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Effects of long-term cattle market conditions on continuous season-long and rotational grazing system revenues

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Abstract. In this study we evaluated the combination of long-term market conditions and the price slide in the cattle market on revenues associated with continuous and rotational grazing systems. A price slide is a market phenomenon in which lighter cattle sell at a higher price per unit of liveweight compared with their heavier counterparts. We used actual herd average starting and ending weights in this market analysis, and analysed the outcome using five years' data from a continuous and rotational comparative grazing study. Despite consistently lower weight gains with rotational grazing, differences in gross revenues per steer between grazing treatments ranged from US$43.46 to minus $5.72 across the study years. We observed annual differences in the net returns across years between the two grazing systems; net returns were greater for steers in the continuous grazing treatment in three of the five years, one year with net returns that did not differ between systems, and one year in which net returns were lower with continuous grazing. These variable results showcase the complexity in having both differences in end of grazing season weight classes between the grazing systems and the differential effects of price slide among weight classes. Therefore, we argue that it may be a better management strategy for land managers to determine the optimal ending weights and the time of year to market livestock to meet the goals of an operation, rather than trying to determine which grazing system is 'best'.

Keywords: Price Slide, Revenues, Ranch Economics.

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Introduction

The high plains of Northern Colorado have historically been grazed by large ungulates (Milchunas *et al.* 1988), resulting in an ecosystem resilient to grazing by large herbivores. Historical grazing by these migrating herds of large ungulates involved short periods (i.e. weeks) of heavy use followed by long periods (i.e. months to years) of rest, providing an opportunity for above- and below-ground regrowth (Holechek *et al.* 1998). Mimicking these grazing patterns is the focus of rotational grazing, which has been adopted by many conservation-minded ranchers and organisations, including the Natural Resource Conservation Service (NRCS), who promote its use by providing cost share assistance through their Environmental Quality Incentives Program (EQIP) (NRCS 2015).

Despite the promoted ecological benefits of the rotational grazing system, infrastructure costs are higher (Windh *et al.* 2019), and cattle weight gains per individual and per unit land area are consistently lower than those in continuous grazing systems when stocking rates are similar between systems (Briske *et al.* 2008; Augustine *et al.* in press). Thus, producers adopting a rotational grazing system typically increase stocking rates above the recommended rate in an attempt to increase weight gains per unit land area. However, these increased stocking rates can counteract the ecological benefits of rotational grazing (Briske *et al.* 2008).

In this study we evaluated the combination of long-term market conditions and the price slide in the cattle market on revenues associated with weight gains from a continuous and rotational comparative grazing study. Price slide is a market phenomenon in which lighter cattle sell at a higher price per unit of liveweight due to the greater ability to put on additional weight compared with their heavier counterparts (Brorsen *et al.* 2001). Cattle markets follow cyclical patterns that are directly related to national cattle inventories; when cattle inventory is up, prices are low, and *vice versa* (Anderson *et al.* 1996). Climatic changes can lead to changes in the national cattle inventory, and therefore prices, as cattle are liquidated due to drought or other events. Furthermore, there are seasonal variations in cattle prices due to the differences in intra-annual supply and demand (Peel and Meyer 2002).

All of these factors make evaluations of cattle revenues temporally sensitive; however, it is possible to minimise the effect of the cattle market on such evaluations, which results in differences in revenue being attributable to cattle weight and the price slide. Given this, we expect that cattle turned off rangelands at lighter weights should sell for a higher price per unit of liveweight compared with cattle at heavier weights. Our objective was to determine differences in cattle revenues from a grazing experiment in northern Colorado (Wilmer *et al.* 2018*a*; Augustine *et al.* in press), while minimising any confounding effects from the cattle market.

The cattle revenues featured in this paper are net revenues (cattle sale price – cattle purchase price) and the authors' goal is to highlight how the cattle market has an effect on revenue generated. Profits (cattle net revenues – costs) are not addressed here, due to the substantial variation in cost structures of different operations and the availability of assistance programs in the USA to alleviate some costs of infrastructure for rotational grazing (Windh *et al.* 2019).

Materials and methods

Study background

Data for this study come from the Collaborative Adaptive Rangeland Management (CARM) experiment comparing continuous season-long grazing with an adaptively-managed, rotational grazing system (Wilmer *et al.* 2018*b*; Augustine *et al.* in press). This study is located at the Central Plains Experimental Range, a USDA Agricultural Research Service (ARS) Long-Term Agroecosystem Research (USDA 2017) network location in northern Colorado. The site is within the shortgrass steppe ecosystem, ~20 km north-east of Nunn, Colorado. Mean annual precipitation is 340 mm. Topography is characterised as gently rolling hills, consisting of Sandy and Loamy Plains ecological sites (NRCS 2007), and dominated by a mix of warm- and cool-season graminoids.

Within the CARM experiment, a group of 11 stakeholders from various disciplines – including ranchers, state and federal land managers, and representatives from non-governmental conservation organisations – are responsible for making the management decisions to achieve objectives including vegetation heterogeneity and biomass, grassland bird species abundance, and cattle production goals. Decisions include stocking rate, grazing sequence and rotation, and other decisions such as prescribed burning or the triggers used to indicate that the cattle need to move to the next pasture. Two grazing treatments were: (1) season-long grazing (mid-May to early October) with yearling steers (n = 21–28 steers per pasture across the five years; total herd size of 214–280 steers) grazing in each of ten, 130-ha (320 acre) pastures, and (2) rotational grazing with one large herd (214–280 yearling steers across the five years) sequentially 'pulse grazing' another set of ten, 130-ha pastures. Stocking rates between grazing treatments within each year were the same; stocking density (number of yearlings per individual pasture being grazed) was 10-fold higher for the pasture being grazed in the rotational grazing treatment whereas the other nine pastures were ungrazed during that grazing period (Wilmer *et al.* 2018*b*). Details on vegetation responses and livestock weight gains are described in Augustine *et al.* (in press).

Steers from both grazing treatments received the same standard of care, including mineral supplementation and veterinary care. The major cost variations between the treatments was fencing infrastructure, water infrastructure, and labour, which are described in detail in Windh *et al*. (2019).

Annual revenues and market analysis

Individual weights from yearling steers were obtained at the beginning (mid-May) and end (early October) of grazing seasons in 2014–2018. We used herd average starting and ending weights each year for the continuous and rotational grazing treatments in this market analysis.

Average season-start (mid-May) and season-end (early October) cattle weights were used to identify 25-pound (lb, ~11 kg) incremental weight classes (season-start: 650 and 675 lbs; season-end: 875, 925, 950, 975, and 1000 lbs (See Table 1 for metric equivalencies)). The market prices for each weight class came from the Livestock Market Information Centre (LMIC) localised to Colorado (LMIC 2018). Weekly reported prices spanned as far back as 1992. Prices were selected within two weeks of the season-start and season-end for each weight class.

To remove the impact of inflation across years, we normalised the 1992–2018 prices for each weight class to 2017 equivalent prices using the St Louis Federal Reserve producer price index (Federal Reserve Bank of St. Louis 2018). Price distributions for each weight class were then created using Palisade @Risk's (Palisade Corporation 2005) batch fit process, which fit the price data to a distribution and defined correlations across the prices. A Monte Carlo simulation was used, which was set to randomly draw 100 000 points from each of the weight class distributions. Using this now robust dataset of prices, we calculated the purchase value, gross revenue, and net revenue for each of the 100 000 iterations, as this helps mitigate the annual variations in the markets without compromising the effects of other market traits, such as the price slide.

To calculate annual revenues, we multiplied the average cattle weight per treatment with the simulated average price for the appropriate weight class (gross revenue) (e.g. for 2014, the actual average season-end weights of 998 and 945 lbs were multiplied by the simulated weight class prices for 1000 and 950 lb steers respectively) and subtracted the simulated purchase

Table 1. Conversion between Imperial and Metric units of weight

Imperial weights (lbs)	Metric conversion equivalent (kg)
25	11.3
650	294.8
675	306.2
875	396.9
925	419.6
950	430.9
975	442.3
1000	453.6

price, resulting in average net revenue per steer. Finally, each years' revenues were multiplied by the corresponding herd size to determine net revenues per grazing treatment for each year of the study. We analysed results using Tukey's HSD test to determine significance of price differences between treatments for each year, and within treatments among years.

Results

The number of weight data-points obtained from LMIC ranged from 14 to 25 for the seven weight classes, due to variability in cattle supplied to the market each year; the 1000 lb weight classes had the lowest number of data points as these large steers were not present in the Colorado market until 2003. Mean prices for each weight class decreased as weights increased, confirming the presence of a price slide. Prices indicate a steeper slide for the 600–700 lb classes than for the 900 lb classes (Fig. 1). The slide steepened again as the weights increased towards 1000 lbs. The high spring prices (600–700 lb weight class) not only reflect the effect of the price slide on lighter weight cattle, but there are also effects caused by seasonality, specifically because demand for low-weight steers is high at the beginning of the grazing season. This seasonality effect can be confirmed in Table 2, where lower spring weights and the higher fall (autumn) weights are highly correlated.

Weight gains were consistently 11–16% lower for the rotational compared with the continuous grazing treatment each year (Augustine *et al.* in press). Yearling cattle were 40–53 lb per head lighter in the rotational than continuous grazing treatment across years (Table 3). Despite consistent reductions

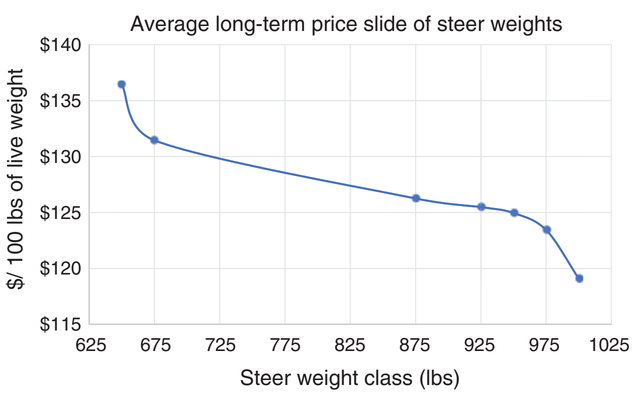

Fig. 1. Visual of the price slide resulting from the @Risk simulated average long-term prices for each steer weight class.

in weight gains with rotational grazing, differences in the simulated gross revenues per steer between grazing treatments ranged from US$43.46 to minus $5.72 across the study years. Gross revenues were highest for continuous grazing in 2014, 2016, and 2018, no differences were observed between grazing treatments in 2015, and gross revenue per steer was greater for rotational grazing in 2017. This variability in grazing treatment responses within and across years is attributable to complexity in (1) differences in end of grazing season weight classes between the grazing systems and (2) differential effects of price slide among weight classes (Fig. 1).

For example, in 2014, 2015, and 2017, end of grazing season weight classes were similar for continuous (1000 lb) and rotational (950 lb) grazing treatments; thus, differential effects of price slide are absent between these years, and these three years can be compared with each other using the same long-term simulated prices per weight class. Both 2016 and 2018, however, provide a different context for gross revenues, as they showcase the complexity in having both differences in end of grazing season weight classes between the grazing systems and differential effects of price slide among weight classes. In 2016, steers in the continuous grazing treatment ended in the 975 lb weight class vs the 925 lb weight class in the rotational grazing treatment. For 2018, the weight classes were lighter, due to the much reduced weight gains associated with the highest stocking rate (280 steers, Augustine *et al.* in press), with the 925 lb weight class for steers off the continuous grazing treatment, and 875 lb weight class for the rotational grazing treatment. The combination of these lower weight classes and differential effects of price slide (Fig. 1) resulted in larger differences in our simulated gross revenue ($35.28 in 2016 and $43.46 in 2018) for the continuous grazing treatment in these two years.

Net revenue per steer and total annual revenue followed the same pattern as gross revenue. Values were higher for continuous grazing than for rotational grazing in 2014, 2016, and 2018, similar in 2015, and greater for rotational grazing in 2017 (Table 3). Cumulatively, we expect the continuous grazing treatment to result in greater than $20 000 difference in total net revenues, a difference of 6% more returns compared with rotational grazing, over the five years.

Discussion

The scale of this study makes it applicable to local producers in northern Colorado, where the average ranch/farm size is 345 ha (USDA National Agricultural Statistics Service (NASS) Colorado Field Office 2012), as well as to other land managers in

Table 2. Correlation of Spring and Fall LMIC weight data

	650 lb (Spring)	675 lb (Spring)	875 lb (Fall)	925 lb (Fall)	950 lb (Fall)	975 lb (Fall)	1000 lb (Fall)
650 lb (Spring)	1.000						
675 lb (Spring)	0.973	1.000					
875 lb (Fall)	0.745	0.687	1.000				
925 lb (Fall)	0.855	0.798	0.912	1.000			
950 lb (Fall)	0.856	0.779	0.878	0.988	1.000		
975 lb (Fall)	0.841	0.767	0.862	0.986	0.994	1.000	
1000 lb (Fall)	0.742	0.699	0.851	0.965	0.982	0.991	1.000

Table 3. Average weights, and simulated gross, net, and total revenues per steer and per treatment
Statistically significantly differences (at 95% CI) are indicated, **

Year	Treatment	Average on weights (lbs)	Average purchase price	Average off weights (lbs)	Difference in average off weights	Gross revenue[A]	Difference in gross revenue	Average net revenue per steer[A]	Total # of steers per treatment	Total annual net revenue
2014	Continuous	684	$899.10	998	53 lbs.	$1188.67	$7.79**	$289.57	214	$61 967.98**
	Rotational			945		$1180.88		$281.78		$60 300.92**
2015	Continuous	667	$876.75	993	49 lbs.	$1182.71	$3.08	$305.97	224	$68 537.28
	Rotational			944		$1179.63		$302.88		$67 845.12
2016	Continuous	642	$876.03	974	44 lbs.	$1202.34	$35.28**	$326.31	234	$76 356.54**
	Rotational			930		$1167.06		$291.03		$68 101.02**
2017	Continuous	640	$873.3	994	42 lbs.	$1183.90	$-5.72**	$310.60	244	$75 786.40**
	Rotational			952		$1189.62		$316.32		$77 182.08**
2018	Continuous	645	$880.13	916	40 lbs.	$1149.49	$43.46**	$269.36	280	$75 420.80**
	Rotational			876		$1106.04		$225.91		$63 254.80**
Five year cumulative	Continuous									$358 069.00**
	Rotational									$336 681.60**

[A]Prices used are the average estimated price based on the Monte Carlo price distributions.

the western Great Plains of North America, since about half run yearlings (Kachergis *et al.* 2013), and two-thirds of managers in this region use extensive intra-growing season rotation with moderate (several weeks) grazing period durations (Roche *et al.* 2015). Diverse management strategies produce similar ecological outcomes in this region (Wilmer *et al.* 2018*a*). Ecological differences – vegetation composition, forage production – did not differ between the continuous and rotational grazing systems in this study, but livestock weight gains were consistently 11–16% lower with rotational grazing (Augustine *et al.* in press). In addition, costs do vary between the two grazing systems, with fencing, water infrastructure, and labour accounting for the most pronounced differences. The cost analysis of this same study can be found in Windh *et al.* (2019), where in addition to the 10 non-contiguous pastures used in the study, the results are also extrapolated out to contiguous parcels of land to be applicable to a wider audience.

Comparing net revenues between contrasting grazing systems – continuous, season-long and rotational – is more than a simplistic accounting of differences in livestock weight gains multiplied by a common selling price. We showcase this by calculating net revenues using long-term simulated average prices, start and end of grazing season weight classes, and incorporating differential effects of price slide among weight classes (Fig. 1). This complexity was evident in the five years of this grazing study as differences occurred across years in off-weight (end of grazing season) weight classes of yearling livestock between grazing systems, combined with the differential price slide adjustment between these weight classes each year.

Annual differences in the net returns across years between the two grazing systems were recorded. Net returns were greater for steers in the continuous grazing treatment in three of the five years, with one year having net returns that did not differ, and one year in which net returns were lower with continuous grazing. For the five years, we observed a 6% greater net return with grazing steers using continuous compared with the rotational grazing strategy. Net returns did not differ between continuous and rotational grazing at either moderate or heavy stocking rates in mixed-grass prairie of Wyoming (Hart *et al.* 1988), but in the tallgrass prairie of Oklahoma, net returns (US$/ha) were reduced by >50% with rotational grazing by yearlings at moderate stocking rates compared with continuous season-long grazing, and this percentage increased as stocking rates increased to heavy (McCollum *et al.* 1999). Neither of these studies appear to have accounted for the price slide in their methods and only used single year prices to determine revenues; therefore, we would argue that the condition of the cattle market in those study years likely had an effect on their findings.

Price slide effects on revenue differ among different livestock weight classes (Fig. 1). As a result, yearling steer off-weights (i.e. end of grazing season weights) can markedly affect revenue for grazing systems. The historical price slide in northern Colorado is magnified between 950 and 975 pounds, and the slide becomes even steeper from 975 to 1000 pounds, although there are fewer years associated with this weight class difference. As a result, producers should have an objective in this rangeland ecosystem of targeting a maximum off-weight from summer grazing of the 950-pound weight class; after the 950-pound weight class, the price decrease resulting from the price slide becomes more pronounced (Fig. 1). To accomplish this, producers can (1) sell yearling cattle earlier (e.g. early September rather than early October) to reduce the probability of these animals moving to the heavier weight classes (Irisarri *et al.* 2019) or (2) begin the grazing season in mid-May with lighter weight yearling cattle (e.g. <650 pounds used in this study). These results focus specifically on the long-term price slide between the different weight classes; annual variations occur in the price slide as a result of each year's market conditions and therefore the difference in prices caused by the price slide will vary annually.

Conclusion

One major consideration in adopting a new grazing strategy is understanding both changes in production and the related economic implications of those changes. Unlike most commodities, impacts to cattle production measures, such as weaning or yearling weights, cannot simply be scaled by a fixed livestock price; rather, the total revenues need to account for both the changes in weight and the associated impact to price per unit of weight. Despite consistent reductions of 11–16% in livestock weight gains with rotational *v.* continuous, season-long grazing (Augustine *et al.* in press), gross revenues per steer were highly variable (US$43.46 to minus $5.72) across the five study years due to ending weight class and the price slide impact. Further complexity is added as these price slide impacts vary with geography as well as within and across years. Rather than trying to determine which grazing strategy is 'best', it may be a better management strategy for operations to first determine the optimal ending weights for their operational goals, and second, the desired the time of year to market livestock if optimum ending weights cannot be met due to environmental conditions (e.g. drought).

Conflicts of interest

The authors declare no conflicts of interest.

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