Supplementary Material: Model Parameters [1]

Table S1. Initialization parameters.

Model Parameter	Distribution Type	Distribution Parameters	Reference	Notes
Iterations	Deterministic	1000	User-defined	The number of iterations the user wishes to run an *i* production year simulation
Initial breeding herd size at calving	Deterministic	100	User-defined	
Breeding herd size goal	Deterministic	100	User-defined	The breeding herd size the user wishes to achieve.
Years to herd size	Deterministic	1	User-defined	The number of years the user wishes to pass in achieving the breeding herd size goal.
Initial heifer replacement rate	Deterministic	0.125	User-defined (default from Wittum et al. [2], USDA [3], Cushman et al. [4], Ringwall [5], and expert opinion)	
Breeding season start	Deterministic	June 1st	User-defined	
Breeding season end	Deterministic	August 3	User-defined	

Table S2. Four-year rolling average Angus genetic trend for birth weight and weaning weight from 1992 to 2018.

Year	Angus Birth Weight EBV (kg): Four Year Rolling Average	Angus Weaning Weight EBV (kg): Four Year Rolling Average
1992	1.66	10.9
1993	1.73	12.3
1994	1.75	13.6
1995	1.73	14.8
1996	1.70	16.1
1997	1.70	17.3
1998	1.70	18.6
1999	1.73	20.2
2000	1.73	21.6
2001	1.73	23.2
2002	1.73	24.5
2003	1.73	25.9
2004	1.70	27.2
2005	1.68	28.4
2006	1.66	29.7
2007	1.61	31.1
2008	1.59	32.7
2009	1.54	34.3
2010	1.50	35.9
2011	1.45	37.2
2012	1.41	38.6
2013	1.36	40.0
2014	1.32	41.3
2015	1.29	42.9
2016	1.25	44.5
2017	1.23	46.3
2018	1.18	48.1

Adapted from American Angus Association [6]
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Table S3. Genetic correlations.

Traits	Genetic Correlation	Reference
Weaning Weight: Mature Cow Weight	0.44	American Angus Association [6]
Birth Weight: Weaning Weight	0.29	American Angus Association [6]
Gestation: Birth Weight	0.30	Gregory et al. [7]
Milk Production: Mature Cow Weight	0.14	Morris and Wilton [8]

Table S4. Manhattan, KS January through August Cumulative Precipitation.

Year	Jan- Aug Cumulative Precipitation, mm
1995	884.7
1996	599.7
1997	512.3
1998	613.4
1999	774.7
2000	391.9
2001	782.8
2002	468.1
2003	649.2
2004	826.5
2005	671.8
2006	665.5
2007	879.3
2008	840.0
2009	748.3
2010	678.2
2011	541.8
2012	443.5
2013	574.0
2014	606.5
2015	782.6
2016	787.6
2017	642.9
2018	507.5

From High Plains Regional Climate Center [9]

Table S5. Diet total digestible nutrient (TDN) concentrations for winter feed, supplement and forage.

Diet	Month	TDN, %
Winter feed	Jan-Dec	57
Supplement	Jan-Dec	70
Bluestem Forage		
	Jan-Mar	43
	Apr	67
	May	63
	Jun	59
	Jul	55
	Aug	51
	Sep	47
	Oct-Dec	43

Calculated using estimates from National Academies of Science, Engineering, and Medicine [10] and Kuhl et al. [11].

Table S6 Daily maximum DMI as percent of SBW and animal production category.

Animal Category	Maximum Daily DMI (percent of SBW)
Post-weaning Non-pregnant Replacement Heifer	2.7
Bred Yearling Heifer	2.7
Two-Year-Old Cow	2.3
Three-Year-Old Cow	2.3
Mature Cow (>= 4-Years-Old)	2.2

SBW = shrunk body weight

Table S7. BCS and corresponding body fat composition, percent of MSBW, and Mcal per kg of EBW loss and EBW gain.

BCS	Body Fat, % EBW	Percent of MSBW (BCS 5)	Mcal per kg EBW Loss	Mcal per kg EBW Gain
1	3.77	71.6	--	4.94
2	7.54	78.7	4.94	5.57
3	11.30	85.8	5.57	6.21
4	15.07	92.9	6.21	6.84
5	18.89	100.0	6.84	7.48
6	22.61	107.1	7.48	8.12
7	26.38	114.2	8.12	8.74
8	30.15	121.3	8.74	9.36
9	33.91	128.4	9.36	--

Adapted from National Academies of Science, Engineering, and Medicine [10]

MSBW = mature shrunk body weight; EBW = empty body weight

Table S8. Maximum winter feed intake by animal production category.

Animal Production Category	Maximum Winter Feed Intake, kg/d
Post-weaning Non-pregnant Replacement Heifer	13.0
Bred Yearling Heifer	13.0
Two-Year-Old Cow	16.0
Three-Year-Old Cow	16.0
Mature Cow (>= 4-Years-Old)	16.0

Table S9. Reproductive cyclicity.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Postpartum Interval Primiparous Cows, d			Ciccioli et al. [12], Berardinelli et al. [13], Endecott et al. [14], and expert opinion
BCS 1	Pert	(350, 350, 350)	
BCS 2	Pert	(135, 150, 165)	
BCS 3	Pert	(85, 100, 115)	
BCS 4	Pert	(65, 80, 95)	
BCS 5	Pert	(55, 70, 85)	
BCS 6	Pert	(45, 60, 75)	
BCS 7	Pert	(30, 45, 60)	
BCS 8	Pert	(30, 45, 60)	
BCS 9	Pert	(30, 45, 60)	

BCS = body condition score (1 = very thin, 9 = obese)

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Table S9 (*cont*). Reproductive cyclicity.

Model Parameter	Distribution Type	Distribution Parameters	Reference
PostPartum Interval Multiparous Cows, d			Graham [15],Rutter and Randel [16], Houghton et al. [17], Cushman et al. [18], Lents et al. [19], and expert opinion
BCS 1	Pert	(350, 350, 350)	
BCS 2	Pert	(135, 150, 165)	
BCS 3	Pert	(75, 90, 105)	
BCS 4	Pert	(55, 70, 85)	
BCS 5	Pert	(45, 60, 75)	
BCS 6	Pert	(35, 50, 65)	
BCS 7	Pert	(30, 35, 50)	
BCS 8	Pert	(30, 35, 50)	
BCS 9	Pert	(30, 35, 50)	

Dystocia Probability per Parturition			McDermott et al. [20], USDA [21], and expert opinion
Multiparous Cow	Normal	(0.05, 0.01, lower = 0)	
Primiparous Cow-Calf birthweight < 40.82 kg	Normal	(0.08, 0.01, lower = 0)	
Primiparous Cow-Calf birthweight >= 40.82 kg	Normal	(0.5, 0.01, lower = 0)	

BCS = body condition score (1 = very thin, 9 = obese)

Table S9 (*cont*). Reproductive cyclicity.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Additional PPI resulting from dystocia, d	Normal	(10, 2, lower = 0)	Doornbos et al. [22], Bellows et al. [23], and expert opinion.
Pregnancy probability at d equal to estrous cycle length after breeding			Spell et al. [24], Chagas et al. [25], Aherin et al. [26], and expert opinion
Heifers	Normal	(0.71, 0.01, upper = 0.8)	Cundiff et al. [27]
Primiparous Cows	Normal	(0.61, 0.01, upper = 0.8)	Cundiff et al. [27]
Multiparous Cows	Normal	(0.71, 0.01, upper = 0.8)	Cundiff et al. [27]

Table S9 (*cont*). Reproductive cyclicity.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Daily mean probability of returning to cyclicity after establishing pregnancy			
d 25 to d 45	Normal	(0.002, 0.0002, lower = 0)	Whittier et al. [28], Lamb et al. [29], Aherin et al. [26], and expert opinion.
d 46 to d 65	Normal	(0.0005, 0.00002, lower = 0)	Whittier et al. [28], Lamb et al. [29], Aherin et al. [26], and expert opinion.
d > 65	Normal	(0.0001, 0.00002, lower = 0)	Dziuk and Bellows [30], van Wagtendonk-de Leeuw et al. [31], Aherin et al. [26], and expert opinion
Individual Gestation length	Normal	(285, 7)	Expert opinion

Table S10. Culling.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Pregnancy determination (days after breeding season end)	Deterministic	60	User-defined
Age of oldest calf at weaning, d	Deterministic	220	User-defined
Maximum cow age	Deterministic	13	User-defined
Minimum culling percentage by cow age (involuntary and voluntary combined), yr		culls within age/exposed within age, percent	Wittum et al. [2], USDA [3], Cushman et al. [4], Ringwall [5], and expert opinion
1	Deterministic	5	
2	Deterministic	10	
3	Deterministic	6	
4	Deterministic	6	
5	Deterministic	6	
6	Deterministic	6	
7	Deterministic	6	
8	Deterministic	6	
9	Deterministic	8	
10	Deterministic	10	
11	Deterministic	40	
12	Deterministic	50	
13	Deterministic	100	

Table S11. Morbidity and mortality.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Daily probability of preweaned calf morbidity			Wittum et al. [2], Sanderson and Dargatz [32], USDA [3], and expert opinion
Dystocia and neonatal period (d 1-3 after parturition)	Normal	(0.01, 0.005, lower = 0)	
No dystocia and neonatal period (d 1-3 after parturition)	Normal	(0.005, 0.001, lower = 0)	
Dystocia and post-neonatal period to weaning	Normal	(0.0004, 0.00001, lower = 0)	
No dystocia and post-neonatal period to weaning	Normal	(0.0002, 0.00001, lower = 0)	

Table S11 (*cont*). Morbidity and mortality.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Daily probability of preweaned calf mortality			Laster and Gregory [33], Patterson et al. [34], Wittum et al. [2], USDA [3], and expert opinion
Dystocia, no morbidity, and neonatal period	Normal	(0.06, 0.005, lower = 0)	
Dystocia, morbidity, and neonatal period	Normal	(0.1, 0.0005, lower = 0)	
No dystocia, no morbidity, and neonatal period	Normal	(0.01, 0.001, lower = 0)	
No dystocia, morbidity, and neonatal period	Normal	(0.05, 0.001, lower = 0)	
Dystocia, no morbidity, and post-neonatal period to weaning	Normal	(0.0001, 0.00001, lower = 0)	
Dystocia, morbidity, and post-neonatal period to weaning	Normal	(0.001, 0.0001, lower = 0)	
No dystocia, no morbidity, and post-neonatal period to weaning	Normal	(0.0001, 0.00001, lower = 0)	
No dystocia, morbidity, and post-neonatal period to weaning	Normal	(0.0005, 0.0001, lower = 0)	

Table S11 (*cont*). Morbidity and mortality.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Daily probability of postweaning mortality			USDA [3], and expert opinion
Dystocia at birth	Normal	(0.00005, 0.00001,lower = 0)	
No Dystocia at birth	Normal	(0.000025, 0.00001,lower = 0)	
Daily probability of mature mortality	Normal	(0.000025, 0.00001,lower = 0)	USDA [3], and expert opinion
Percent reduction in WW from morbidity	Normal	(0.065, 0.0065)	Wittum et al. [2]

WW = weaning weight

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Table S12. Calf growth.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Calf birthweights			
Bull calf, two-year-old dam mean birthweight adjustment, kg	Deterministic	-3.63	Beef Improvement Federation [35]
Bull calf, three-year-old dam mean birthweight adjustment, kg	Deterministic	-2.27	Beef Improvement Federation [35]
Bull calf, four-year-old dam mean birthweight adjustment, kg	Deterministic	-0.91	Beef Improvement Federation [35]
Bull calf, eleven-year-old and older dam mean birthweight adjustment, kg	Deterministic	-1.36	Beef Improvement Federation [35]

Table S12 (*cont*). Calf growth.

Model Parameter	Distribution Type	Distribution Parameters	Reference
Calf birthweights			
Heifer calf, two-year-old dam mean birthweight adjustment, kg	Deterministic	-3.17	Beef Improvement Federation [35]
Heifer calf, three-year-old dam mean birthweight adjustment, kg	Deterministic	-2.27	Beef Improvement Federation [35]
Heifer calf, four-year-old dam mean birthweight adjustment, kg	Deterministic	-0.91	Beef Improvement Federation [35]
Heifer calf, eleven-year-old and older dam mean birthweight adjustment, kg	Deterministic	-1.36	Beef Improvement Federation [35]

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