Opportunities of grazing personality genetics for steep and rugged rangelands

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Abstract

Globally, extensive pastoral grazing systems are facing multiple pressures, including to address emerging public concerns about environmental impact and animal well-being. This may require new regulatory constraints to be met, while maintaining the economic viability of the systems. One novel approach to addressing these challenges is to capitalize on naturally occurring differences in livestock behaviors, specifically differences in grazing personalities, to assist the production systems deliver more effective and responsible use of rangelands. Herbivores may exhibit consistent grazing behaviors over time and across spatial contexts, which differ among individuals and between groups leading to distinctive grazing patterns known as grazing personalities. A study conducted in steep and rugged rangelands of New Zealand with GPS-tracked cows (n = 303) that were genotyped for variation in a 'grazing gene', the glutamate metabotropic receptor 5 gene (*GRM5*), revealed genetic associations ($P < 0.02$) and trends towards associations ($P < 0.1$) with home range, movement tortuosity, elevation range and horizontal distance travelled. In an average herd, two *GRM5* genotypes associated with medium-sized home ranges accounted for 72% of cows, another two genotypes associated with the largest home ranges accounted for 16% and the remaining 12% had the genotype with the smallest home range. Furthermore, genotypes with the largest home range had the least 'crooked' movement tortuosity. Here, we propose changing the proportion of *GRM5* genotypes in cattle herds to better match the collective grazing patterns within steep and rugged rangelands. For example, increasing the proportion of *GRM5* genotypes with largest home ranges and straightest movement tortuosity may lead to decreasing grazing frequency of vegetation at several scales (e.g., individual plants, plant communities and ecological sites) and better utilization of the available forage. We highlight opportunities of a *GRM5* grazing personality approach to improving collective grazing patterns of beef cattle in steep and rugged rangelands to enable more sustainable pastoral grazing systems.

Introduction

Public concerns about the environmental impact and animal well-being in extensive pastoral grazing systems are challenging ranchers and researchers worldwide to meet new production regulations while maintaining the economic viability of their livestock production systems. One inherent challenge to pastoral grazing systems is the utilization of the entire grazing land available with livestock that may prefer certain areas over others, and thus graze rangelands unevenly. For example, in steep and rugged terrain a minority of individuals might graze the steeper and/or remote country which accordingly remains under-utilized and/or not grazed at all, while more visited areas may undergo higher grazing pressure than recommended for managing rangeland health.

Animal personality theory suggests animals do not behave the same but rather have differences in behaviors that have been observed consistently over time and under different situations and contexts. A grazing personality model (GP-model) (Moreno García *et al.* 2020) hypothesized that herbivores might exhibit genetically determined grazing behaviors that are correlated and/or concatenated resulting in distinctive grazing patterns among individuals and between groups. Thus, a novel approach to addressing livestock distribution challenges might be using genetically-driven differences in the grazing personalities of herbivores

to manipulate their individual and collective grazing patterns towards more effective and responsible use of rangelands.

Genetically-driven differences in grazing personalities might make feasible the selection of animals at large scale upon quick, accurate and relatively inexpensive DNA testing once a specific genetic marker (i.e., single nucleotide polymorphism, SNP) is identified. In cattle, a genome-wide analysis identified a chromosomal region that contained *the* glutamate metabotropic receptor 5 gene (*GRM5*), which was associated with indexes of terrain use (Bailey *et al.* 2015) suggesting *GRM5* is a putative grazing behavior gene. Moreno García *et al.* (2022) used finer genotyping (i.e., single-strand conformational polymorphism) to report associations between *GRM5* genotypes and the daily home range and movement trajectory of mature cows grazing in steep and rugged rangelands of New Zealand, and these associations between variation in the bovine *GRM5* and movement behaviors are consistent with research reporting associations in other animal models (e.g., mice, see references in Moreno García *et al.*, 2022).

Methods

Moreno García *et al.* (2022) conducted a study on four commercial farms with steep and rugged rangelands (Tozer *et al.* 2021) in Canterbury, New Zealand. Daily grazing behaviors with 24 days repeated measurements of free-ranging cows (n = 303 + 3 excluded from association analysis) were derived from geo-relocations (GPS-tracking collars set at 5-min frequency) and digital elevation models (SRTM imagery, 16 meters resolution). These cows were subsequently DNA-typed for variation in *GRM5*. The authors applied generalized linear models to test associations between *GRM5* variation and several grazing behaviors (see Moreno García *et al.*, 2022 for details).

Results and Discussion

GRM5 genotypic variation

Six *GRM5* genotypes were found in 14 herds from four ranches (Table 1); the genotypic representation was unbalanced. For example, the *BC* and *CC* genotypes accounted for 72% [65 to 79%] of the cows in a herd and were associated with medium values of exploration behaviors; genotypes *AB* and *AC* were present in 16% of cows [11 to 21%] and corresponded to largest size home ranges and straightest trajectories (i.e., lowest movement tortuosity); homozygous *BB* was present in 12% of cows [5 to 24%] corresponding to the smallest home range and the most crooked trajectories. The *AA* genotype was present in three cows (1%) and these were excluded from the association analyses.

Table 1. Percentage of *GRM5* genotypes per ranch and total number of cows

Geno-type	Ranch				
	1	**2**	**3**	**4**	**All**
AA	0%	2%	1%	1%	1%
AB	5%	5%	5%	9%	6%
AC	13%	10%	6%	12%	10%
BB	6%	5%	24%	13%	12%
BC	43%	38%	30%	32%	36%
CC	33%	41%	35%	33%	35%
Cows	83	61	84	78	306

Genetically-driven differences in grazing behaviors

Moreno García *et al.* (2022) reported associations ($P < 0.02$) between *GRM5* genotypes and home range and movement tortuosity. Trends towards associations ($P < 0.1$) were also revealed for elevation range and horizontal distance travelled. Furthermore, the study revealed a negative correlation (r = - 0.27; $P < 0.001$)

between home range size and movement tortuosity suggesting a trade-off for these behaviors as per the marginal mean values derived from the generalized linear models (Table 2). For example, *BB* genotype was associated with the smallest home ranges (6.60 ha/d) and the most crooked movement tortuosity (665 m/ha), while the opposite was observed with genotypes *AB* and *AC* (i.e., largest home ranges and straightest movement tortuosity). Similarly, elevation range was associated with lowest values for *BB* (~85 m), highest values for *AB* and *AC* (~94 m), and medium values for *BC* and *CC* (~86 m). Differences between maximum and minimum values per *GRM5* genotype were about 20% for behaviors with association and around 10% for those with trends towards association (Table 2).

Table 2. Grazing behaviors associated and with trends towards association with *GRM5* genotypes in free-ranging cows

Genotype	Grazing behavior			
	Home range	Movement tortuosity	Elevation range	Horizontal distance
	ha/d	m/ha	m	m/d
AB	7.88	540	94.9	3655
AC	7.82	568	93.0	3950
BB	6.60	665	84.9	3818
BC	7.25	616	86.2	3885
CC	7.29	602	85.4	3842
Max-min difference	**19.4%**	**23.1%**	**11.8%**	**8.0%**

The study also revealed that behavioral differences between *GRM5* genotypes were more prominent in cows at and above 4 years of age, while less pronounced differences between genotypes occurred in 3-years old cows.

Applying grazing personality genetics for range management

The GP-model (Moreno García *et al.* 2020) proposed that grazing genes determine consistent behaviors for foragers at the individual and collective level. The findings presented here suggest that variation in *GRM5* is associated with home range size and movement tortuosity of beef cattle grazing steep and rugged terrain in New Zealand rangelands. Furthermore, the representation of different *GRM5* genotypes in cattle herds tested seems to be unbalanced with the majority of cows holding either of the two genotypes associated with medium values of grazing behaviors. We hypothesize that the unbalanced representation of *GRM5* genotypes gives opportunities to modify collective behaviors of cattle with promising application in range management of steep and rugged rangelands.

For example, increasing the proportion of *GRM5* genotypes *AB* and *AC* — genotypes associated with the largest-home ranges and least tortuous movements — may lead not only to the use of larger areas in rangelands and more even grazing distribution in rangelands (Pauler *et al.* 2020) but also to decreasing the grazing frequency of vegetation at several scales (e.g., individual plants, vegetation patches and even plant communities or ecological sites). In such a scenario, beef herds would make better use of the available forage potentially increasing the productivity of pastoral livestock systems. Moreover, a higher proportion of *AB/AC* cows would spread the grazing pressure and give longer resting periods to forages, potentially enhancing rangelands health and the overall sustainability of the system (Tainton 1999).

In research with zebrafish (*Danio rerio*), Tang *et al.* (2020) suggested genetic control over collective behaviors displayed by free-swimming groups of fish. The study included, among with other genes, a GRM5-like gene (*grm5a*), which was related to collective exploratory behaviors such as polarization, moving time and centroid speed. New experiments with beef cattle may test the effects of *GRM5* variation in collective level behavioral metrics affecting grazing patterns in rangelands. Here, we pose a few questions with unknown answers that might feed the agenda of future research:

- If cows' daily exploration is consistent over time and across situations, yet varies among individuals with different *GRM5* genotypes, how different is their energy expenditure in exploration? How different is the acquisition of energy? If energy balance differences are associated with *GRM5* variation, what are the implications in animal production?
- Given *GRM5* genotypes are associated with differences in grazing behaviors leading to differences in rangeland exploration, what then are the differences in the use of heterogeneous plant communities, or sensitive ecological sites?
- How much overlap and mismatch of grazing areas takes place among cattle with different *GRM5* genotypes?
- Is the proportion of *GRM5* genotypes in the beef herds a good predictor of the grazing personality of the herd? Specifically, can we manipulate the collective exploration of beef cattle by changing the proportion of *GRM5* genotypes?

Conclusions and/or Implications

The GP-model highlights the genetic control over consistent grazing behaviors, which has been supported by the associations found between *GRM5* variation and grazing behaviors of cattle. Furthermore, *GRM5* genotypes appeared to be unequally represented in cattle herds giving opportunity to manipulate collective grazing behaviors towards more efficient and sustainable pastoral livestock systems. Future research might elucidate and quantify the effective size and potential impact of applying grazing personality genetics in extensive pastoral grazing production.

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