Research Paper

Stocking rate and marketing dates for yearling steers grazing rangelands: Can producers do things differently to increase economic net benefits?

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On the Ground

- The combination of stocking rate and marketing date that maximizes average net return per head will not necessarily maximize average net return per hectare.
- The combination of stocking rate and marketing date that maximizes average net return per hectare often comes with risk-related tradeoffs, such as a higher risk and magnitude of negative net returns.
- The combination of stocking rate and marketing date will have implications (not quantified in this study) for the quantity of standing forage residue, which could be used for fall/winter grazing within the same year or for drought preparedness in the following year.

Keywords: economics, marketing, price slide, sale dates, semiarid rangeland, shortgrass steppe.

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Introduction

Producers grazing yearling cattle (i.e., stockers) on rangelands deal with both weather/climatic variability and market volatility. As a result, their decision-making about stocking rate and marketing date is highly dynamic and involves complex tradeoffs. The many permutations of stocking rate and marketing date decisions can be overwhelming to producers, especially if they perceive less flexibility to change stocking rate and marketing strategies, relative to grazing rotation decisions.[1] Rangeland research has emphasized economic and ecological evaluations of within-season grazing management decisions.[2-4] Decisions about within-season grazing season length and marketing timing have received less attention.

Stocking rate decisions can target maximization of weight gains per animal or per unit land area, or optimization of both,[5,6] with an eye on the overarching goal of maximizing animal returns to invested resources. Nonflexible (rigid) stocking rates within years (intra-annually) and across years (inter-annually)[7] can negatively impact annual returns because they limit producers' ability to take advantage of "good" years. Specifically, this strategy does not allow for the potential of achieving more returns if positive price movements occur or if forage conditions vary considerably from "average conditions." An alternative to rigid stocking rates is an adaptive stocking strategy, which has the potential to increase animal returns across variable climate and market conditions by allowing for greater flexibility.[8]

Marketing date decisions may be influenced or constrained by contractual obligations if cattle are contracted for delivery, length of grazing leases (if applicable), seasonality of labor for gathering cattle and trucking availability, cash flow and debt obligations, interest rates, seasonal price cycles, and other external factors (e.g., drought, pandemic, etc.).[8,9] Regional and temporal variability interactions of market prices can also impact returns, for example if cattle are sold at a time other than what is regionally conventional. Net returns over a 15-year period for yearling steers in northeastern Colorado were highest in early September, which is approximately 1 month earlier than when many yearlings are typically marketed off grass in this region.[2] Marketing earlier in August, however, consistently reduces net returns because feedlots are still awaiting delivery of current-year feed sources (e.g., silage and corn), and thus cannot easily accommodate yearlings marketed early.

Another reason for considering an earlier (albeit not too early) marketing date is that animal daily gains generally decline as the grazing season progresses.[10] Producers changing their marketing date to earlier in the grazing season would effectively reduce stocking rate for the typical grazing season. Therefore, producers marketing earlier in the year would need to increase the number of cattle for the shorter grazing season to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season. An alternative for producers would to be graze remaining forage in pastures later in the fall or in winter by other livestock to reach the full stocking rate. Another alternative would be to "grassbank" this extra forage as insurance against the always-present risk of dry/drought conditions occurring in the next year.[11]

Optimally, producers would have complete flexibility in marketing date and stocking levels. This would allow producers to adaptively graze yearlings in response to dynamic changes in the forage supply and quality due to weather/climatic variability. Adaptive grazing attempts to match animal demand to available forage quantity and quality to benefit average daily gains by cattle while also proactively taking advantage of any market changes that could be beneficial to the producer. Alas, the real world presents several challenges (rigid stocking rates, sale contracts, lease agreements, varying seasonal prices, etc.), making it difficult to achieve such flexibility.

Considering these real-world challenges noted above, here we present an evaluation of net returns from yearlings grazing the shortgrass steppe of Colorado. Our experiment involved nine combinations of three stocking rates (light, moderate, and heavy) and three marketing dates (mid-August, mid-September, and mid-October). Our analysis provides some practical guidance to producers regarding their grazing and marketing decisions for yearling steers in this semiarid rangeland ecosystem.

Methods

Our study used data obtained from the USDA-ARS Central Plains Experimental Range, a 6,270-ha (155,000 acres) site within the Long-Term Agroecosystem Research (https://ltar.usda.gov/) network, located at the northern end of the shortgrass steppe ecosystem in northeastern Colorado. Mean annual precipitation is 340 mm (13.4 inches) with 70% (239 mm [9.4 inches]) occurring during the May-to-September growing season.

Three long-term (since 1939) grazing treatment pastures (130 ha [320 acres] each), all dominated by the Loamy Plains ecological site (R067BY002CO), represent a gradient in stocking rate from light (9.3 animal unit days per hectare [AUD/ha; 3.8 AUD/acre]) to moderate (12.5 AUD/ha [5.1 AUD/acres]) to heavy (18.6 AUD/ha [7.5 AUD/acres]).[6] Vegetation in the heavy grazed pasture is dominated by blue grama (*Bouteloua gracilis*), a warm-season (C4) shortgrass, whereas the abundance of cool-season (C3) perennial grasses increases in the light grazed pasture.[12] Yearling steers grazing the pastures are a cross of British beef breeds, which were provided by local ranches. Individual animal weights were recorded when cattle arrived at the beginning of the grazing season (mid-May), and every 28 days during the grazing season until cattle were shipped out (typically in early October).

We evaluated marketing dates of mid-October (typical for the region), 1 month earlier (mid-September), and 2 months earlier (mid-August). We determined economic returns from the different stocking rate/marketing date combinations using livestock weight data from the beginning of the grazing season and from the 28-day weight measurements starting in mid-August. We used the average weight of all individuals in a treatment for each study year (2000-2019). We obtained feeder steer prices from the Livestock Marketing Information Center (LMIC), Colorado Auction Feeder Cattle Summary, weekly and monthly average prices, for medium and large frame #1 feeder steers, which were categorized by weight in increments of 22.7 kg (50 lb). For each study year, we calculated prices for each month during the grazing period (i.e., May through October) by averaging across all weekly reports available for that month. When the weekly reported price information was missing, we used the next geographically closest price report, namely from the Western Kansas (Dodge City) Cattle Auction Prices. We adjusted all prices to 2019 values using the Producer Price Index (Federal Reserve Economic Data, PPI, All Commodities).

Because livestock prices are highly variable across years, across months, and between weight classes within a year, our analysis incorporated a Monte Carlo simulation, using Palisade @Risk,[13] to create a probability distribution to represent each price series during this 20-year period.[14] We used 100,000 random draws from these probability distributions for analysis—a complete discussion of analysis can be found in Baldwin.[15] We used this approach on each production year ($n = 20$) to provide a more comprehensive economic assessment rather than the single year observed price values. Encompassing the variability in livestock weight gains across the 20-year period, combined with the Monte Carlo simulation for prices, results in a robust assessment of both production and economic variability for producers. We acknowledge that an artifact of the simulation process when $n = 100{,}000$ is that statistically significant results may detect differences that have limited biological significance.

For each marketing date, average gross returns were calculated as the difference between beginning (mid-May) value per head (i.e., average spring weight per head in kg multiplied by a simulated price in $/kg) and the marketing date-value per head (Table 1). Net returns were then determined by subtracting from average gross returns the following costs: interest paid (8%) on funds used to purchase cattle in the spring, charged for the duration of time yearlings grazed on pasture; miscellaneous costs (ranging from $11.95/head for light to $7.92/head for heavy) for salt, insecticides, and land taxes; and grazing fee costs ($18.50/AUM) for eastern Colorado.[16] Net returns for the nine combinations of stocking rate/marketing

Table 1
Summary of production data and cost inputs per head for each stocking rate/marketing date combination, using historical cattle weight data from study period (2000-2019) and miscellaneous costs including salt, insecticide spray, land tax costs, and a grazing fee. Changing from the typical October marketing date to one earlier in the grazing season (August or September) would effectively reduce stocking rate so increasing the number of cattle for the shorter grazing season would be needed to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season.

		Light			*Moderate*			*Heavy*	
Hd*259 ha^{-1}		30			40			60	
AUD*ha^{-1}		9.29			12.50			18.61	
Spring kg*hd^{-1}		279.5			279.0			278.9	
Marketing Date	*Aug*	*Sep*	*Oct*	*Aug*	*Sep*	*Oct*	*Aug*	*Sep*	*Oct*
Sale kg*hd^{-1}	380.3	409.6	411.8	370.8	396.8	398.5	366.7	392.0	391.7
Total Gain kg*hd^{-1}	100.9	130.1	132.3	91.8	117.8	119.5	87.8	113.1	112.8
ADG*hd^{-1}	0.84	0.87	0.73	0.76	0.79	0.66	0.73	0.75	0.63
Total Mgmt Cost*hd^{-1}	$64.04	$81.38	$96.60	$61.60	$78.40	$93.29	$59.62	$76.27	$90.82

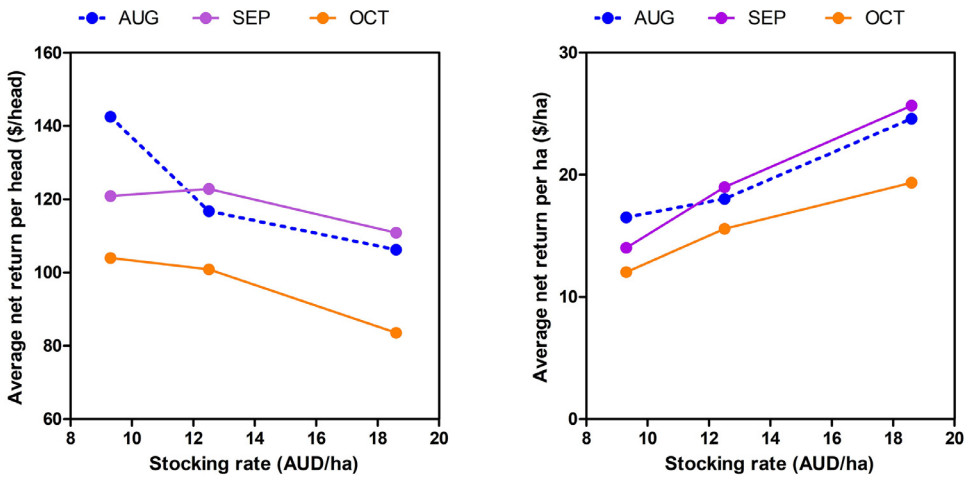

Figure 1. Average net returns per head and per hectare for each stocking rate/marketing date combination, using inflation-adjusted prices (US$, 2019) from Monte Carlo distributions for 2000 to 2019. Changing from the typical October marketing date to one earlier in the grazing season (August or September) would effectively reduce stocking rate so increasing the number of cattle for the shorter grazing season would be needed to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season.

date were compared using two-tailed Tukey, multiple means comparisons, with significance assumed at $P < 0.05$.

Results and discussion

The "business as usual" decision for yearlings in this rangeland ecosystem (i.e., moderate stocking; 12.5 AUD/ha [5.1 AUD/acres] and mid-October marketing date [Mod/Oct]) yielded the second lowest net return per head, $100.84/head (Fig. 1), with relatively high standard deviation (SD, $180.01/head) and coefficient of variation (CV; 1.79; Table 1). Net return per head was highest for light stocking (9.3 AUD/ha [3.8 AUD/acre]) and a mid-August marketing date ($142.50/head; Fig. 1), with a relatively low SD ($139.83) and the lowest CV (0.98; Table 1). This combination requires the animals to be marketed two months earlier than usual. Light/Aug would have been a 16% higher value than the second-best scenario of a moderate stocking rate and a September marketing date ($122.82/head). Net return *per head* was lowest for heavy stocking (18.6 AUD/ha [7.5 AUD/acre]) and a mid-October marketing date ($83.54/head; Fig. 1), with a relatively high SD ($178.31) and the highest CV (2.13). The inverse relationship between net return per head and stocking rate is not surprising because light stocking rates promote high individual animal gains, whereas heavy stocking rates often result in lower individual animal gains.[5,17] Moreover, targeting lower stocking rates and selling earlier than usual would decrease the interannual variation in the price sellers can achieve. Note, however, a producer's goal might not be to maximize net return per head, rather to maximize net return to the operation as a whole, or to some fixed resource, such as the land base. For this reason, next we analyze how well the nine combinations perform in terms of net return per hectare.

The "business as usual" combination of stocking rate and marketing date, Mod/Oct, for yearlings in this ecosystem yielded the third lowest net return per hectare ($15.57/ha

Table 2
Average net return per head and summary statistics for each stocking rate/marketing date combination, using inflation-adjusted prices (US$, 2019) from Monte Carlo distributions for 2000-2019. Different superscript letters in Average net return per head indicate significant differences between Stocking Rate/Marketing Date combinations at $P < 0.05$. Numbers in parentheses represent negative net returns (i.e., costs exceed gross returns). Changing from the typical October marketing date to one earlier in the grazing season (August or September) would effectively reduce stocking rate so increasing the number of cattle for the shorter grazing season would be needed to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season. CV indicates coefficient of variation; SD, standard deviation.

Stocking Rate/Marketing Date	Average	SD	CV	5th Percentile	95th Percentile
Light/Aug	$142.50 [a]	$139.84	0.98	($ 85.57)	$364.82
Mod/Sep	$122.82 [b]	$145.74	1.19	($114.39)	$355.77
Light/Sep	$120.87 [c]	$147.09	1.22	($115.36)	$356.08
Mod/Aug	$116.70 [d]	$138.20	1.18	($110.80)	$334.04
Heavy/Sep	$110.84 [e]	$144.91	1.31	($126.22)	$341.25
Heavy/Aug	$106.18 [f]	$137.56	1.30	($121.15)	$321.52
Light/Oct	$103.96 [g]	$181.02	1.74	($182.52)	$400.65
Mod/Oct	$100.84 [h]	$180.01	1.79	($185.44)	$394.34
Heavy/Oct	$ 83.54 [i]	$178.31	2.13	($201.72)	$372.85

[$6.30/acre]; Fig. 1) among the nine combinations (Table 2). Highest net return per hectare was observed with the three heavy stocking rates. A mid-September marketing date yielded the highest result ($25.67/ha [$10.39/acre]), which was 4.4% higher than Heavy/Aug ($24.59/ha [$9.95/acre]) and 32.7% higher than Heavy/Oct ($19.35/ha [$7.83/acre]). Lowest net return per hectare was observed for light stocking and a mid-October marketing date (Light/Oct), $12.03/ha ($4.84/acre; Fig. 1). An important aspect of selling in October, independent of stocking rate, is the maximization of interannual variation of net returns, which highlights the price volatility during this time of year. Increases in interannual variation during the grazing season also increase the potential loss of revenue to ranchers in extreme situations.

With light stocking rates, higher individual animal performance does not compensate for the lower number of yearlings, thus weight gain and net return per unit area are lower.[5,17,18] Combining the relatively low beef production with a relatively late marketing date (mid-October) results in a double-lost opportunity for producers—lower total weight gains for which the producers receive a lower price per weight unit (because supply is typically higher such that price is reduced at this time of year in the region).

In contrast, the combination of heavy stocking and mid-September marketing generates the highest net return per hectare for two reasons. First, a larger number of yearlings more than compensates for lower individual animal weight gains, resulting in more total weight gain and weight gain per hectare.[5,17,18] This is only achievable, however, because the mid-September marketing date removes steers from rangelands early enough to avoid the largest reductions in individual weight gains at the end of the grazing season.[2] If the heavy-stocked steers are instead kept for another month and marketed in mid-October, then reductions in individual weight gains become severe enough to offset the benefit of having more animals, generating less total weight gain (Table 1), in addition to receiving a lower price per unit.

What about net returns for producers who do not have the flexibility to choose from among all nine stocking rate/marketing date combinations? Perhaps they are restricted, for any number of reasons, to a single stocking rate or to a single marketing date. To provide insights for such producers, we looked at each stocking rate and examined how marketing date influences net return per hectare. Next, we looked at each marketing date to see which stocking rate generated the best net return per hectare.

For producers constrained to using a light stocking rate, the mid-August marketing date provided the highest net return per hectare ($16.51/ha [$6.68/acre]; Fig. 1), on average, and generated positive net returns in 87% of all years (Table 2). For producers constrained to using a moderate stocking rate, mid-September marketing provided the highest net return per hectare, ($18.98/ha [$7.68/acre]) on average and generated positive net returns in 83% of all years. If the stocking rate is heavy, mid-September marketing provided the highest net return per hectare, ($25.67/ha [$10.39/acre]) on average and generated positive net returns in 81% of all years.

Additionally holding animals longer also increased the risk and level of potential loss (Tables 2 and 3, specifically the "% >0" and "5th Percentile" rows). For example, even though holding a moderate stocking rate into September outperformed an August marketing date, on average, (i.e., $18.98/ha for September vs. $18.01/ha for August [$7.68/acre vs. $7.29/acre]) the potential risk and size of loss for marketing in September was higher than marketing in August. September had a 5% risk of losses being $17.67/ha ($7.15/acre) or worse, and August had a 5% risk of losses being $17.12/ha ($6.93/acre) or worse.

In addition to comparing downside risks, there are upside risks to consider as well, and ultimately an individual's risk preferences will determine which combination of stocking rate and marketing date is best for them. For example, while an October marketing date for moderate stocking, on average, generated lower net return per hectare than market-

Table 3
Average net return per hectare for three stocking rate treatments (light, moderate, and heavy) for three different marketing dates (mid-August, mid-September, and mid-October), ranking of values from highest (1) to lowest (9), percent of distributions greater than the zero, and 5th and 95th percentiles. Changing from the typical October marketing date to one earlier in the grazing season (August or September) would effectively reduce stocking rate so increasing the number of cattle for the shorter grazing season would be needed to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season.

	Light			Mod			Heavy		
	Aug	Sep	Oct	Aug	Sep	Oct	Aug	Sep	Oct
Average	$16.51	$14.01	$12.03	$18.01	$18.98	$15.57	$24.59	$25.67	$19.35
Rank	6	8	9	5	4	7	2	1	3
% > $0.00	86.9%	82.2%	74.1%	83.0%	82.8%	73.7%	81.0%	80.7%	70.3%
5th Percentile	($9.91)	($13.37)	($21.15)	($17.12)	($17.67)	($28.64)	($28.07)	($29.23)	($46.88)
95th Percentile	$43.74	$41.24	$48.88	$51.60	$54.96	$60.91	$74.48	$79.05	$86.39

ing in either August or September, October marketing had the highest potential payoff (i.e., the 95th percentile). That is, October had a 5% chance of generating a net return per hectare of $60.91 ($24.65/acre) or more, which was over 10% larger than that for a September marketing date (i.e., a 5% chance of net return per hectare being only $54.96 [$22.24/acre] or more). However, October marketing also had a more severe worst-case scenario (i.e., 5th percentile) than September marketing. More specifically, October had a 5% chance of losing $28.64/ha ($11.50/acre) or worse, whereas September had a 5% chance of losing $17.67/ha ($7.15/acre) or worse. The marketing decision clearly becomes more complicated when a producer considers both upside and downside risks, in addition to average net return. Rarely does one option perform best in all three economic measures.

For producers constrained to marketing in mid-August, mid-September, or mid-October, a heavy stocking rate provided the highest average net return per hectare ($24.59/ha [$9.95/acre] for August, $25.67/ha [$10.39/acre] for September, and $19.35/ha [$7.83/acre] for October) with positive returns in 81% of all years for August and September but declined to 70% for October (Table 3). However, even though heavy stocking outperformed moderate and light stocking for all months both on average and for the best-case scenario (i.e., 95th percentile), it had a lower chance of breaking even, and had more severe worst-case scenarios (i.e., its 5th percentile value was more negative than that of moderate stocking and light stocking). Again, management options that perform best on average often involve some risk-related tradeoff.

Conclusions and implications

Stocking rate and marketing date decisions for producers with yearling steer operations are complex, and the factors influencing those decisions are interrelated. Tradeoffs often exist between maximizing average net returns per hectare and minimizing different forms of downside risk. Exogenous events, such as drought, corn prices, fire at a packing plant, disease outbreak, etc., can substantially impact forage conditions and/or market prices thereby creating uncertainty for producers.

Our findings on net return per hectare, using 20 years of livestock weight gain data and Monte Carlo simulations from probability distribution of prices, provide benchmarks and comparative insights for producers trying to evaluate different combinations of stocking rate and marketing date for yearlings in the shortgrass steppe rangeland ecosystem. Across all three marketing dates analyzed, heavy stocking rates produced the highest net returns on average, but with substantial economic variability and risk across years, as returns fluctuate widely and unexpectedly due to many sources including precipitation. Producers need to be cognizant that short-term (few years) profit gains of heavy grazing practices[12,19,20] need to be considered within the context of altered vegetation composition and structure and forage production occurring with heavy compared with light stocking implemented over several decades Also, heavy stocking in 1 year may reduce the operation's forage resources and grass bank (i.e., drought preparedness) in the following year.

If a producer in the study region were to implement a marketing date earlier than the typical mid-October, stocking levels in the pastures would be reduced due to reducing the duration of grazing (i.e., number of days). For example, the same numbers of yearlings in pastures for the full grazing season (removal in early-October for a mid-October marketing) at a heavy stocking rate would result in a moderate stocking rate if steers were removed in mid-September, and a light stocking rate if mid-August was the removal date. Producers may realize higher individual animal gains with reduced stocking rates, which can be achieved by removal of animals in the grazing season for an earlier marketing date. Additionally, flexibility in marketing date can allow producers to avoid late-season reductions in individual animal weight gains[5,17] and possible depletion of forage resources to a level that may induce ecosystem degradation and financial risk. Producers could incorporate flexibility in their between-year stocking rates by changing marketing dates. Benefits associated with removing cattle early, including the likely higher individual

Table 4
Average net return per hectare for three marketing dates (mid-August, mid-September, and mid-October) for three different stocking rates (light, moderate, and heavy), ranking of values from highest (1) to lowest (9), percent of distributions greater than the zero, and 5th and 95th percentiles. Changing from the typical October marketing date to one earlier in the grazing season (August or September) would effectively reduce stocking rate so increasing the number of cattle for the shorter grazing season would be needed to maintain the same stocking rate as with a full grazing season. This would result in a higher stocking density for the shorter grazing season.

	Aug			Sep			Oct		
	Light	Mod	Heavy	Light	Mod	Heavy	Light	Mod	Heavy
Average	$16.51	$18.01	$24.59	$14.01	$18.98	$25.67	$12.03	$15.57	$19.35
Rank	6	5	2	8	4	1	9	7	3
% > $0.00	86.9%	83.0%	81.0%	82.2%	82.8%	80.7%	74.1%	73.7%	70.3%
5th Percentile	($9.91)	($17.12)	($28.07)	($13.37)	($17.67)	($29.23)	($21.15)	($28.64)	($46.88)
95th Percentile	$42.24	$51.60	$74.48	$41.24	$54.96	$79.05	$48.88	$60.91	$86.39

animal gains, are not accounted for in our analysis. Another benefit would be the value of additional forage residue for grass banking. Residue could be fall and/or winter grazed by other livestock or could remain stockpiled to reduce risk associated with dry/drought conditions the following growing season.[21]

Rather than reducing stocking rate with an earlier marketing date, producers could choose to maintain the same stocking rate across years. To do this, producers would need to increase the numbers of yearlings in pastures proportional to the percentage reduction in the grazing season duration associated with the earlier marketing date. For example, producers using a heavy stocking rate in a 259-ha (640-acre) pasture are grazing 60 yearlings for the full grazing season, about 140 days (Table 1). If the producer chooses to reduce the grazing season duration by 30 days, or 21%, for a mid-September market date, they would need to increase the number of yearlings to 73 head to maintain the heavy stocking rate. If a mid-August marketing date was chosen, then the number of yearling steers would increase to 86 for the shorter grazing season with a heavy stocking rate. Increasing the numbers of yearlings means that stocking density (i.e., number of animals per unit land area) increases, which has negative effects on individual animal weight gains.[22] Marketing options such as use of the futures market and forward contracting can stabilize the price received for cattle in a price-volatile market.[23]

A producer's willingness to change their stocking rate, marketing date, or both will be influenced by average net returns, associated risk, risk preference, financial situation, and attitude toward change. A beginning producer who is highly leveraged might decide to employ stocking-rate and marketing-date strategies most likely to help them consistently reduce debt. They might choose a combination with the least amount of downside risk and greatest chance of positive net returns, even if the expected return is lower than that for another combination with higher expected return but larger and likely more downside risk. Alternatively, a long-tenured, highly solvent producer might feel less risk averse in the short term and be interested in increasing average net returns, despite larger and more likely downside risk. Each individual producer has unique characteristics, circumstances, constraints, marketing options (e.g., forward contracting), and incentives, as well as other management goals and considerations related perhaps to production, conservation, quality of life, or intergenerational transfer. These factors influence decisions about an "optimal" stocking rate and marketing date. Our analysis sheds light on some important economic components for producers' consideration; however, it cannot prescribe a universally optimal strategy (Table 4).

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships, which may be considered as potential competing interests. The authors certify that they have no financial interest in the subject matter discussed in the manuscript. H.W. is a current member of the Rangelands Steering Committee but was not involved in the review or decision process for this manuscript.

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