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Restoration of orchid-rich dry calcareous grasslands by rotational goat pasturing

Wiederherstellung orchideenreicher Kalk-Trockenrasen durch Ziegen-Rotationsbeweidung

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Abstract

Dry calcareous grasslands are one of the most species-rich habitats in the cultural landscape of Central Europe. The species richness largely resulted from the activities of humans and their livestock. Due to large-scale abandonment driven by socio-economic changes during the last century, shrub encroachment is one of the main threats to many orchid-rich calcareous grasslands. Goat pasture has been reported to efficiently restore highly shrub encroached habitats. However, positive effects may be opposed by negative effects on target species, in particular, orchids, but long time data on goat-restored orchid sites are still rare. Over 10 years, we studied the development of large-scale woody plant cover and plant species on 12 permanent 25-m² plots in a spring, summer and autumn goat paddock and three unpastured control slopes. In the summer paddock and an adjacent unpastured site, where the largest population of the main orchid target species *Ophrys sphegodes* occurred, individual number, leaf index, number of blossoms and seed capsules, annual recruitment, mortality, and vegetative dormancy were observed on seven 1-m² plots.

Woody plant cover was significantly reduced in all paddocks with best results in the spring and summer paddock, whereas the unpastured control showed a significant increase. The goat observations revealed a high browsing frequency for the most abundant shrubs *Cornus sanguinea* and *Viburnum lantana*. The number and cover of characteristic dry calcareous grassland species increased or remained stable in pastured sites, whereas they finally declined in unpastured sites.

Ophrys sphegodes individual number significantly increased in the summer paddock and unpastured plots. Pasturing promoted a higher recruitment probably due to enhanced light availability and the creation of open soil. But we also observed a higher mortality and vegetative dormancy through stronger desiccation of these open soil patches, leading to higher population dynamics on the pastured sites. However, the main advantage of reduced shrub encroachment trades off possible individual losses in the long term. Other orchid species showed high year-to-year variations but were still abundant in the paddocks after eight years of regular pasture. We conclude, that goat pasturing is suitable to restore shrub encroached dry calcareous grasslands with a higher efficiency in spring and summer. However, spring pasturing must be adapted to the phenology of occurring orchid species, especially if they are locally rare, or should be alternately combined with summer or autumn pasture to ensure generative reproduction. Generally, the high year-to-year variations of orchid species call for a long-term scientific monitoring to evaluate the restoration outcomes.

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Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Dry calcareous grasslands are one of the most species rich habitats in the cultural landscape of Central Europe (POSCHLOD & WALLISDEVRIES 2002, WILSON et al. 2012). Therefore, the restoration and maintenance of these valuable habitats and their species are specified in the European Fauna-Flora-Habitats Directive by the European network NATURA 2000 (FFH-RL 92/43/EWG). The exceptional species richness, including many orchid species, largely resulted from the activities of humans and their livestock (e.g. grazing, mowing, burning) (HABEL et al. 2013) and can only be maintained by continued use. Grazing is widely seen as the formerly most wide-spread management (POSCHLOD & WALLISDEVRIES 2002). Today, due to the current socio-economic situation, (traditional) grazing is no longer adequately guaranteed in many areas characterized by calcareous grasslands. As a result of this abandonment, these areas have high maintenance deficits, which pose an acute threat to biodiversity (WILLEMS 2001). In particular, shrub encroachment is one of the main threats to many orchid-rich calcareous grasslands (WILLEMS 1983, CALACIURA & SPINELLI 2008). Potential restoration measures to counteract enhanced shrubbery are mechanical shrub clearance (REDHEAD et al. 2012), (goat) pasturing (ELIAS et al. 2018a) or both combined. However, clearance is highly cost-intensive (particularly on steep inaccessible slopes), needs to be repeated in relatively short intervals due to the fast re-growth rate of many woody plant species and offers no selective grazing effects (BACON 2003, MACCHERINI et al. 2007, ELIAS et al. 2014). Goat pasturing, on the other hand, has repeatedly been observed to be sufficient to reduce woody plant cover more sustainably due to the preference of browsing shrubs (SCHWABE 1997, RAHMANN 2000, CZYLOK et al. 2013, HEJCMANOVÁ et al. 2016, ELIAS et al. 2018a), especially on rocky slopes (DOLEK & GEYER 2002), but knowledge about the goat preferences for specific woody species is still rare. ELIAS et al. (2018a) showed, that the highest browsing rate on shrubs are achieved in spring, when palatability of woody plants is still higher. However, since shrub-encroached dry calcareous grasslands often still harbour remnants or small populations of valuable plant species, conservationists and grassland managers fear a further decrease or complete loss of sensitive and palatable plant species such as orchids by heavy or repeated pasturing during the growing and flowering period in spring, as it may damage the individuals and prevents flowering and ripening of the seeds of target species (MEYSEL & PETTERS 2011, CALACIURA & SPINELLI 2008, TAMIS et al. 2009, HUTCHINGS 2010). Therefore, positive effects of goat grazing by reduced shrub cover may be opposed by reduced individual numbers of orchid species. In addition, site managers are often concerned that grazing may lead to negative eutrophication effects and the spread of ruderal plant species (CROFTS & JEFFERSON 1999).

Overall, there is a considerable lack of knowledge about the influence of restorative goat pasturing within shrub-encroached dry calcareous grasslands on threatened plant species, particularly orchids. To determine the impact of goat pasturing on remnant orchid populations, we compared three goat paddocks at different pasturing periods, with unpastured plots within a large-scale dry calcareous grassland area that is strongly threatened by shrub encroachment. Since orchids have strong year-to-year variations of above-ground plant parts in response to unsuitable wheater conditions (e.g. late frost, low spring precipitation) often referred to as vegetative dormancy (SHEFFERSON et al. 2005, HUTCHINGS 2010), it was necessary to sample and analyse long-term data.

As *Ophrys sphegodes* is threatened with extinction according to the red list of Saxony-Anhalt (FRANK et al. 2004), we classified this orchid species as main target species in our study area. Thus, we set an intensive population monitoring scheme to study the species' response to the rotational goat pasturing system. In other occurring orchid species only counts of adult individuals were performed.

Our study focused on the following questions: (1) Which woody plant species are frequently browsed by the goats? (2) How does pasturing affect woody plant cover in general and how do the different pasturing periods influence woody plant cover reduction? (3) Can goat pasturing promote characteristic species of dry calcareous grasslands or does it favour the establishment of ruderal species? (4) How do the occurring orchid species develop under restorative goat pasturing, especially the rare target species *Ophrys sphegodes*?

2. Study area and rotational pasturing concept

The study was carried out in the nature reserve and NATURA 2000 site „Tote Täler südwestlich Freyburg“ (NSG 0128, FFH 0151) in the Lower Unstrut Valley in Central Germany. The climate is sub-continental with an average annual precipitation of 521 mm and mean annual temperature of 8.8° C (Freyburg/Unstrut; REICHHOFF et al. 2001). Elevations range from 120 to 215 m a.s.l. The hilly region is characterized by calcareous bedrock (Muschelkalk) partly covered by shallow loess layers (REICHHOFF et al. 2001).

Historically, the steep slopes were used for vine cultivation until the outbreak of phylloxera pest around 1890. Small quarries on the slope tops supplied the surrounding cities with extrackted limestone until about 1960 (KUGLER & SCHMIDT 1988). After the decline of vine cultivation the sites were (irregularly) grazed by sheep, goats and other livestock, promoting dry calcareous grassland species (mostly species of the *Trinio-Caricetum humilis* Volk in Br.-Br. et Moor 1938 em. Schubert 1995). Socio-economic changes during the last century led to reduced livestock herding resulting in large-scale abandonment of calcareous grasslands across the whole region. Today, calcareous grasslands in the Lower Unstrut region still cover approx. 430 ha (including 260 ha of important orchid sites), but are heavily endangered by shrub and/or grass encroachment (Landesamt für Umweltschutz, Biotopkataster, unpubl. data, 2015).

In 2012, three goat paddocks on steep south and south-west-facing slopes were enclosed by permanent electric fences with five strands (Table 1). Before pasturing started, the paddocks were predominantly heavily shrub encroached (but not grass encroached as reported from other sites [ELIAS et al. 2018a; plateau area in the same nature reserve, KÖHLER et al. 2016]) but still harboured species-rich vegetation of the *Trinio-Caricetum humilis* with dominance of *Anthericum ramosum* as characteristic sub-association in Saxony-Anhalt (6210*). The orchid species *Gymnadenia conopsea*, *Ophrys apifera*, *O. insectifera*, *O. sphegodes*, *Orchis militaris* and *O. purpurea* led to the classification as priority habitat (SCHUBOTH & FRANK 2010) and occurred across all slopes. Rudimentarily developed steppe grassland vegetation of the *Festuco valesiacae-Stipetum capillatae* (Libbert 1931) Mahn 1959 em. Schubert 1995 (6240*) was found on the spring paddock only. Species of the *Alysso-Sedion* Oberd. et Müller apud Müller 1961 (6110*) were established on the former small quarry

Table 1. Characterization of the paddocks, target natural habitat types in Annex I of the Habitats directive and individual number of all orchid species on three 25-m² plots in 2010. 6110* Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*, 6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates including important orchid sites, 6240* Sub-Pannonic steppic grasslands.

Tabelle 1. Charakterisierung der Weideflächen, Ziel-Lebensraumtypen des Anhang I der Fauna-Flora-Habitat-Richtlinie und Individuenanzahl aller Orchideenarten auf den drei 25-m² plots im Jahr 2010. 6110* Lückige basophile oder Kalk-Pionierrasen (*Alysso-Sedion albi*), 6210* Naturnahe Kalk-Trockenrasen und deren Verbuschungsstadien (*Festuco-Brometalia*) (* besondere Bestände mit bemerkenswerten Orchideen), 6240* Subpannonische Steppen-Trockenrasen.

Paddock	Size (ha)	Geographical position	Pasturing period	Target Habitat types of Annex I	Nb. orchid individuals
Spring	2.7	51°12'01"N 11°44'38"E	Mid of May–June	6110*, 6210*, 6240*	74
Summer	4.5	51°11'37"N 11°44'09"E	July–Aug	6110*, 6210*	80
Autumn	4.0	51°11'43"N 11°44'05"E	Sept–Okt	6110*, 6210*	127

areas. The paddocks were surrounded by xerothermophilic shrubs and woodland. The dry calcareous grassland communities of the nature reserve Tote Täler have been described in detail in PIETSCH (2006) and KÖHLER et al. (2015).

As only one herd of about 30 goats was available from May to October, we defined priority paddocks: i) The slope harbouring the largest population of 73 flowering individuals of *Ophrys sphegodes* in the study area and further orchid species with high abundances was pastured at the supposed optimum time frame in summer (July–August), when we expected a sufficient reduction of woody cover (ELIAS et al. 2018a) but no damage on *O. sphegodes*. ii) The spring paddock contained a lower abundance of other orchid species, whereas iii) the autumn paddock inhabited the highest abundance of other orchid species, and very low numbers of *O. sphegodes* (6 flowering individuals).

The paddocks were pastured by Boer goats and crossbreeds with an annual stocking rate of approx. 0.25 LU/ha (one goat accounts for 0.15 LU), which was adapted to the low productivity on the shallow soil and loose gravel on the steep slopes without grass encroachment (MANN & NECKER 2019). In each of the paddocks water was supplied in tanks connected to a drinking fountain. A simple plastic cabin served as shelter. In the winter months the goats were placed in a stable. The goat grazing showed heterogeneous patterns in utilization. Grazing was rather heavy especially on the upper parts of the slopes and around the resting areas. The lower or more remote parts and the valley bottoms were often moderately to undergrazed.

As we observed a real-life project, the pasturing management was optimized in order to improve the less successful restoration on the autumn paddock. Thus, mechanical clearance and spring pasturing was applied on smaller parts of the autumn paddock in 2019. Therefore, we renounced to analyze and display the 2019 data of the autumn paddock in the result section.

Unpastured control sites were located on three south-exposed slopes in the vicinity of the paddocks and exhibited similar vegetation stands. The shrub encroachment was slightly lower than on the pastured plots at the beginning of the vegetation survey, but no other sites were available for comparison in the surroundings.

Table 2. Sum of monthly precipitation (mm) from February to May of each year (DWD 2020, station Leipzig/Halle).

Tabelle 2. Monatssummen der Niederschlagshöhen (mm) von Februar bis Mai eines jeden Beobachtungsjahres (DWD 2020, Station Leipzig/Halle).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sum of precipitation	201.4	74.2	107.3	209.6	163.3	84.4	128.4	127.5	113.5	85

As weather conditions may affect plant growth and abundance, the sum of monthly precipitation from February to May of each observation year were calculated (Table 2). Extreme drought occurred in the study area in 2018 and 2019 (UFZ 2020).

3. Material and Methods

3.1 Behavioural observations

Direct goat observation is used to gain locally detailed insights into the goats' preferences of browsed species, the proportions of total browsing and variations between the seasons. By knowing the feeding behaviour, management decisions for optimizing the pasture regime can be made more efficiently. This approach has been widely used in previous studies, e.g. EL AICH et al. (2007), MANCILLA-LEYTÓN et al. (2013), ELIAS & TISCHEW (2016). At 26 observation days we observed one goat in one-minute-intervals from sunrise to sunset in 2012 and 2013 on the three paddocks. The observed goat was randomly chosen at the beginning of each observation day. Browsed woody species were identified to species level and their occurrence (cover) has been categorized in very low (class 1 = < 1%, single trees or groups of shrubs) to very high abundances (class 5 = > 20%, dominant species) within paddocks.

3.2 Vegetation sampling

Floristic observations started prior to pasturing in 2010, two years before the pasture project was started to gain sufficient information about the occurring dry grassland species, in particular orchids. Development of woody plant cover at large scale was estimated annually (except for 2011 and 2016) on initially defined polygons with ± homogenous woody plant cover. The area of each paddock or unpastured control slope was completely covered with several polygons of varying sizes from 500 to 10,000 m².

In addition, vegetation development was annually analyzed in three permanent 25-m² plots in each paddock or unpastured control slope from 2010 until 2019 in May / June (except for 2016 and 2018 due to the lack of funding). In total, 96 relevés were conducted. Abundance of plant species was estimated as percentage cover. Fertile and vegetative orchid individuals were counted on each permanent plot.

Nomenclature of vascular plants follows JÄGER (2017), and of plant communities SCHUBERT (2001). Specimens were identified to species level except for *Crataegus* spp. (predominantly *C. monogyna*) and *Polygala amara* agg.

3.3 Sampling of *Ophrys sphegodes*

The orchid species *Ophrys sphegodes* developes winter rosette leaves in September, flowers in April/ May, and ripens seeds until mid of June (MEYSEL 2011). Development of *O. sphegodes* was observed annually on seven randomly distributed permanent 1-m² plots on the summer paddock only, because the spring and autumn paddocks harboured only three and six individuals, respectively. For comparison, seven permanently marked plots (1 m²) with *O. sphegodes* were located in unpastured control sites. On these plots x and y coordinates of each emergent plant were noted in each year to an accuracy of 0.5 cm in order to relocate it in subsequent years. This method was previously used by

HUTCHINGS (2010) or SHEFFERSON et al. (2005). Number, lenght and width of leaves of each individual were observed in March/ April, flowering and fruiting individuals and their number of blossoms and capsules were noted in April and May, respectively.

3.4 Data analyses

For evaluating the species composition of the relevés, we selected three ecological groups: target species, other dry grassland species including thermophilic fringe species, and ruderal species. Target species were defined as species being characteristic of the habitat types 6210* (Semi-natural dry grasslands and scrubland facies on calcareous substrates including important orchid sites), 6110* (Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*) and/or 6240* (Sub-Pannonic steppic grasslands) (SCHUBOTH & FRANK 2010). Due to their tendency for grass encroachment the characteristic species of the habitat type 6210 *Brachypodium pinnatum* und *Bromus erectus* were only classified as "other dry grassland species". Thermophilic fringe species of the *Trifolio-Geranietea sanguinei* Müller 1961 typical of less intensively managed dry calcareous grasslands (SCHUBERT 2001, DIERSCHKE 2006) were merged with the group "other dry grassland species". Species associated to the *Artemisietea vulgaris* Lohmeyer et al. in Tx. 1950, *Sisymbrietea officinalis* Gutte & Hilbig 1975 or *Stellarietea mediae* Tx. et al. in Tx. 1950 were defined as "ruderals" to observe potential negative grazing impact on the dry grassland vegetation.

A simple leaf index of individuals of *O. sphegodes* was calculated by using lenght x width x number of leaves in order to compare individual sizes. The annual recruitment (new seedling in each year), mortality (death of the individual in the year before) and vegetative dormancy (no above-ground plant parts are produced for one or more vegetation periods, SHEFFERSON et al. 2005) was calculated for each individual. For the last year, no mortality and vegetative dormancy were calculated as the proceeding status was unclear.

We applied nonparametric Friedman tests to analyse the development of woody plant cover, target species, other dry grassland and thermophilic fringe species, and ruderal species on pastured paddocks and unpastured slopes over the period of eight observation years. Repeated measures analyses of variance were conducted for all observed parameters of *O. sphegodes* on pastured and unpastured plots over the period of 10 observation years. Year of observation was used as the within subject effect and management (pastured vs. unpastured) as the between subject effect. Parameters served as dependent variables. If Mauchly´s test indicated that the assumption of sphericity has been violated, we applied the Greenhouse-Geisser test, which did not require sphericity. All analyses were conducted using IBM SPSS Version 20.

4. Results

4.1 Goat browsing behaviour

The woody vegetation of the three paddocks was dominated by a mosaic of thermophilic shrub communities of the *Rhamno-Prunetea spinosae* Rivas Goday et Borja Carbonell 1961 ex Tx. 1962, mainly consisting of the species *Viburnum lantana*, *Cornus sanguinea*, *Prunus spinosa*, *Corylus avellana*, *Crataegus* spp., and with lower coverage *Carpinus betulus*, *Ligustrum vulgare*, *Rosa canina*, *R. rubiginosa*, *R. elliptica* and *Sorbus torminalis*.

The goat observations revealed the highest browsing frequency for *C. sangiunea* and *V. lantana*, which were also most abundant in the paddocks (Table 3). Spearman´s rank correlation revealed positive relationships of browsing frequency and shrub abundance on spring (r = 0.80), summer (r = 0.66) and autumn (r = 0.67) paddock. In spring the feeding spectrum was more diverse with four species browsed approximately equally (additionally *Carpinus betulus* and *Corylus avellana*). In autumn *C. avellana* was consumed much less intensively. In particular, *V. lantana*, *Frangula alnus* and *Fraxinus excelsior*

Table 3. The five most frequently browsed woody plant species per paddock/ season and species abundance before the beginning of pasturing (2010). Low abundance = 1, highest abundance = 5. Mean observation (%) ± standard deviation related to total woody species browsing. *n* = number of observation days (during daylight).

Tabelle 3. Die fünf am häufigsten gefressenen Gehölzarten je Weidefläche und ihre Abundanz vor Beweidungsbeginn (2010). Geringe Abundanz = 1, höchste Abundanz = 5. Mittlere Beobachtungszeit (%) ± Standardabweichung anteilig an der gesamten Fraßzeit. *n* = Anzahl Beobachtungstage (von Sonnenauf- bis -untergang).

Species	Abundance	Mean observations (%)	± SD
Spring paddock (*n* = 8)			
Cornus sanguinea	4	22.8	19.2
Viburnum lantana	3	18.4	11.3
Carpinus betulus	2	17.9	20.5
Corylus avellana	2	11.9	8.1
Prunus spinosa	2	6.5	5.4
Summer paddock (*n* = 12)			
Cornus sanguinea	5	49.5	10.5
Viburnum lantana	3	12.8	12.6
Corylus avellana	2	5.1	5.0
Ligustrum vulgare	2	4.5	3.4
Crataegus spp.	2	4.2	2.7
Autumn paddock (*n* = 6)			
Viburnum lantana	4	28.1	21.5
Cornus sanguinea	4	25.7	14.2
Corylus avellana	4	8.9	9.2
Ligustrum vulgare	2	6.1	4.0
Betula pendula	2	5.2	5.9

were selectively bark-peeled by the goats, even if the latter two were not common, whereas *C. avellana* was broken apart to reach the leaves. Even species considered toxic such as the invasive *Syringa vulgaris* were intensively browsed. On the other hand, valuable thermophilic tree species such as *Sorbus torminalis* were protected by their thick bark in adult stage. Thorny woody species such as *Prunus spinosa* or *Crataegus* spp. occurred relatively rarely on the pastures. In general, the goats spent approx. 70% of their feeding time with browsing and approx. 30% with grazing herbs and grasses.

4.2 Development of woody plants encroachment

In 2010 the initial mean woody plant encroachment on the three paddocks was 53.2%. Woody plant cover was significantly reduced by goat browsing beginning in spring 2012 (Table 4). Decrease of woody plant cover varied on the paddocks that were pastured at different seasons. On the spring and summer paddocks goat pasturing reduced woody plant cover most efficiently. After eight years woody plant cover comprised 16.8% in the spring paddock, 22.1% in the summer paddock, and 44.1% in the autumn paddock (after seven years). On the contrary, woody plant cover on the unpastured control slopes increased during the same time from 38.6 to 52.9%. Woody species cover was reduced directly by browsing of branches, twigs, leaves and buds, but also indirectly by peeling the bark with subsequent dieback.

Table 4. Results of Friedman tests and means ± standard error of woody plant cover on spring, summer and autumn paddocks, and unpastured slopes (large-scale observation on polygones). Beginning of pasture in 2012. Missing data are indicated by --.

Tabelle 4. Ergebnisse der Friedman Tests und Mittelwerte ± Standardfehler der Gehölzdeckung auf Frühjahrs-, Sommer- und Herbstweide sowie unbeweideten Hängen (Erfassung auf flächendeckenden Polygonen). Beweidungsbeginn 2012. Fehlende Werte gekennzeichnet mit --.

Woody plant cover	years								Friedman test		
	2010	2012	2013	2014	2015	2017	2018	2019	*p*	df	Chi-s.
Spring (*n* = 9)											
Mean	51.1	44.4	36.1	28.3	23.7	18.9	16.7	16.8	< 0.001	7	61.996
SD	24.6	19.4	17.5	17	16.5	15.1	13.2	13.2			
Summer (*n* = 12)											
Mean	53.3	39.6	30.4	33.3	28.8	25.8	23.8	22.1	< 0.001	7	63.807
SD	27.0	20.9	17.1	16.7	14.2	13.6	12.3	11.6			
Autumn (*n* = 11)											
Mean	55.0	53.6	49.1	49.6	49.1	49.1	44.1	--	0.001	6	23.543
SD	30.3	30.6	30.5	29.4	28.4	28.4	27.1				
Unpastured (*n* = 7)											
Mean	38.6	41.4	42.9	42.9	42.9	43.6	43.6	52.9	0.002	7	23.243
SD	25.5	26.4	22.3	22.3	22.3	21.4	21.4	25.6			

4.3 Development of floristic species composition on the 25-m² plots

4.3.1 Number and cover of ecological species groups

In total, 60 target species were observed on all plots (25-m²) during the eight years of observation. Cover of target species in the spring and summer paddock increased by 14.8% (almost significantly, Friedman test: $p = 0.056$) and by 9.0%, respectively (Fig. 1, Table 5). Cover of target species in the autumn paddock remained constant. On the contrary, in the unpastured control plots target species cover decreased by 19.6% since 2010 ($p = 0.079$). Target species number remained stable in the spring and autumn paddock (species-rich stands despite abandonment), but slightly (not significantly) increased in the summer paddock ($p = 0.098$). Low competitive dry grassland species dependent on bare soil benefited from pasturing, especially xerothermophilic dwarf shrubs such as *Teucrium chamaedrys*, *T. montanum*, *Helianthemum canum*, or *H. nummularium*. We observed no change in target species number on the control plots over the years except for a decrease in the last year.

In the pastured plots cover of “other dry grassland and thermophilic fringe species” developed differently (but none of them significantly). In the spring paddock cover decreased especially in the last observation year, in the summer paddock it increased, and remained stable in the autumn paddock. We observed no significant changes in species number of “other dry grassland and thermophilic fringe species” except of a significant increase in the summer paddock ($p = 0.024$). In contrast, species cover of this group significantly increased in the control plots ($p = 0.016$), but species number remained constant. Thermophilic fringe species such as *Geranium sanguineum* or *Melampyrum nemorosum* decreased with pasturing intensity and made way for species of earlier succesional stages such as *Teucrium* spp. The fringe species increased on the non pasture plots.

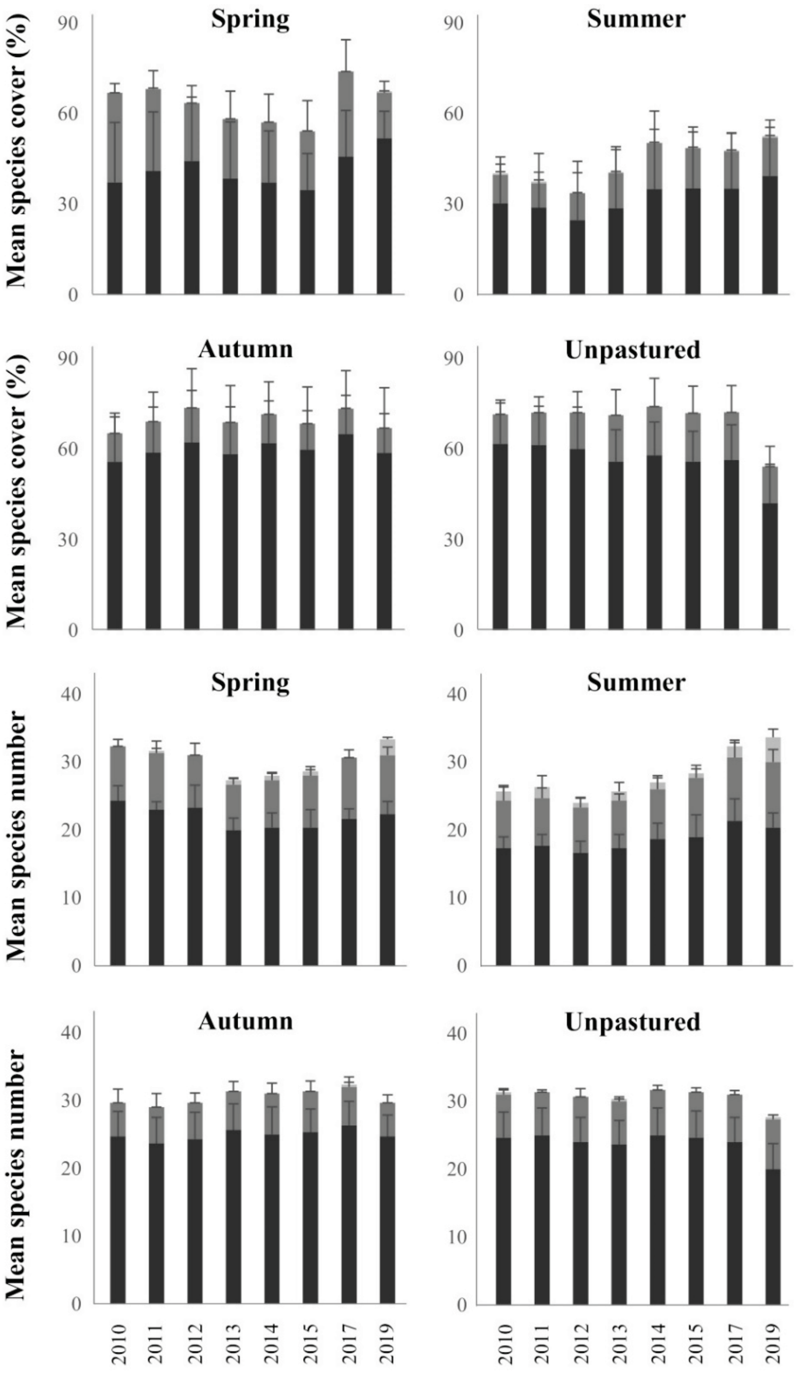


Fig. 1. Development of target (dark grey bars), other dry grassland & fringe (grey bars) and ruderal species (light grey bars) on 25-m² plots (*n* = 3). Beginning of pasture in 2012. Means ± standard error.

Abb. 1. Entwicklung der Zielarten (dunkelgraue Balken), weitere Trockenrasen- & Saumarten (graue Balken) und Ruderalarten (hellgraue Balken) auf 25-m² Flächen (*n* = 3). Beweidungsbeginn 2012. Mittelwerte ± Standardfehler.

Table 5. Results of Friedman tests on pastured paddocks and unpastured control slopes (small scale) from 2010 to 2019 ($n = 3$). Beginning of pasture in 2012. $p \leq 0.001$ = extremely significant, $0.01 \geq p > 0.001$ = very significant, $0.05 \geq p > 0.01$ = significant, $p > 0.05$ = not significant.

Tabelle 5. Ergebnisse der Friedman Tests der beweideten und unbeweideten Flächen (small scale) von 2010 bis 2019 ($n = 3$). Beweidungsbeginn 2012. $p \leq 0,001$ = extremely significant; $0,01 \geq p > 0,001$ = very significant; $0,05 \geq p > 0,01$ = significant; $p > 0,05$ = not significant.

Ecological groups	Spring paddock			Summer paddock			Autumn paddock			Unpastured		
	p	df	Chi-s.	*p*	df	Chi-s.	*p*	df	Chi-s.	*p*	df	Chi-s.
Target species (%)	0.660	7	5	0.056	7	13.749	0.452	7	6.778	0.079	7	12.740
Target species (number)	0.109	7	11.762	0.172	7	10.296	0.518	7	6.189	0.098	7	12.068
Other dry grassland + fringe species (%)	0.360	7	44.019	0.270	7	8.771	0.159	7	10.557	0.016	7	17.177
Other dry grassland + fringe species (number)	0.293	7	8.475	0.024	7	16.161	0.723	7	4.481	0.84	7	3.451
Ruderal species (%)	0.153	7	10.689	0.319	7	42.583	0.429	7	7	0.596	7	5.526
Ruderal species (number)	0.043	7	14.506	0.285	7	8.569	0.429	7	7	0.596	7	5.526

We recorded a total number of 17 ruderal species during the years of observation. In general, cover of ruderal species was very low on pastured and control plots. Species number significantly increased in the spring paddock ($p = 0.043$) and slightly increased in the summer paddock. Species such as *Campanula rapunculoides*, *Medicago* × *varia*, *Papaver rhoeas* or *Taraxacum* sect. *Ruderalia* showed higher frequencies in the paddocks, but altogether with a very low cover.

4.3.2 Individual numbers of orchid species on the 25-m² plots

In total, six additional orchid species were observed in the three paddocks and four on the unpastured plots (Table 6). Every observed orchid species showed high year-to-year variation both on pastured as on unpastured plots. Highest overall abundance was observed in 2010, and lowest in the extremely dry year 2019. Generally, the orchid species occurred throughout the observed years, but dormancies for more than one year were observed. In the spring paddock severe damage through grazing was noted, but none of the species got extinct in any paddock.

4.4 Development of Ophrys sphegodes populations on the 1-m² plots

In the seven 1-m² plots of the summer paddock we observed a significantly increasing number of *Ophrys sphegodes* individuals on both the pastured (from 86 to 133) and unpastured sites (from 84 to 145) (Fig. 2). Total number of individuals was growing faster on pastured plots except for the last extremely dry year. The leaf index showed similar significantly decreasing values in both treatments. Mean number of both blossoms and seed capsules showed high year-to-year variation but similar annual development on both treatments. The effect of pasture (between subject effect) was not significant for all indices.

Ophrys sphegodes also increased in the spring and autumn paddocks that were pastured at less optimal times for this species. In 2010, three flowering individuals were observed in

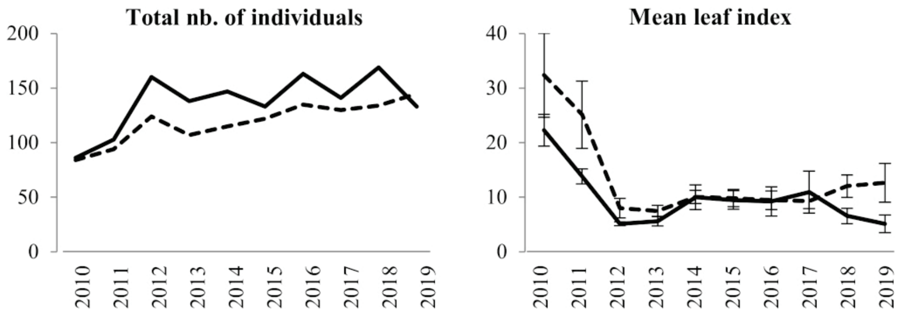
Table 6. Additional orchid species on three 25-m² plots in the paddocks and unpastured control plots. Cumulative individual numbers (fertile and vegetative) recorded in each year of observation. Years prior to pasture are marked grey.

Tabelle 6. Zusätzliche Orchideenarten auf drei 25-m² plots je Weidefläche bzw. unbeweideter Kontrollflächen. Kumulative Individuenanzahl (fertil und steril) jedes Erfassungsjahres. Jahre vor Beweidungsbeginn sind grau markiert.

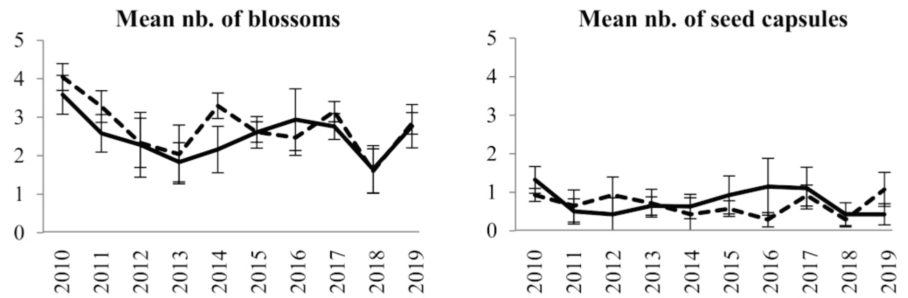
	2010	2011	2012	2013	2014	2015	2017	2019
Spring paddock								
Epipactis atrorubens	32	10	32	2	20	10	1	0
Gymnadenia conopsea	.	.	.	.	.	.	.	.
Ophrys apifera	6	14	14	9	9	27	1	7
Ophrys insectifera	27	78	84	50	63	82	31	33
Orchis militaris	.	.	.	.	.	.	.	.
Orchis purpurea	9	16	11	7	13	10	10	6
Total nb. of individuals	74	118	141	68	105	129	43	46
Summer paddock								
Epipactis atrorubens	.	.	.	.	.	.	.	.
Gymnadenia conopsea	.	.	.	.	.	.	.	.
Ophrys apifera	.	.	.	.	.	.	.	.
Ophrys insectifera	16	0	3	15	15	24	18	10
Orchis militaris	16	1	12	15	9	6	8	0
Orchis purpurea	48	3	17	13	5	6	2	29
Total nb. of individuals	80	4	32	43	29	36	28	39
Autumn paddock								
Epipactis atrorubens	0	12	18	23	4	5	1	0
Gymnadenia conopsea	15	6	3	2	3	3	0	2
Ophrys apifera	0	0	0	1	1	0	4	0
Ophrys insectifera	82	0	1	62	52	68	18	7
Orchis militaris	30	0	0	0	0	8	3	0
Orchis purpurea	0	2	0	2	6	0	0	0
Total nb. of individuals	127	20	22	90	66	84	26	9
Unpastured								
Epipactis atrorubens	6	1	2	0	0	0	0	0
Gymnadenia conopsea	10	5	0	1	7	1	9	0
Ophrys apifera	.	.	.	.	.	.	.	.
Ophrys insectifera	23	5	0	7	10	1	17	5
Orchis militaris	.	.	.	.	.	.	.	.
Orchis purpurea	1	0	0	0	1	1	7	0
Total nb. of individuals	40	11	2	8	18	3	33	5

the spring paddock considering the total paddock area (large scale) and in 2019, 21 individuals were observed. In the autumn paddock six flowering individuals were recorded in 2010 and 72 in 2019.

Annual recruitment, except for the extremely dry spring in 2019, but also mortality was significantly higher on pastured plots (Fig. 3). The pastured plots showed a trend for higher vegetative dormancy ($p = 0.056$).



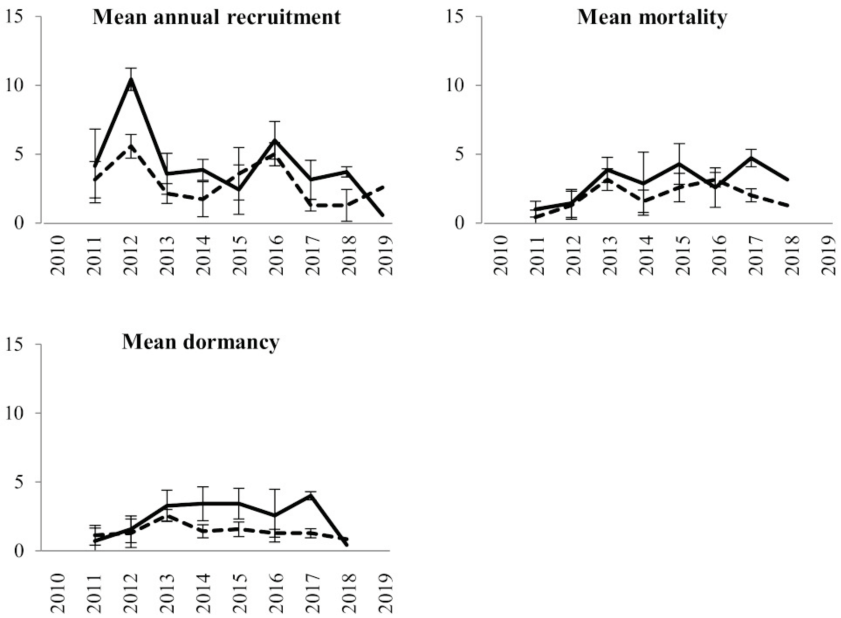
	F	p	F	p
Year	3.760	0.045	12.468	< 0.001
Pasture	0.341	0.570	2.940	0.112
Year x Pasture	0.550	0.562	1.501	0.243



	F	p	F	p
Year	3.439	0.011	0.921	0.459
Pasture	0.336	0.573	0.061	0.808
Year x Pasture	0.472	0.781	0.903	0.469

Fig. 2. Repeated measurement ANOVA results of *Ophrys sphegodes* parameters on permanent 1-m² plots within the summer paddock; within subject effect = year, between subject effect = pasture. Means ± standard error for pastured (line) and unpastured plots (dotted line) are shown ($n = 7$). Beginning of pasture in 2012. $p \leq 0.001$ = extremely significant, $0.01 \geq p > 0.001$ = very significant, $0.05 \geq p > 0.01$ = significant, $p > 0.05$ = not significant.

Abb. 2. Ergebnisse der Messwiederholungs-ANOVA der *Ophrys sphegodes* Parameter auf 1-m² Flächen innerhalb der Sommerweide. Innersubjekteffekt = Jahr, Zwischensubjekteffekt = Beweidung. Mittelwerte ± Standardfehler der beweideten (Linie) und unbeweideten Flächen (gestrichelte Linie). Beweidungsbeginn 2012. $p \leq 0,001$ = extremely significant; $0,01 \geq p > 0,001$ = very significant; $0,05 \geq p > 0,01$ = significant; $p > 0,05$ = not significant.



	Mean an. recruitment		Mean mortality		Mean dormancy	
	F	*p*	*F*	*p*	*F*	*p*
Year	6.242	<0.001	2.795	0.049	2.955	0.056
Pasture	1.311	0.275	1.505	0.243	1.372	0.264
Year x Pasture	1.571	0.194	0.732	0.550	1.396	0.264

Fig. 3. Repeated measurement ANOVA results of *Ophrys sphegodes* parameters on permanent 1-m² plots within the summer paddock; within subject effect = year, between subject effect = pasture. Means ± standard error for pastured (line) and unpastured plots (dotted line) are shown (n = 7). Beginning of pasture in 2012. $p \leq 0.001$ = extremely significant, $0.01 \geq p > 0.001$ = very significant, $0.05 \geq p > 0.01$ = significant, $p > 0.05$ = not significant.

Abb. 3. Ergebnisse der Messwiederholungs-ANOVA der *Ophrys sphegodes* Parameter auf 1-m² Flächen innerhalb der Sommerweide. Innersubjekteffekt = Jahr, Zwischensubjekteffekt = Beweidung. Mittelwerte ± Standardfehler der beweideten (Linie) und unbeweideten Flächen (gestrichelte Linie). Beweidungsbeginn 2012. $p \leq 0{,}001$ = extremely significant; $0{,}01 \geq p > 0{,}001$ = very significant; $0{,}05 \geq p > 0{,}01$ = significant; $p > 0{,}05$ = not significant.

5. Discussion

5.1 Reduction of woody plant cover and goat browsing behaviour

Woody plant cover was significantly reduced in all paddocks with best results in the spring and summer paddock, probably due to the more palatable fresh leaves and still soft twigs, causing severe damage to the woody plants (Dostálek & Frantík 2008, Elias & Tischew 2016), whereas the unpastured slopes showed significant increase in shrub cover. The decrease of woody plant cover by goat pasturing has also been observed by other authors for dry habitats (Rahmann 2000, Beinlich et al. 2009, Veith et al. 2012, Czylok et al. 2013, Elias et al. 2018a). The restoration service of the goats results from their typical

Fig. 4. Goat browsing on woody plants (here on *Crataegus* sp. in the summer paddock) significantly reduced woody plant cover on formerly heavily shrub encroached calcareous dry grasslands (Photo: M. Köhler, 2012).

Abb. 4. Durch den Gehölzfraß der Burenziegen (hier an *Crataegus* sp. auf der Sommer-Weidefläche) konnte bereits eine deutliche Reduktion der Gehölzdeckung der vormals stark durch Verbuschung degradierten Kalk-Trockenrasen erreicht werden (Photo: M. Köhler, 2012).

feeding behaviour. Goats cover a high share of their food requirements by browsing and peeling the woody plants (VON KORN & LAMPRECHT 2004) (Fig. 4). To maximize forage height they are able to reach shrubs up to a height of 1.8 m on their hind legs (facultative bipedality) (RAHMANN 2000, EL AICH et al. 2007).

In the study area, the most frequently browsed woody species were also the most abundant on the respective sites, which was also reported by ELIAS & TISCHEW (2016) for the Lower Saale Valley. There, even strongly spiny woody plants (e.g. *Berberis vulgaris*) were significantly reduced if frequent in the paddock. Although not highly abundant in our study, the bark of *Carpinus betulus* was intensively peeled leading to a fast decline. Generally, bark peeling was reported to to be a more severe damage to woody plants than reducing the sprouts (RAHMANN 2000). A further decisive advantage of goat pasturing is the gradual dieback of the woody plants, in contrast to immediate complete removal by mechanical clearance. The available woody debris may offer valuable habitat for invertebrate fauna (RIEHL 1992).

5.2 Development of ecological species groups

In our goat paddocks, pasturing did not negatively affect the characteristic floristic species composition of the calcareous dry grasslands during eight years of pasturing. Recently, an increase in target species cover was recorded for the spring and summer paddock. We assume that in recent extremely dry years dry gassland species benefited from their capacity to gain ressources even under severe drought conditions. Generally, the reduced shading and competition improved light conditions on the ground through livestock grazing and trampling (ROSENTHAL et al. 2012, ELIAS et al. 2018a,b) which increased germination probabilities, establishment and vegetative spread for low-competitive (calcareous) dry grassland species (SCHWABE 1997, SCHWABE et al. 2013, ELIAS et al. 2018a, b, SILVA et al. 2019) (Fig. 5).

Several "other dry grassland species & fringe species" such as *Geranium sanguineum* or *Polygonatum odoratum*, were heavily pastured on our paddocks and declined in cover, but did not completely disappear from the paddocks. Contrary to previous studies (BRIEMLE 2000, RAHMANN 2000), goats preferentially grazed also on species considered toxic, such as *Pulsatilla vulgaris* or *Dictamnus albus*. Similar to studies of DOSTÁLEK & FRANTÍK (2008) or ELIAS et al. (2018a) we recorded a slight increase in ruderal species numbers (mean 2.3 species), which is often discussed as problematic in grazing areas, in the spring (and summer) paddock, but we did not observe an increase in cover as other authors did (e.g. SÜSS & SCHWABE 2007). As long as ruderal species occur in low abundances, they should be evaluated as an intrinsic part of grazed areas enhancing the species richness (ELIAS et al. 2018a). Undesired establishment of larger abundaces of nitrophilous ruderals on dry grasslands is generally prevented by water limitation (EICHBERG et al. 2007), provided that no additional feeding in the paddocks (except for minerals) is applied. Higher abundances of

Fig. 5. Reduced shading and competition through goat pasturing enhanced light availability on the ground and promoted very species-rich calcareous dry grasslands inhabiting target species such as *Anthericum ramosum*, *Carex humilis*, *Euphorbia cyparissias*, *Helianthemum canum*, *H. nummularium*, *Hippocrepis comosa*, *Inula hirta*, *Ophrys sphegodes*, *Salvia pratensis*, *Stipa pennata*, *Teucrium chamaedrys* and *T. montanum* (Photo: M. Köhler, 2020).

Abb. 5. Die beweidungsbedingt verringerte Beschattung und Konkurrenz erhöhte die Lichtverfügbarkeit am Boden und förderte sehr artenreiche Kalk-Trockenrasenbestände mit Zielarten wie *Anthericum ramosum*, *Carex humilis*, *Euphorbia cyparissias*, *Helianthemum canum*, *H. nummularium*, *Hippocrepis comosa*, *Inula hirta*, *Ophrys sphegodes*, *Salvia pratensis*, *Stipa pennata*, *Teucrium chamaedrys* und *T. montanum* (Photo: M. Köhler, 2020).

ruderal species were only locally observed near highly frequented plain resting areas on the steep south-exposed paddock slopes (outside the relevés). Additionally, at these positions typical dry grassland species showed enhanced growth due to faeces fertilization.

In our study, the rotational pasture system of the three paddocks resulted in enhanced habitat connectivity that may promote species interaction by various zoochory vectors and thus strengthen meta population dynamics. Fragmentation of habitat patches, which affected the slopes in the study area prior to goat pasture for decades, is seen as one of the main drivers of species threat at the local scale (HABEL et al. 2013).

Species richness at abandoned sites can be maintained for relatively long periods (particularly on steep slopes with shallow soils), but we already recorded a decreasing richness in the last observation year. In contrast to the significant reduction of woody coverage on the paddocks, the slopes without pasture showed significantly increasing shrub encroachment over the observed period of 10 years. This gives a clear confirmation of the severe threat of abandonment that will finally lead to the local extinction of characteristic dry grassland species.

5.3 Development of orchid species

All observed orchid species showed high year-to-year variation independently of treatment and timing of pasture. Extreme high values were found in 2010, when supposably suitable weather conditions resulted in an overall high abundance of orchids in the whole study area. In contrast, the fewest number of orchid individuals emerged in 2019, most likely due to the severe drought in 2018/2019 (see chapter 2).

Vegetative dormancy is a widespread phenomenon in the orchid family (SHEFFERSON et al. 2005). In dormant plants no vegetative above-ground organs are produced for one or more vegetation periods due to environmental stress and to buffer survival against it (SHEFFERSON et al. 2005). HUTCHINGS (2010) observed an average of almost 30% of dormant plants in *Ophrys sphegodes*, which is higher than in our study (mean 11% on pastured, 8% on unpastured plots). Variation in fruit and seed set may also depend on the prevailing climate conditions and their impact on phenology and pollinator abundance (VAN DER MEER et al. 2016).

Grazing and trampling enhances light availability at ground level (ROSENTHAL et al. 2012) that probably promote the annual recruitment of *O. sphegodes* in our study, but also higher mortality and vegetative dormancy through faster and more extreme desiccation of these open soil patches (probably also through trampling the tubers). Thus, higher population dynamics were recorded in the pastured sites. However, the main advantage of reduced shrub encroachment trades off possible individual losses.

In a long-term individual-based study by HUTCHINGS (2010) *O. sphegodes* also showed a population increase which may have been promoted by the creation of gaps made by cattle grazing. HUTCHINGS (2010) also refered to the recruitment of almost all new plants of *O. sphegodes* by seed; vegetatively produced rosettes are reported to form less than 5% of the emergent population in any year. Positive grazing effects by goats on several orchid species were also described by BEINLICH et al. (2009). In other studies on orchid species in dry grasslands grazed by goats, contrasting results were described (e.g. GLAVAC 1983, CROFTS & JEFFERSON 1999). In our case, orchid species responded consistently neutral or positively to goat pasture and none of the observed orchid species got extinct in any paddock.

Population increase and spread of some orchid species is generally observed in the region presumably promoted by climate change (e.g. for *O. sphegodes*: MEYSEL 2011, for *Himantoglossum hircinum*: VAN DER MEER et al. 2016), but without pasturing suitable sites will further disappear due to increasing shrub encroachment.

6. Conclusions

Pasturing effects can strongly vary depending on the grazing species, the intensity, and the period used (ROSENTHAL et al. 2012, VADÁSZ et al. 2016). In our study, goat pasturing at approx. 0.25 LU/ha reduced shrubs most efficiently on spring and summer paddocks. Summer and autumn pastures tended to be more favourable for orchid species than the spring pasture. For the rare *Ophrys sphegodes*, summer pasture with goats proved to be an appropriate restoration measure to counteract the negative effects of shrub encroachment. Population size increased and parameters of population dynamics indicated vital populations. But *O. sphegodes* also increased in the number of individuals despite spring pasturing. Generally, it seems to be possible to pasture orchid sites in spring if the phenology of the orchid species has been taken into account. Furthermore, pasture intensity has to be adapted to population sizes to allow regular seed dispersal of at least some individuals. However, spring pasture in alteration with summer or autumn pasture seems to be a good compromise if locally rare orchid species occur in the paddocks. In such cases, a decision on a case-by-case basis has to be applied and monitored. Due to high year-to-year variation of orchid species long datasets (at least 5-10 years) are neccessary to understand restoration responses. Our conclusions do not apply for pasturing types with significantly higher stocking densities such as sheep grazing with large herds. As we were not able to realize an experimental study design in the real-life project we suggest to conduct further studies on this subject.

As the unpastured slopes still harboured species-rich dry grassland vegetation but increased in shrub cover with foreseeable negative impact, suitable pasture restoration measures should be expanded in the study area.

7. Management implications

On sparsely vegetated and rocky/gravelly sites inhabiting valuable plant species livestock units should be low on goat paddocks (< 0.3 LU/ha) and adapted yearly to the habitat conditions, wheather, sprouting of shrubs and available fodder (MANN & NECKER 2019). Increasing pasture pressure might be beneficial to autumn paddocks.

To promote a reduction of shrub cover as well as to allow all (orchid) species flowering and seed setting the pasture concept should be adapted by changing spring and autumn paddocks every few years or stopping pasture for one or more years, if agri-environmental schemes allow for such a management.

In our study area, several goats were infected to death by the small liver fluke (*Dicrocoelium dendriticum*), frequently occurring on calcareous substrates, in the first year of pasturing. Thus, we recommend to not only use young animals as older ones resisted the parasite.

If fringe species are to be preserved, measures such as fencing off the fringe area should be applied at least alternately over years; without any management this area remains subject to succession to forest.

Motor-mechanical shrub clearance as single measure without integration into any subsequent management regime cannot achieve the desired effects with respect to the decline of woody plants and the maintenance or development of dry calcareous grassland vegetation (RAHMANN 2000, MACCERINI et al. 2007, ELIAS et al. 2014). GLAVAC (1983) and ELIAS et al. (2014) even reported strongly enhanced regrowth in most woody species and increased root sprouting in polycormone-forming species after shrub clearance as the only measure.

Erweiterte deutsche Zusammenfassung

Einleitung – Kalk-Trockenrasen zählen zu den artenreichsten Lebensräumen unserer Kulturlandschaft (POSCHLOD & WALLISDEVRIES 2002, WILSON et al. 2012). Daher sind Erhaltung und Entwicklung dieser wertvollen Lebensräume in der europäischen Fauna-Flora-Habitat-Richtlinie durch das europäische Netzwerk NATURA 2000 festgelegt. Aufgrund der weitreichenden Beendigung der Tierhaltung in der Landschaft infolge von sozio-ökonomischen Veränderungen während des letzten Jahrhunderts weisen viele Trockenrasen heute jedoch starke Pflegedefizite durch Verbrachung auf (insb. Verbuschung und Vergrasung), welche die Artenvielfalt akut gefährden. Insbesondere der Verbuschung von Trockenrasen kann durch Ziegenbeweidung effizient entgegengewirkt werden (RAHMANN 2000, VON KORN & LAMPRECHT 2004, ELIAS et al. 2018a). Auf orchideenreichen Standorten wird (insb. Frühjahrs-) Beweidung als Renaturierungsmaßnahme jedoch oftmals kritisch gesehen (CALACIURA & SPINELLI 2008, TAMIS et al. 2009, HUTCHINGS 2010). In dieser Studie untersuchen wir das Fraßverhalten der Burenziegen und die Auswirkungen einer Rotationsbeweidung im Frühjahr, Sommer und Herbst auf die Gehölzentwicklung, die charakteristischen Pflanzenarten der Kalk-Trockenrasen und vorkommenden Orchideenarten mit Schwerpunkt *Ophrys sphegodes*.

Untersuchungsgebiet – Die Studie wurde im Naturschutz- und FFH-Gebiet „Tote Täler südwestlich Freyburg" im südlichen Sachsen-Anhalt (Deutschland) durchgeführt. Subkontinentales Klima, Muschelkalk und vielfältige Nutzung führten zur Ausbildung von äußerst artenreichen Kalk-Trockenrasen mit großflächigen Orchideenvorkommen (überwiegend *Trinio-Caricetum humilis* (FFH-LRT 6210*), kleinflächiger *Alysso-Sedion albi* (6110*), *Festuco valesiacae-Stipetum capillatae* (6240*)). Abgesehen von kleinflächigen Entbuschungsmaßnahmen wiesen die flachgründigen Trockenrasen nach ca. 60-jähriger Verbrachungsphase stark vorangeschrittene Verbuschungs- jedoch keine Vergrasungsstadien auf, das charakteristische Artenspektrum in der Krautschicht war noch überwiegend vorhanden. Detaillierte Beschreibungen zu Flora und Vegetation des Gebietes können PIETSCH (2006) und KÖHLER et al. (2015) entnommen werden.

Material und Methoden – 2010 wurde mit den Status-Quo-Erhebungen auf den Untersuchungsflächen begonnen. Die Beweidung erfolgte ab 2012 mit Burenziegen mit einer jährlichen Besatzstärke von 0,25 GVE/ha in Anpassung an die flachgründigen, nährstoffarmen Bodenverhältnisse ohne Vergrasungsstadien. Die Wasserversorgung der Ziegen wurde auf allen Weideflächen im Untersuchungsgebiet mit Tanks und Trinkbrunnen gewährleistet. Die Unterstände bestanden aus einer Plastikhütte. In den Wintermonaten versorgte der Bewirtschafter die Ziegen in einem Stall. Da nur eine Herde mit etwa 30 Ziegen von Mai bis Oktober zur Verfügung stand, wurden prioritäre Weideflächen festgelegt: i) Der Hang mit der größten *O. sphegodes*-Population (73 fertile Individuen 2010) und weiteren Orchideenarten mit hoher Abundanz wurde zur angenommenen optimalen Zeit für *O. sphegodes* im Sommer (Juli–August) beweidet, wo eine hohe Gehölzreduzierung, aber ein möglichst geringer Schaden an den Orchideen vermutet wurde. ii) Die Frühjahrsweide wies eine niedrigere Abundanz weiterer Orchideenarten auf, iii) die Herbstweide dagegen die höchste Abundanz weiterer Orchideenarten, aber nur wenige *O. sphegodes* (6 fertile Individuen) (Tab. 1). Um das Fraßverhalten der Ziegen zu dokumentieren, erfolgten direkte Tierbeobachtungen an 26 Tagen von Sonnenauf- bis -untergang. Die Deckung der Gehölze wurde flächendeckend in Polygonen für jede Weidefläche und jeweils unbeweideten benachbarten Hängen jährlich geschätzt. Zur Analyse der Vegetationsentwicklung wurden je Weide- bzw. unbeweideter Fläche drei Vegetationsaufnahmen auf Dauerbeobachtungsflächen á 25 m² erstellt und alle fertilen und sterilen Orchideen-Individuen gezählt. Zur detaillierten Untersuchung von *O. sphegodes* wurden je sieben 1 m² große Dauerbeobachtungsflächen auf der Sommerweide und einer unbeweideten Fläche eingerichtet und sowohl Blattparameter sowie Blüten- und Samenkapselanzahl der in ein Koordinatensystem eingemessenen Individuen ermittelt als auch jährliche Etablierung neuer Individuen, Mortalität und Dormanz berechnet.

Ergebnisse – Die Ziegen fraßen am häufigsten an *Cornus sanguinea* und *Viburnum lantana*, Gehölzarten, die auch den größten Anteil an der Gehölzdeckung auf den untersuchten Hängen darstellten (Tab. 3). Die mittlere Gehölzdeckung der drei Weideflächen betrug vor Beweidungsbeginn 53,2 % und wurde auf allen drei Weiden signifikant reduziert (Tab. 4). Die besten Ergebnisse wurden auf der Frühjahrs- und Sommerweide ermittelt (Reduktion um jeweils 32,9 und 41,5 %). Auf den unbeweideten Hängen erhöhte sich die Gehölzdeckung signifikant von 38,6 auf 52,9 % im selben Zeitraum. Das charakteristische Arteninventar der Kalk-Trockenrasen (= Zielarten) entwickelte sich auf den 25-m²-Dauerbeobachtungsflächen positiv oder blieb stabil (Tab. 5, Abb. 1). Die Individuenanzahl von *O. sphegodes* nahm sowohl auf der Sommerweide als auch auf den unbeweideten Flächen signifikant zu (Abb. 2). Auf den beweideten Flächen wurden im Vergleich zu den unbeweideten Flächen eine höhere jährliche Etablierung neuer Individuen, aber auch eine höhere Mortalität und Dormanz dokumentiert (Abb. 3). Die Art breitete sich auch auf den vorher fast unbesiedelten Frühjahrs- und Herbstweiden aus. Ruderalarten nahmen in Bezug auf Deckung und Artenzahl nur unwesentlich zu. Die weiteren untersuchten Orchideenarten unterlagen starken jährlichen Schwankungen, blieben insgesamt aber auf allen Weideflächen erhalten. (Tab. 5). Es musste aber ein starker Verbiss auf der Frühjahrsweide festgestellt werden.

Diskussion – Die Gehölzdeckung wurde auf allen Weideflächen signifikant reduziert, wobei die besten Ergebnisse auf der Frühjahrs- und Sommerweide erzielt wurden, vermutlich aufgrund der schmackhafteren, frischen Blätter und noch weichen Zweige, was zur intensiven Schädigung der Gehölze führte (DOSTÁLEK & FRANTÍK 2008, ELIAS & TISCHEW 2016) (Abb. 4). Dabei wurden häufig vorkommende Arten auch häufig verbissen. Intensiver als durch reines Fressen der Blätter und Zweige werden die Gehölze durch zusätzliches Schälen der Rinde geschädigt und damit dauerhaft zurückgedrängt (RAHMANN 2000). Damit ist Ziegenbeweidung nachhaltiger als alleinige motor-manuelle Pflege, vor allem, wenn schon ein höherer Verbuschungsgrad erreicht ist (MACCERINI et al. 2007, ELIAS et al. 2014).

Die Ziegenbeweidung über acht Jahre beeinflusste die charakteristische Kalk-Trockenrasenvegetation nicht negativ. Am Ende der Untersuchungsperiode wurde sogar ein Anstieg der Zielartendeckung auf der Frühjahrs- und Sommerweide beobachtet. In den letzten Jahren mit extremer Trockenheit profitierten die Trockenrasenarten vermutlich von ihrer Fähigkeit, Wasser- und Nährstoffressourcen auch unter sehr trockenen Bedingungen erschliessen zu können. Generell erhöhte die verringerte Beschattung und Konkurrenz die Lichtverfügbarkeit am Boden (ROSENTHAL et al. 2012, ELIAS et al. 2018a, b), wodurch sich die Keimungswahrscheinlichkeit, Etablierung und vegetative Vermehrung für konkurrenzschwache (Kalk-) Trockenrasenarten verbesserte (SCHWABE 1997, SCHWABE et al. 2013, ELIAS et al. 2018a, b; SILVA et al. 2019) (Abb. 5). Ähnlich zu den Ergebnissen von DOSTÁLEK & FRANTÍK (2008) oder ELIAS et al. (2018a) beobachteten wir zwar einen leichten Anstieg der Anzahl der Ruderalarten (mittlere Artenzahl 2.3), die Deckung blieb allerdings gleichbleibend sehr gering. Sofern Ruderalarten nur in geringen Abundanzen auftreten, sind diese als natürlicher Bestandteil einer Weidefläche anzusehen, die auch deren Artenvielfalt erhöht (ELIAS et al. 2018a). Die unerwünschte Ausbildung flächiger Bestände von nitrophilen und wuchskräftigen Ruderalarten auf Trockenrasen wird allgemein durch die Wasserlimitierung verhindert (EICHBERG et al. 2007). Voraussetzung hierfür ist jedoch auch, dass keine Zufütterung (Ausnahme Mineralien) auf den Flächen stattfindet.

Auf den unbeweideten Flächen blieb die Artenvielfalt über einen relativ langen Zeitraum erhalten (insb. auf den flachgründigen Steilhängen), im letzten Erfassungsjahr wurde jedoch schon eine Abnahme der Zielartendeckung beobachtet. Im Gegensatz zur signifikanten Gehölzreduzierung auf den

Weideflächen nahm die Verbuschung auf den unbeweideten Hängen über den Zeitraum von 10 Jahren signifikant zu. Diese Entwicklung unterstreicht die akute Bedrohung der artenreichen Trockenrasen durch Brachfallen, die ohne Eingriffe von Außen letztendlich zum lokalen Aussterben der charakteristischen Arten führen wird.

Alle untersuchten Orchideenarten wiesen hohe jährliche Fluktuationen auf, die unabhängig von der Beweidung als auch der Beweidungszeit auftraten. Sehr viele Individuen wurden 2010 aufgrund günstiger Witterungsbedingungen im Frühjahr erfasst. Dagegen machten sich die extrem trockenen Jahre 2018/2019 mit deutlich verminderter Abundanz bemerkbar. Dormanz, ein Stadium, in dem die Individuen für eine oder mehrere Vegetationsperioden keine oberirdische Blattmasse bilden, ist ein verbreitetes Phänomen unter den Orchidaceen, vermutlich um ungünstige Umweltbedingungen abzupuffern (SHEFFERSON et al. 2005). Für *O. sphegodes* beispielsweise gibt HUTCHINGS (2010) eine mittlere Dormanzrate von 30 % an; für die von uns untersuchten Populationen wurden jedoch geringere Werte ermittelt (durchschnittlich 11 % auf den beweideten, 8 % auf den unbeweideten Flächen).

Die Zielart *O. sphegodes* zeigte gleichlaufende Entwicklungen hinsichtlich der (stark angestiegenen) Individuenanzahl und weiterer Vitalitätsparameter auf den beweideten und unbeweideten Flächen. Die Schaffung lichtreicherer Bedingungen durch die Beweidung (ROSENTHAL et al. 2012) begünstigt zwar offensichtlich die Etablierung von Jungpflanzen, bedingt aber auch eine erhöhte Mortalität und Dormanz durch verstärkte Austrocknung dieser offenen Bodenstellen (ggf. auch durch Trittbelastung der Knollen). Dadurch war auf diesen Standorten insgesamt eine höhere Dynamik zu verzeichnen. Mittel- und langfristig werden aber die deutlichen Vorteile einer Verbesserung des Erhaltungszustandes bei Fortführung der standortangepassten Beweidung infolge der Gehölzreduktion überwiegen.

Schlußfolgerung – Beweidungseffekte können in Abhängigkeit der verwendeten Weidetierart, der Intensität und der Weideperiode sehr unterschiedlich ausfallen (ROSENTHAL et al. 2012, VADÁSZ et al. 2016). In unserer Studie erzielte die Ziegenbeweidung mit ca. 0,25 GVE/ha im Frühjahr und Sommer die besten Ergebnisse hinsichtlich der Reduzierung der Gehölzdeckung. Generell können orchideenreiche Standorte im späteren Frühjahr beweidet werden, wenn die Phänologie der vorkommenden Arten beachtet und eine generative Reproduktion regelmäßig wenigstens teilweise ermöglicht wird. Alternativ kann das Konzept so angepasst werden, dass die Frühjahrs- und Herbstbeweidung im Abstand von einigen Jahren wechselt bzw. eine ein- oder ggf. mehrjährige Nutzungspause eingeschoben wird, sofern die Art der landwirtschaftlichen o. ä. Förderung dies zulässt. Für lokal sehr seltene Arten muss eine Einzelfallentscheidung getroffen, diese überprüft und ggf. das Management angepasst werden. Für Beweidungsformen mit deutlich höheren Besatzdichten wie beispielsweise der Schafbeweidung mit großen Herden, gelten unsere Schlußfolgerungen nicht.

Managementempfehlungen – Auf felsigen/schotterigen Hängen mit spärlicher Vegetation und wertvollen Pflanzenarten sollte mit einer geringen Besatzstärke beweidet werden (< 0,3 GVE/ha), die jährlich bzw. bei Bedarf an Veränderungen des Lebensraums, Witterung, Gehölzaustrieb und Nahrungsverfügbarkeit angepasst wird (MANN & NECKER 2019). Um die Verbißleistung der Ziegen im Herbst zu erhöhen, kann eine höhere Besatzstärke sinnvoll sein.

In unserem Untersuchungsgebiet erlagen mehrere Jungtiere einer Infektion mit dem kleinen Leberegel (*Dicrocoelium dendriticum*), der auf Kalk-Trockenrasen häufig vorkommt. Durch die Verwendung (auch) älterer Ziegen kann dem letalen Verlauf der Infektion vorgebeugt werden, da diese oftmals immunisiert sind.

Zur Evaluierung und Anpassung der Renaturierungsmaßnahmen wird eine naturschutzfachliche Erfolgskontrolle empfohlen.

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Author contributions

MK, ST developed the research questions and plot selection; MK, GH collected the data; MK, GH analyzed the data; MK wrote the manuscript; DE, NH, ST contributed critically to the drafts and gave final approval for publication.

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