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Effects of traditional salt placement and strategically placed mineral mix supplements on cattle distribution in the Western Italian Alps

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Effects of traditional salt placement (TS) and strategically placed mineral mix supplements (MMS) on cattle distribution were compared in the Italian Alps. Salt was placed within flat and herbaceous sites following the traditional method of farmers, whereas MMS blocks were placed on steep and shrub-encroached sites within three large pastures (44 ha on average). Each TS and MMS site was paired with a control site and eleven cows were tracked with GPS collars. Within 10 and 50 m of TS and MMS, treatment sites were used more than control sites ($P < 0.05$). No differences were detected ($P > 0.05$) in the number of visits by cows within 10 and 50 m of TS and MMS placements. No differences were detected in time spent within 10 m of TS and MMS placements, but cows spent more time ($P < 0.05$) within 50 m of TS. With either TS or MMS, cattle preferred areas with gentler terrain, higher forage pastoral value and closer to water ($P < 0.001$). When MMS was available cattle also preferred areas near MMS ($P < 0.001$). Shrub and herbaceous cover decreased near MMS placements ($P < 0.05$) from cattle grazing and trampling. Placement of MMS is a promising tool to enhance cattle distribution and potentially reduce shrub-encroachment in rugged mountain pastures.

Traditional salt vs. mix supplements

Additional keywords: Alps, beef cows, Global Positioning System-tracking, grassland restoration, grazing patterns, rotational grazing system.

Introduction

Cattle grazing distribution and its impacts on vegetation composition and structure are a critical concern for rangeland managers around the world. For example, researchers have been trying to improve uniformity of grazing by using salt and mineral supplement as attractants in the United States (Martin and Ward, 1973; Ganskopp, 2001; Bailey and Welling, 2007; Bailey *et al.*, 2008; Aubel *et al.*, 2011), in Brazil (Goulart *et al.*, 2008), and in Europe (Putfarken *et al.*, 2008; Probo *et al.*, 2013). In the Alps, semi-natural grasslands have become widely encroached by shrubs, because socio-economic transformations have led to a large-scale decline in livestock farming and agriculture during the 20th century (Kräuchi *et al.*, 2000). Through processes of natural succession, grasslands gradually have turned into shrublands and, ultimately, to forests, adversely affecting biodiversity and increasing the probability of wild-fires, erosion, and avalanches (Freléchoux *et al.*, 2007; Jewell *et al.*, 2007). In the western Italian Alps, the effects of grassland abandonment combined with widespread extensive continuous grazing systems and related vegetation natural succession has decreased permanent grassland and meadow cover by 62 % during the last 50 years (ISTAT 2010; Regione Piemonte 2011), leading to a marked increase in shrub and tree encroachment in sub-alpine and alpine environments. For these reasons, conservation and restoration of semi-natural grasslands have become an important agri-environmental issue. Restoration and conservation can be applied through agronomic and silvicultural actions, such as manual or mechanical shrub-clearing (Barbaro *et al.*, 2001), mowing (Stampfli and Zeiter, 1999), prescribed burning (Lyet *et al.*, 2009; Ascoli *et al.*, 2013), or with the use of livestock grazing management. On rugged alpine locations, livestock may be an effective and sustainable tool to conserve or restore grassland vegetation through the combined effects of trampling, grazing, seed transport, and nutrient redistribution due to fecal deposition (Muller *et al.*, 1998; Olff and Ritchie, 1998; Gillet *et al.*, 2010).

Recently, some European agri-environmental payments in the Piedmont region (north-western Italy) have economically supported techniques that use cattle management to conserve or restore semi-natural grasslands, such as the implementation of rotational grazing systems at recommended stocking rates (Probo *et al.*, 2014), the establishment of temporary night camp areas (Tocco *et al.*, 2013), and the strategic placement of mineral supplements (Probo *et al.*, 2013). These techniques, in comparison with most of other agronomic and silvicultural actions, require lower capital and labor costs. The implementation of rotational grazing systems at recommended stocking levels has increased uniformity of grazing and decreased cow grazing selectivity within each pasture, and can potentially preserve grassland community structure and composition and consequently avoid shrub and tree encroachment (Probo *et al.*, 2014). Moreover, strategic placement of supplements, such as mineral mix supplements (MMS), can be used to lure cattle to traditionally underutilized areas (Bailey and Welling, 2007; Bailey and Jensen, 2008) which in alpine environments are usually steep and far from water sources. Farmers in the Alps traditionally supplement with loose salt (NaCl) to facilitate periodic inventories (counts) and health inspections of their cows. Farmers lead cows towards flat and accessible areas and pour the salt on flat rocks. Salt is often placed at the same location several times during the grazing season and continued year after year, which can lead to overgrazing, soil erosion, and nitrophilous vegetation community dominance around traditional salt placements (TS). Recently, Probo *et al.* (2013) used strategic placement of MMS over steep and shrub-encroached areas for free-ranging cattle as tool for the restoration of sub-alpine and alpine grasslands with promising results in the short-term (i.e. significant increase in the use of steep and traditionally underused locations and reduction in shrub species cover due to the action of trampling by cattle around MMS placement areas).

The goal of the present study was to compare the effects of traditional salt placement on cattle grazing distribution under a rotational grazing system and to evaluate if strategic placement of mineral mix supplements can enhance cattle use of steep, underused, and shrub-encroached locations. More specifically, the objectives were to: 1) examine how MMS and TS supplementations affect cattle grazing patterns; 2) determine which supplementation system (MMS or TS) was more effective to lure cattle; 3) evaluate how vegetation and terrain interact with TS placement and strategic placement of MMS on cattle grazing patterns; and 4) document changes in the vegetation layer near MMS supplement that may result from cattle trampling and grazing.

Materials and methods

Study area and grazing systems

The study was conducted in Val Troncea Natural Park, Piedmont, in the south-western Italian Alps (lat 44°57'N, long 6°57'E), which is an area representative of the changes that have occurred on sub-alpine and alpine grasslands throughout the last decades due to pastoral abandonment. Similar to many other areas in the Italian Alps shrub cover in Val Troncea Natural Park increased, from 2 % in 1982 (IPLA1982) to 18 % in 2011 (Probo *et al.* 2013), with an associated reduction in the extent of grassland cover. The altitudinal gradient at the study site varied from 1910 m to 2600 m a.s.l.. Slopes ranged from 0 to 53° (average 26°). Grassland areas were dominated by *Festuca curvula* Gaudin, *Festuca* gr. *violacea*, *Festuca quadriflora* Honk, *Helianthemum nummularium* L., *Festuca* gr. *rubra*, and *Agrostis tenuis* Sibth. Woody vegetation (shrubs) was predominantly composed by *Vaccinium gaultherioides* Bigelow, *Juniperus nana* Wild, *Rhododendron ferrugineum* L., and *Vaccinium myrtillus* L. Dominant soils were gravelly and nutrient-poor, originating form calcareous parent rock. Annual average air temperature was 0.8 °C (January: -8 °C; July: 9.5 °C) and the long-term (1951-1986) annual average precipitation was 956 mm (Biancotti *et al.*, 1998).

The study area consisted of four pastures managed under a rotational grazing system during the summers 2013 and 2014. The grazing period during 2013 was from 20 June to 26 August, and during 2014 it was from 23 June to 30 August. Water for livestock was available in the perennial streams that flowed through the pastures. Study pastures were grazed by a herd of Piedmontese beef cows including heifers, non-lactating cows and suckling cows varying in age from 1 to 15 years. In 2013, 84 Animal Units (AU - Allen *et al.*, 2011) (119 cattle) were used in the study, and 87 AU (106 cattle) were used in 2014. Pastures were grazed in rotation, according to the sequence traditionally used in alpine rotational grazing systems, i.e. starting from the lower altitude pastures to the higher altitude pastures, following the seasonal patterns of forage growth. The first pasture (6 ha) was not monitored, because it was used to familiarize cows to the supplements, and the other three pastures used in the analyses were 27-ha, 45-ha, 60-ha in size (Table 1). Since pastures at lower elevations typically are more productive, pasture size was adjusted to equalize vegetation carrying capacity, which was measured following the method of Cavallero *et al.* (2007). Each pasture was grazed for 17 ± 1.1 days (mean ± SE).

Table 1. Basic biotic and abiotic characteristics of the three study pastures. Pastoral values are based on Probo *et al.* (2014).

Pasture	Area (ha)	Grassland cover (%)	Grazable area (ha)	Bare ground and rock (%)	Shrub (%)	Average altitude (m)	Average slope (°)	Average pastoral value	Average distance to water (m)
1	26.6	0.72	19.1	19	10	2005	25.2	20.1	119
2	45.2	0.61	27.8	21	18	2278	26.8	16.1	159
3	59.7	0.54	32.2	36	10	2598	25.5	13.2	196

Supplementation and experimental design

Effects of the supplement type on grazing patterns of the cattle herd were compared using a cross-over design similar to the approach used by Bailey *et al.* (2008). The grazing period of each pasture was divided into two equal sub-periods (i.e. about 9 days each), during which two different types of supplements were alternatively available to cattle. Supplement fed during the two sub-periods was randomly assigned. The traditional supplement (TS) was salt (NaCl), which was supplied in loose granular form and placed by the farmer every 3 to 4 days simulating the traditional supplementation technique. The farmer carried the salt and walked to locations with large flat rocks within herbaceous areas with gentle terrain, and then poured the salt onto the rocks. A total of 25-kg of salt were supplied in each TS sub-period. The other supplement was 5-kg blocks of mineral mix supplement (MMS) (Table 2), which were placed on five metal poles (i.e. 25-kg of MMS in the pasture) along 50-m linear transects on steep (average slope of 26 ± 3.5°), traditionally undergrazed, and shrub-encroached locations. Poles with MMS were placed in a line to gradually attract cows from accessible zones to rugged terrain, increase trampling of shrub layer and enhance nutrient deposition in the soil from fecal pats. The linear arrangement of MMS (rather than a clustered arrangement) was used to help spread cows across these underutilized areas and to help cows find all the MMS sites. Cows were not herded to the MMS placements.

Both MMS and TS placement sites were located at similar distances from water (102 m on average) and fences (92 m on average) within each pasture. A paired control site (i.e. a site without supplement) with similar vegetation and topographic characteristics was identified for each supplement (TS or MMS) placement site. For MMS control areas, markers were placed along a transect rather than MMS supplement poles. Timing of supplement feeding (first or second sub-period) as well as spatial assignment of supplement or control to paired sites were randomly assigned in 2013 and assignments were reversed in 2014 in a cross-over design.

Mineral mix supplement intake was measured at the end of each MMS sub-period. Disappearance of MMS (disappearance = 25 kg – kg of MMS left) was considered equivalent to consumption (Aubel *et al.*, 2011). Average daily intake was calculated by dividing the total disappearance of supplement by the number of cows and the number of days in the MMS sub-period for each pasture (Bailey *et al.*, 2008). At the end of each TS sub-period salt intake was always equal to the amount provided by the farmer, as cattle consumed all the salt supplied.

Table 2. Chemical compositions of mineral mix supplements (MMS).

Mineral	Concentration (mg/kg)
Phosphorus	140000
Sodium	130000
Calcium	95000
Magnesium	2400
Iron	1400
Copper	500
Manganese	480
Zinc	330
Iodine	120
Cobalt	40
Selenium	10

Animal tracking

Fourteen randomly-selected cows were tracked with global positioning system (GPS) collars during both years. The collars were GPS Model Corzo, Microsensory SLL Fernàn Nùñez, (Andalusia, Spain), which the manufacturer reports having an average accuracy within 5 m in rugged mountain terrain. Collars were placed one week before the beginning of the grazing season in both 2013 and 2014 to allow cattle to become accustomed to the GPS collars. Positions were recorded every 15 min to ensure sufficient battery life for the entire study period each year. Supplement placements (TS and MMS), water sources, and fence line locations were recorded with a hand-held GPS (Stonex S2, Stonex® Europe S.r.l., Monza, Italy) with an accuracy of 1 m.

Vegetation and topographic variables affecting pasture use by cattle

To detect vegetation cover and topographic variables affecting cattle grazing patterns, 568-sample points spaced at 50-m intervals were generated for the entire study area. Within 20 m of each sample point (termed sample area), canopy cover of shrub and herbaceous vegetation, as well as bare ground and rock cover were visually estimated. The proportion of graminoid species (i.e. grasses and sedges) and forbs was also assessed by visual estimation at each sample area. In addition, the proportion of dominant species was visually assessed at each sample area in order to identify vegetation types and ecological groups and to estimate forage pastoral value (PV) based on procedures described by Probo *et al.* (2014). Distance to the nearest water source and the nearest MMS or TS supplement placement was calculated from each sample point. The average slope was calculated from a Digital Terrain Model (DTM, 5-m resolution) for each sample area using GIS software (ArcView, ESRI, 2011).

Vegetation height and basal cover in mineral mix supplement sites

In order to analyse the patterns of the distribution of grazing by cows, we first identified the time periods that grazing occurred most frequently. We used two variables to classify periods of grazing and not grazing: horizontal distance travelled by cows and the average activity measured by motion sensors every 15 min per each cow (Ungar *et al.* 2005). Grazing periods were identified as times when horizontal distance travelled and motion sensor-based activity were higher and resting periods were assigned time when these values were lower. Comparisons of horizontal distance travelled and motion-sensors readings for the grazing and non-grazing (resting) periods were conducted with the Wilcoxon signed-rank test (Sokal and Rohlf 1995). For all the following analyses, only data recorded during the grazing period were used. Positions recorded during periods classified as resting were excluded.

Data analyses

As the focus of the work was grazing, all analyses of tracking data were performed using only positions recorded from 0600 to 2200 hours when cattle were generally most active and grazing (Probo *et al.* 2014). Similar to Ganskopp (2001) and Schlecht *et al.* (2004), Probo *et al.* (2014) used horizontal distance traveled by cattle and the average activity measured by head motion sensors to identify periods when cows were grazing. Grazing periods were identified as times when horizontal distance traveled and motion sensor based activity were highest and resting periods were assigned time when these values were lowest. Probo *et al.* (2014) found that cattle grazing in nearby pastures in Val Troncea Natural Park were usually less active at night (2200 to 0600 hours) and travelled shorter distances. Consequently, positions recorded at night (2200 to 0600 hours) were excluded from the following analyses.

Mineral mix supplement intake by cows. An independent-sample *t*-test (Lehner, 1996) was carried out to assess if the average daily intake per cow differed between 2013 and 2014. The MMS intake data met the requirements for parametric statistical analyses based on Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of variance.

Spatial comparison: treatment sites compared to control sites. Use of MMS and TS supplement sites and respective control sites was evaluated at two spatial scales, within 10 m and 50 m of supplement placements. Ten meters was a distance where it was likely that cows went to consume the supplement (Bailey and Welling, 2007). The 50-m buffer area was a distance in which vegetation and topographic conditions were relatively homogeneous in our study area. We evaluated the use of supplement and control sites in terms of number of visits and time spent within the 10- or 50-m buffer areas. The beginning of a visit was defined as the time that an animal's position was first within the 10- or 50-m buffer area of a supplement and control site after being preceded by two consecutive positions (30 minutes) spent further than 10 or 50 m from a supplement (Bailey and Welling, 2007). Total time spent by cows near a supplement and control site was defined by the count of the number of GPS locations within the 10- or 50-m buffer area, considering each fix as representative of a 15-minute period. Use of supplement placement sites (numbers of visits and time spent within 10- and 50-m buffer areas) was compared to paired control sites using Generalized Linear Mixed

Models (Zuur *et al.*, 2009). The experimental unit was the 10- or 50-m buffer area surrounding TS and MMS placements. The models included type of site (supplement or control), timing (to indicate if the number of visits or time spent occurred in the first or second sub-period) as fixed effects, and pasture and year as random effects.

Temporal comparison: traditional salt sites versus mineral mix supplement sites. To evaluate if MMS treatment sites were frequented more than TS treatment sites, cattle use near supplement placements during the 9-day sub-period (experimental unit) was compared. A GLMM with supplement type (MMS or TS) and timing as fixed effects and pasture and year as random effects was used for both a 10- and 50-m buffer area surrounding supplement placements. A similar model was also performed to assess if time spent or visits between MMS sites and TS control sites were different.

Vegetation and topographic variables affecting pasture use by cattle. Relationships between vegetation and topographic variables and spatial use of pastures when cows were supplemented with MMS and TS were evaluated using GLMMs. The number of GPS positions recorded in each vegetation sample area (during MMS or TS period, respectively) was modeled with eight continuous variables (shrub cover, graminoid species cover, forb cover, bare ground and rock cover, forage pastoral value, distance to the nearest TS or MMS placement site, distance to the nearest water source, and slope). Pasture and year were added as random effects. Independent variables were standardized (Z-scores) to analyze the size of each effect by comparing model parameter estimates (β coefficients). A correlation analysis was used to exclude independent variables with high collinearity ($r > |0.70|$). A negative binomial distribution was specified for the dependent variable, as it was a count over-dispersed variable (over-dispersion was tested with the *qcc* R package, according to Scrucca (2004)).

Vegetation height and basal cover in mineral mix supplement sites. Analysis of covariance was used to evaluate the effects of cattle grazing and trampling on shrub and herbaceous height within MMS sites. We compared differences in vegetation heights measured before and after cows grazed at MMS sites and paired control sites. The difference (shrub and herbaceous) in height before and after grazing were used as the dependent variable, and treatment type (MMS supplement or control) and treatment type by distance from MMS pole interaction as fixed effects. Pasture, pasture by treatment type interaction, MMS pole and year were used as random effects in the model. The pasture by treatment interaction was used as the error term for evaluating differences between the MMS treatment and control. Distance of the vegetation height measure from the MMS placement (or from similar transect pole in control areas) was used as a covariate. Separate analyses were conducted for herbaceous and shrub height layers. A negative binomial distribution was used in the covariance analyses because the overdispersion test showed that the dependent variables were overdispersed.

Wilcoxon signed-rank tests (Sokal and Rohlf, 1995) were used to compare the effects of cattle grazing and trampling on basal cover near MMS poles and corresponding points in control areas. The Kolmogorov-

Smirnov test for normality and Levene’s test for homogeneity of variance indicated that requirements for parametric statistical test were not met for these basal cover data.

Generalized Linear Mixed Models were performed using the glmmADMB R package (Fournier *et al.*, 2012) of R statistical program, version 3.0.1. (R Development Core Team, 2012). Other statistical analyses were performed with IBM SPSS Statistics 20 (SPSS, 2011).

Results

During 2013 and 2014 a total of 36 934 and 36 981 spatial locations, respectively, were recorded by 11 out of 14 GPS collars. Three collars failed each year. A total of 24 291 and 24 137 positions recorded during the 0600 to 2200 hours grazing period in 2013 and 2014, respectively, were used in the analyses. No differences in intake of MMS were detected ($P > 0.05$) between 2013 (13.7 ± 1.47 g/d, mean ± SE) and 2014 (9.3 ± 2.09 g/d).

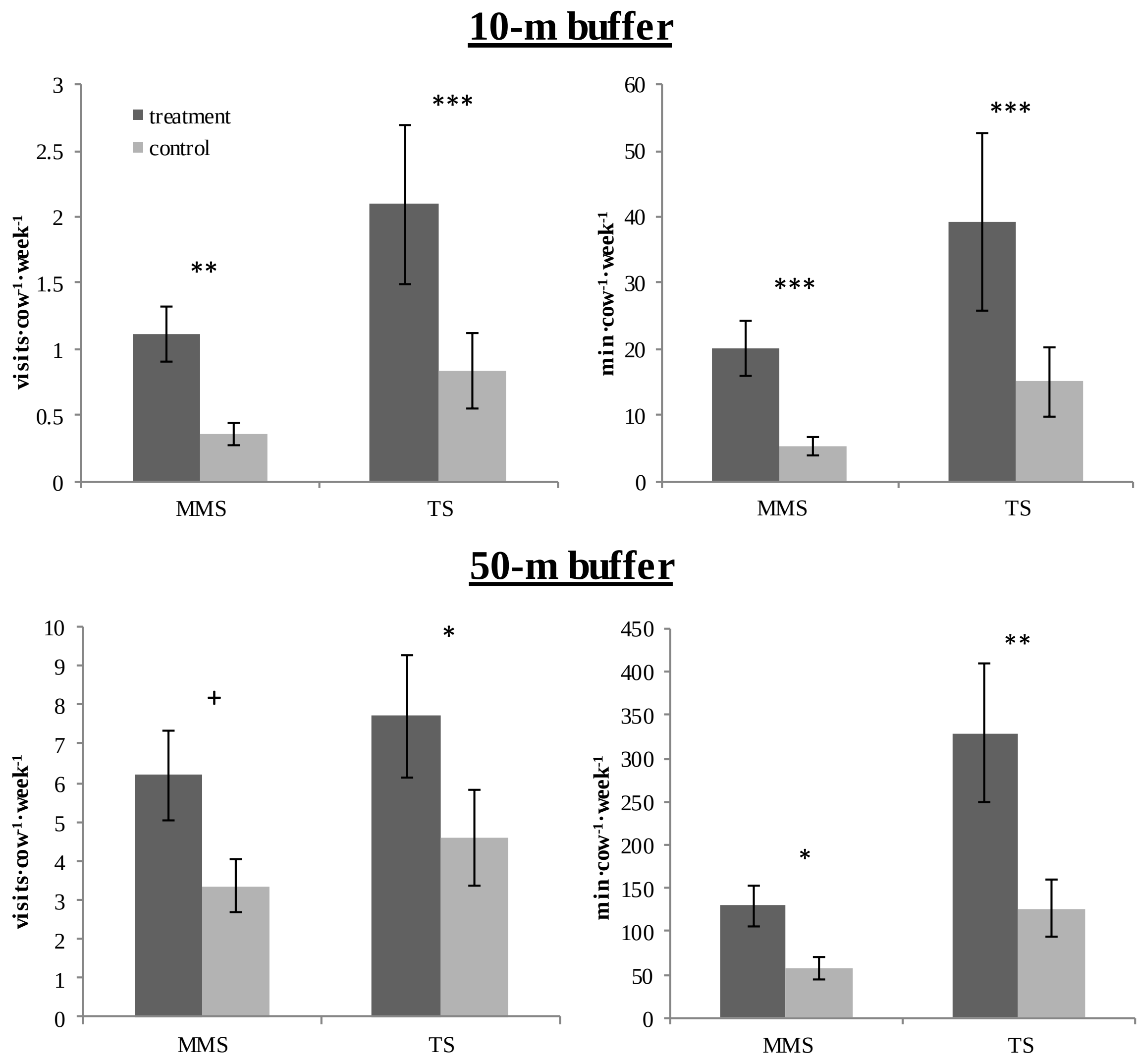
Spatial comparison: treatment sites compared to control sites

In 2013, 10 of 11 collared cows (91%) visited MMS sites (cow location with 10 m of supplement placement), while 11 of 11 cows visited TS sites. Within 50 m of supplement placements, 11 of 11 cows (100%) visited both MMS and TS sites. During 2014, 11 of 11 collared cows visited both MMS and TS sites at both spatial scales. Cows visited and spent more time within supplement sites than at related control sites at both 10- and 50-m buffer area spatial scales (Fig. 1). Timing of supplementation (first or second sub-period) was not an important effect ($P > 0.05$).

Temporal comparison: traditional salt sites versus mineral mix supplement sites

Vegetation transects were classified into 29 vegetation types and five vegetation ecological groups (Table 3, Fig. 4). Under the CGS, meso-eutrophic and snow-bed ecological groups were preferred ($P < 0.05$), whereas shrub-encroached, oligotrophic, thermic and rocky ecological groups were avoided ($P < 0.05$) by grazing cows (Table 4). Selection of vegetation ecological groups was more homogeneous under the RGS than the CGS, with shrub-encroached, meso-eutrophic, and oligotrophic groups being preferred ($P < 0.05$), the snow-bed group used in proportion to its presence, and thermic and rocky group avoided ($P < 0.05$). A marked monthly variation in the selection of different vegetation ecological groups under the CGS was detected (Fig. 5). In June, grazing cows selected the meso-eutrophic group and avoided all the other groups ($P < 0.05$). In July, the snow-bed group was the most preferred, whereas in August and September selection of different vegetation ecological groups was more homogeneous, with meso-eutrophic and snow-bed groups being the most preferred ($P < 0.05$). The thermic and rocky ecological groups were avoided throughout the entire summer, whereas selection of the shrub-encroached group increased over time, with the group being avoided in June and July, used indifferently in August, and preferred in September ($P < 0.05$).

Figure 1. Visits and time spent by collared cows within 10 and 50 m of supplement sites (mineral mix supplement (MMS) and traditional salt (TS)) and related control sites. Bars represent the standard errors of the means. Asterisks represent the P-values for differences between treatment and control sites.



*	P < 0.05.
**	P < 0.01.
***	P < 0.001.
+	P < 0.1.

Vegetation and topographic variables affecting pasture use by cattle

Bare ground and rock cover were excluded from the analyses because they were negatively correlated with graminoid species cover (r = - 0.75; P < 0.001). During TS placements, cattle preferred (P < 0.001) areas with gentler terrain, closer to streams and with higher forage pastoral value (Table 3). No relationships were detected (P > 0.05) between cattle grazing spatial patterns and proximity to TS placement sites, graminoid species cover, and forb cover. Shrub cover was not related to cattle grazing patterns in the TS grazing sub-periods (P > 0.05). During the MMS sub-period, cattle spatial use was related to slope and distance to MMS supplements (P < 0.001). Cows selected areas with gentler terrain and locations near MMS placement sites. Furthermore, cows spent more time in locations with a higher cover of forbs, closer to streams and with a higher forage pastoral value (P < 0.001). Shrub and graminoid cover were not important predictors of use of pastures by cattle during MMS periods (P > 0.05).

Table 3. Effects of vegetation, topographic, and management factors on spatial use of pastures by cattle during traditional salt (TS) and mineral mix supplement (MMS) sub-periods. Significant factors (P < 0.05) are given in bold face.

	TS grazing sub-period			MMS grazing sub-period		
	Stand. β[1]	SE[2]	*P*- value	Stand. β	SE	*P*- value
Intercept	-216.616	108.294	0.046	179.471	96.898	n.s.[3]
Shrub cover	0.009	0.04	n.s.	0.051	0.038	n.s.
Graminoid species cover	0.097	0.053	n.s.	0.063	0.049	n.s.
Forb cover	0.085	0.049	n.s.	0.223	0.046	<0.001
Forage pastoral value (PV)	0.191	0.036	<0.001	0.123	0.033	<0.001
Distance to TS or MMS points	-0.034	0.035	n.s.	-0.342	0.032	<0.001
Distance to water	-0.210	0.04	<0.001	-0.212	0.037	<0.001
Slope	-0.513	0.036	<0.001	-0.382	0.033	<0.001

[1]Stand β indicates that each coefficient of the variables (β) has been standardized, that is measured from their means in units of standard deviations.

[2]SE of standardized coefficients (β).

[3]ns indicates not significant (P > 0.05).

Vegetation height and basal cover in mineral mix supplement sites

Effects produced on vegetation height and basal cover at MMS sites by cows were similar in 2013 and 2014. Cattle trampling and grazing effects on herbaceous and shrub layers were more pronounced within MMS treatment sites than at related control sites. The reduction of herbaceous height within MMS placement sites was greater than at related control sites within 50-m buffer area (P < 0.001). The reduction was more pronounced (P < 0.001) near MMS poles than areas located farther away (Fig. 2). Compared to control sites a reduction of shrub height occurred near MMS, which was significant from 0 to 5 m (P < 0.001) (Fig. 3). From 10 to 50 m of MMS poles (or marker in control sites), no differences of shrub height reduction between MMS placements and corresponding control sites were detected (P > 0.05).

Figure 2. Reduction in the herbaceous height by cattle grazing (difference between pre- and post-grazing heights) within 0-50 m of mineral mix supplement (treatment) sites and control sites. Bars represent the standard error of the means.

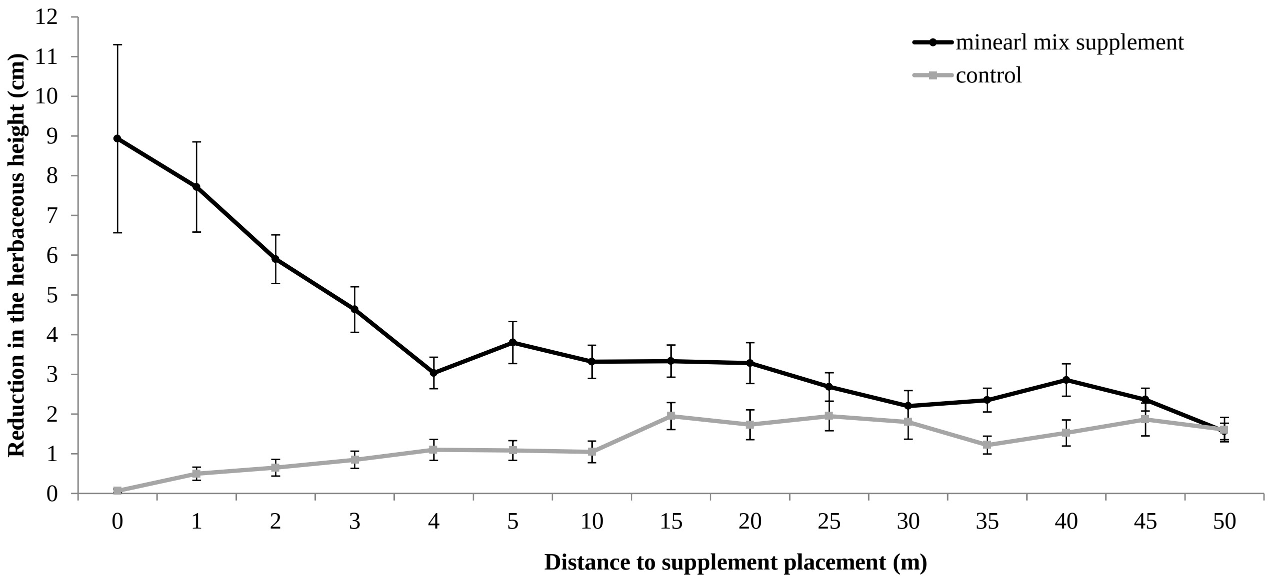
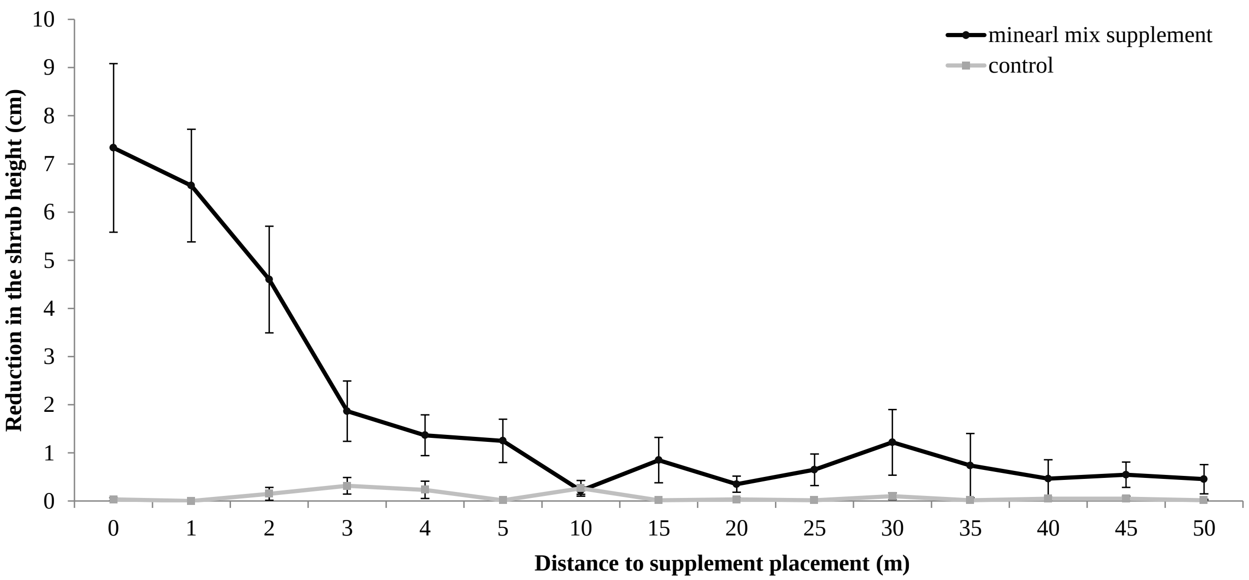
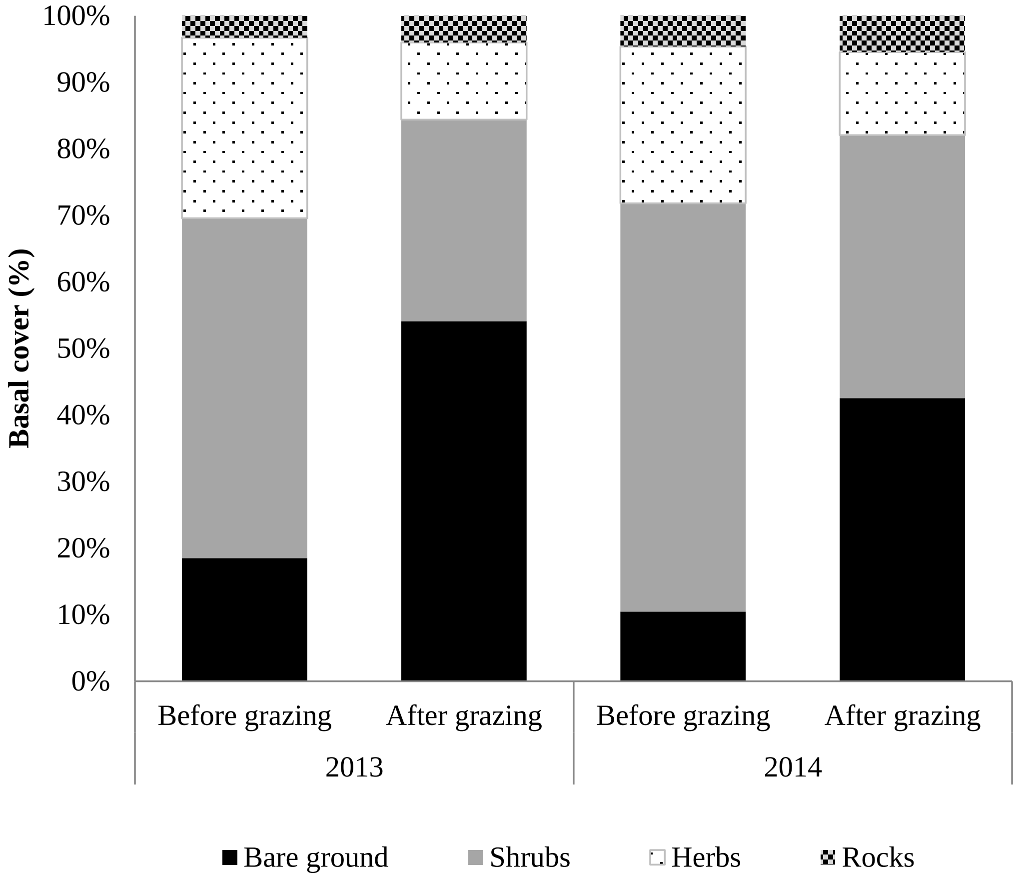


Figure 3. Reduction in the shrub height by cattle grazing (difference between pre- and post- grazing heights) within 0-50 m of mineral mix supplement (treatment) sites and control sites. Bars represent the standard error of the means.



Shrub and herbaceous cover decreased and bare ground increased ($P < 0.001$) within 4 m of MMS placement sites (Fig. 4), whereas in corresponding control sites no differences were detected ($P > 0.05$). However at 25 and 50 m from each pole, no changes in cover were detected ($P > 0.05$). Cattle trampling and grazing reduced shrub cover by 21 ± 2.7 %, and herbaceous cover by 13 ± 2.3 % ($P < 0.001$). As a consequence, bare ground cover increased by 34 ± 3.5 % ($P < 0.001$) after cattle grazing. Most of the trampling and grazing impacts on basal cover occurred within a radius of 2.8 ± 0.15 m (corresponding to a highly impacted area of 30.6 ± 2.53 m^2) of MMS poles.

Figure 4. Changes of bare ground, herbaceous, rock and shrub cover detected within 4 m of mineral mix supplement (MMS) poles due to cattle grazing and trampling action.



Discussion

Spatial comparison: treatment sites compared to control sites

The use of two spatial scales (10 m and 50 m) facilitated our evaluation of cattle use near supplements. Both TS and MMS placement sites were used more than corresponding control sites at the two spatial scales, regardless the order they were supplied to cattle (i.e. first or second grazing sub-period). This result suggests that both supplements were always attractive to cattle. It is important to remember that in this study MMS blocks were placed on steep slopes that were shrub encroached and historically received little, if any, grazing. In contrast, TS was supplied by the farmer on flat rocks within sites with gentle slopes, which were more accessible and offered better quality forage. This was a traditional practice that occurred several years before and during the study. Cows likely remembered the TS placement sites since cattle have accurate spatial memories (Bailey and Sims, 1998). By strategically placing MMS supplement, it was possible to increase cattle use of historically underused, steep and shrub encroached sites despite the less optimal vegetation and rugged topographic conditions. In contrast, cattle preferred gentle terrain when they were lured there by the farmer with TS supplementation. Not only cows consumed salt, but they grazed the herbaceous areas nearby and used these sites for resting and ruminating.

Temporal comparison: traditional salt sites versus mineral mix supplement sites

Despite the vegetation and topographic differences, cows spent about the same amount of time within 10 m of TS and MMS placement sites and visited these locations at about the same regularity. Cows were willing to travel to steep and shrub-dominated areas to consume MMS at the same intensity as salt placed within gentle areas with more comfortable conditions. Based on data from the 50-m buffer area around placement sites, cows spent more time near TS than MMS but we did not detect any differences in number of visits. Cattle likely spent more time grazing near TS sites not only because of the presence of salt, but probably due to more palatable forage (higher forage pastoral values) and terrain (gentler slope) characteristics. However, this difference could be also attributed to a different preference of cattle for the two supplements supplied. Furthermore, cattle use within 10 and 50 m of MMS placement sites was similar to use of TS control sites, which contained more optimal conditions, gentle terrain and primarily herbaceous vegetation.

Vegetation and topographic variables affecting pasture use by cattle

The type of supplement affected cattle behavior. Cattle grazing patterns were affected by presence of MMS supplements to roughly the same degree as slope. Grazing distribution was more influenced by MMS placements than by proximity to water sources, and it is known that distance to water is one of most important factors affecting cattle spatial distribution (Valentine, 1947; Mueggler, 1965; Bailey, 2005; Putfarken *et al.*, 2008). Furthermore, strategic placement of MMS increased the use of traditionally underused vegetation communities, which generally have a higher percentage of forb cover than more intensively managed areas (Krahulec *et al.*, 2001; Fischer and Wipf, 2002, Lonati *et al.* 2015). This result can help to explain cattle preference for areas with greater forb cover. Supplementation of TS did not appear to have as much effect as MMS on cow grazing distribution. Cows preferred to graze areas with gentler terrain, higher forage pastoral value and shorter travel distance to water, which were collocated with TS placement sites. The difference in spatial use of pastures between MMS and TS could be likely due to the different technique used to supply MMS and TS. Mineral mix supplements were always available to cattle during the 9 days of the sub-period. In contrast, TS was manually supplied by farmer 2-3 times during each sub-period and consequently not continuously available to cattle. Similarly, Bailey and Jensen (2008) found that a self-fed protein supplement (low moisture block) was more effective as an attractant for cattle than a supplement that was hand fed (range cubes).

Vegetation height and basal cover in mineral mix supplement sites

The use of MMS sites by cows was not only documented by GPS tracking but similar results were documented from vegetation height and basal cover changes within 50 m of supplement placements. A greater reduction of herbaceous height occurred within treatment sites than within control sites. Herbaceous vegetation heights were reduced by a combination of grazing and trampling (especially within 5 m of supplement placements). Shrub height was reduced within 3 to 5 m of MMS poles and was likely the result of cattle trampling, because shrubs in this study area are generally not palatable (Probo *et al.* 2014).

Cattle trampling reduced herbaceous and shrub height and cover, with a consequent increase of bare ground and rock cover within 5 m of MMS placements, but at 25 and 50 m from MMS placements no changes in cover were detected. These results are in line to those of Tocco *et al.* (2013) and Probo *et al.* (2013), who conducted similar research in study areas and determined that cattle trampling effects on shrubs are limited in size. Tocco *et al.* (2013) and Probo *et al.* (2013) used pairs of MMS blocks placed 5-m apart and observed that the mean area modified by cattle was 69.1 m2 and 45.2 m2, respectively. Placing MMS blocks along a linear transect (i.e. 50 m) resulted in a decrease in shrub cover over a wider area (about 150 m2) and new paths through the dense shrub layer were created by cattle traveling between the MMS poles.

The increase of cattle use of locations that have been historically undergrazed and where shrubs have encroached herbaceous vegetation communities, could increase soil fertility within localized areas of large pastures. Indeed, a more homogeneous cattle distribution would result in a more homogenous distribution of nutrients due to deposition of cow faeces and urine. Increased uniformity of grazing in alpine environments should help to prevent or slow down increases in already excessive nutrient concentration within flat areas and help to increase soil fertility within oligotrophic sites (Güsewell *et al.*, 2005). Furthermore, increased light penetration due to shrub elimination or reduction by cattle trampling, in complement with increased fertility from cattle faeces and urine deposition, might facilitate grass recovery. However, long-term studies are needed (Bakker *et al.*, 1996) to determine if strategic placement of MMS can be used to establish desired herbaceous vegetation in alpine grasslands.

Conclusions

Strategic placement of mineral mix supplements under rotational grazing systems appear to be a promising tool to enhance grazing distribution within large pastures, also when farmers need to concentrate cattle for periodic herd counts and health inspections through occasional placement of salt in accessible areas. Based on this study, mineral mix supplement placements improved the use of steep, shrub-encroached, and historically underused sites. Increased use of steep and shrub encroached areas by cattle facilitates trampling, defoliation, and fecal deposition which may help to restore vegetation structure and composition around supplement sites, reducing shrub abundance and increasing fertility of soil and forage quality and quantity in the years to come.

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