line with the forage maturation hypothesis (e.g. Mysterud et al. 2017) stating that cervids select for young plant material, which is easy to digest and high in nutrients. Consequently, the higher forage removal in mown grasslands can be explained by the elevated productivity and forage quality after the cut in late summer. Camera surveillance of open plots corroborated that red deer actually frequented the mown

grasslands more often than the other treatments (Riesch et al. 2020). Therefore, mowing specific areas could be used to influence the habitat use of red deer by providing attractive forage in the late season.

Analysing different vegetation parameters, we showed that the forage removal by red deer helped maintain the characteristic vegetation structure and diversity of both grasslands and heathlands. During the three study years, vegetation height increased and litter accumulated in the fenced plots. Litter accumulation, which can limit the germination and establishment of plant species (Kelemen et al. 2013), and increasing dominance of competitive plant species (as indicated by decreasing Inverse Simpson index, Riesch et al. 2020) could have contributed to the decreasing plant species richness in the fenced grassland plots. The fact that plant diversity decreased in all other plots than the open plots in mown grasslands suggests that relatively productive habitats, such as hay meadows, can be preserved well by combining red deer grazing with an annual cut.

In heathlands, plant species richness was not affected by red deer exclusion, but we observed that the cover of bare soil, which is vital for heathland flora and fauna (Chytrý et al. 2001, Cameron and Leather 2012), decreased. Actually, in the third study year, the cover of bare soil in fenced plots fell below the official requirements (5−25%) for a favourable conservation status of European dry heaths. At the same time, the biomass contribution of *C. vulgaris* increased, which might indicate a development towards mature or degenerate Calluna life-history stages (Barclay-Estrup 1970). Grazing by wild red deer could hence promote the vitality of Calluna heaths similar to livestock grazing at appropriate stocking rates (Fagúndez 2012). The much larger number of woody plant individuals in the fenced heathland plots (Riesch et al. 2020) provided further evidence that the exclusion of wild red deer had allowed for the beginning of forest succession, which is one of the main threats to the conservation of this habitat type (Fagúndez 2012). As severe summer grazing might have detrimental effects on *C. vulgaris* (Gimingham 1989), it seems particularly favourable that the grazing impact of red deer in heathlands in our study was most pronounced in winter.

We conclude that red deer grazing could be a viable management opportunity for many areas of high conservation value, such as military training areas, core zones of national parks or other large nature reserves, if hunting regimes were modified in a way that enabled red deer to forage in open areas where grazing is considered beneficial. This could not only help the conservation of semi-natural open habitats but also reduce damage in commercial forests (Zweifel-Schielly et al. 2012). In addition, implementing grazing by an autochthonous wild ungulate species would be a timely conservation approach that reduces the need for human interventions and allows restoring more natural grazing regimes and ecological dynamics.

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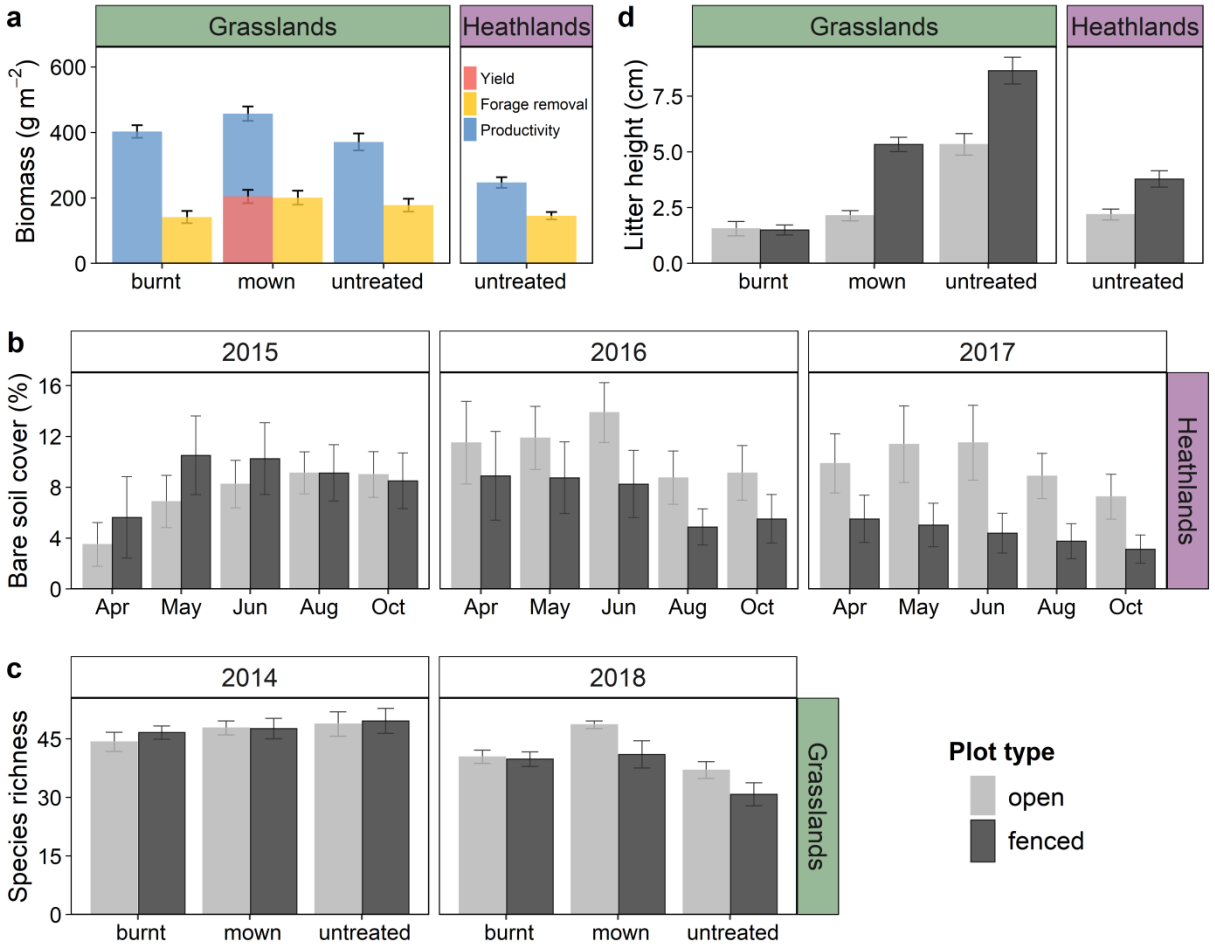

above-ground net primary productivity and forage removal by red deer in grasslands and heathlands in Grafenwöhr military training area in 2015−2017, (b) percent cover of bare soil in heathlands in plots protected against (fenced) or open to red deer grazing, (c) grassland plant species richness per 25 m^2-relevé in 2014 before the start of the experiment and 2018 after three years of red deer exclusion from fenced plots and (d) litter height in grasslands and heathlands (cf. Riesch et al. 2019, 2020).