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Optimization of "herd-in-calf rate" with respect to the length of the post-partum anoestrous period in Angus cows suckling calves

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ABSTRACT

A model is constructed to give the probability of conception conditional on the previous calving date in a herd of Angus beef cows. The parameters of the model are the anoestrous period following calving, the length of the oestrous cycle (both independent random variables having normal probability distributions), and the conception rate at each oestrus occurring within the mating period. The anoestrous period is assumed to depend linearly on the calving date.

The observed calving distributions of 10 consecutive years in a beef cow herd were used in the model to estimate the optimum herd conception rate for the parameters "anoestrous period" and "regression between anoestrous and calving date".

A conception rate at each oestrus during mating of 0.7 was assumed. Anoestrous period was constrained by experiment to between 50 and 90 days. The regression between anoestrous and calving date was constrained to between 0 and -0.5 days per day. These constraints constituted a non-linear programming problem.

The optimum values for the anoestrous period under these conditions lay between 60 and 70 days for the 10 years of data analysed. It is shown that the anoestrous period has very little effect on herd in calf rate below 70 days in the calving distributions considered. It is suggested that resources should not be used to reduce the anoestrous period below 70 days.

The anoestrous period tended to have a greater effect on herd conception rate if less than 90% of the herd had calved before day 40 of the calving period, and the anoestrous period was longer than 70 days.

Beginning mating 7 days earlier generally increased the herd conception rate by about 1% over the 10 years considered.

Keywords Anoestrous, calving date, mating period, conception, optimization.

INTRODUCTION

After calving a cow has an anoestrous period of variable duration. In cows suckling calves this anoestrous varies between 50 and 80 days, where cows calving later in the herd have a shorter anoestrous period than cows calving earlier in the herd. Cows of the British beef breeds commonly used as beef-breeding cows in New Zealand, have a gestation length averaging 282 days (Preston and Willis, 1970). This means that an early-calving cow needs to conceive on the first oestrus after calving if her calving date is to be maintained annually.

The probability of conception of an early-calving cow is dependent upon an interaction between her calving date, the beginning of the mating period, and the period of anoestrous. For example, to maintain an annual date when calving is expected to begin in the herd (day 1) mating should begin on day 83. Then the

optimum time for a cow which calved on day 1 to show oestrous would be on day 83. This means having either an anoestrous period of 83 days, or an anoestrous of 62 days and a 21-day oestrous cycle etc. But an anoestrous between 63 days and 82 days would be less favourable than an anoestrous of 83 days because oestrous would occur some time after herd mating begins.

A complex situation exists. It is the purpose of this paper to examine this problem by the construction of a model for the probability of conception in a herd of Angus cows suckling calves.

THE MODEL

The period of post-partum anoestrous is assumed to be a random variable having a normal distribution with mean $p + b(t - \bar{t})$, and variance σ_p^2 . Here p is the average herd anoestrous period, b is the regression coefficient

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TABLE 1 Numbers of cows calving and the cumulative percentage calving distribution (10-day intervals) in each of the years used in the model.

Year	Number	Expected Day of Calving							
		<9	<10	<20	<30	<40	<50	<60	≤70
1970	69	13	42	62	77	84	94	94	100
1971	102	14	38	65	74	84	92	96	100
1972	108	3	24	58	80	89	97	100	
1973	95	3	27	63	83	91	98	98	100
1974	92	8	15	60	83	90	97	98	100
1975	85	5	40	71	80	99	100		
1976	84	10	35	57	75	99	100		
1977	122	3	37	71	87	97	100		
1978	131	0	5	51	86	97	100		
1979	104	0	19	52	72	89	100		

between calving date and the anoestrous period (usually negative), t is the calving date of the cow under consideration and \bar{t} is the average herd calving date. After anoestrous the length of the oestrous cycle is assumed to be a random variable normally distributed with mean 21 days and variance σ_c^2 . The length of the oestrous cycle and the period of anoestrous are assumed to be independent.

Mating takes place over a fixed period of 63 days (3 average oestrous cycles), from day 83 to day 146, counting day 0 as the expected day for the herd to begin calving. During mating a cow which experiences oestrous may conceive with probability c , ($0 \leq c \leq 1$).

Given that a cow calves on day t the conditional probability that she has her first post-calving oestrous during the mating period will be:

$$P[1] = \int_{83}^{146} N(p + b(t - \bar{t}), \sigma_p^2) dz$$

The probability that a cow has her second post-calving oestrous during the mating season will be:

$$P[1] = \int_{83}^{146} N(p + b(t - \bar{t}) + 21, \sigma_p^2 + \sigma_c^2) dz$$

and the probability that a cow has her m^{th} post-calving oestrous during the mating season will be:

$$P[1] = \int_{83}^{146} N(p + b(t - \bar{t}) + 21(m-1), \sigma_p^2 + (m-1)\sigma_c^2) dz$$

The probability that a cow will conceive at her first oestrous after the mating season will be $cP[1]$. The probability that a cow will conceive at her second oestrous after the mating season will be:

$$P[2] - cP[1 \cap 2]$$

where $P[1 \cap 2]$ is the probability of having a second oestrous during the mating season given that the cow has already had a first oestrous during the mating season. Now

$$P[1 \cap 2] = P[1].P[2:1]$$

where $P[2:1]$ is the conditional probability of having second oestrous during the mating season given that the cow has already experienced first oestrous during the mating season. But the length of the oestrous cycle is assumed independent of the anoestrous period so $P[2:1] = P[2]$ and

$$p[1 \cap 2] = P[1]P[2]$$

TABLE 2 Optimum parameters for anoestrus and optimum herd conception rates (%) in each of the years recorded.

Year	Herd in-Calf Rate (%)	Without Regression	Anoestrus with Regression (days)	Regression Coefficient days/day	Anoestrus Without Regression Coefficient (days)
1970	93.0	(90.3)	64.6	-0.31	50.2
1971	93.4	(90.8)	64.1	-0.31	50.2
1972	94.5	(93.1)	63.1	-0.34	55.2
1973	94.1	(92.6)	69.0	-0.30	63.1
1974	94.4	(93.2)	67.2	-0.31	64.7
1975	94.7	(94.1)	65.5	-0.30	60.6
1976	94.5	(93.4)	68.6	-0.45	62.2
1977	94.8	(93.8)	65.8	-0.48	61.4
1978	95.0	(94.1)	59.4	-0.36	59.9
1979	94.1	(93.3)	64.3	-0.41	50.2

Thus the probability of a cow conceiving at her second oestrous cycle after calving will be:

$$c\{ P[2]-cP[1]P[2] \} = cP[2]\{ 1 - cP[1] \}$$

Similarly the probability of a cow conceiving at the m th oestrous cycle after calving will be:

$$cP[m]\{ 1 - cP[m-1](1-cP[m-2] (1-cP[m-3] ...)) \}$$

For the model to be useful certain constraints must be placed upon the values of the parameters. These constraints have been established by experiment. The average herd anoestrus interval for cows suckling calves has been reported as between 50 and 90 days, and the regression coefficient between anoestrus and calving date has been reported between 0 and -0.5 days per day under New Zealand grazing conditions (Knight and Nicoll, 1978, Morris *et al.*, 1978; Nicoll, 1979; Pleasants and Barton, 1985). So in the model the parameter p is constrained between 50 and 90 days, and the parameter b is constrained between 0 and -0.5 days per day. Furthermore, the shortest anoestrus interval observed in a late-calving cow has been 44 days (Pleasants and Barton unpublished Massey University data), so the explicit constraint

$$p + b(t_1 - \bar{t}) \geq 44$$

has been added, where t_1 is the calving date of the cow to calve last in the herd.

The Model constructed is, of course, conditional on the calving date t. To obtain a conception rate for the herd the sum of the probabilities of conception for each cow is taken and divided by the number of cows in the herd.

MATERIALS AND METHODS

The objective of this work was to study the relationship between the length of anoestrus and herd conception rate. The model constructed is conditional on calving date; data from 10 consecutive years of records of the Massey University Angus beef cow herd were used. This herd was run at Tuapaka, Massey University's hill-country farm and was intensively recorded.

The standard deviation of the period of anoestrus was taken as 3 days (Pleasants and Barton, 1985), and the standard deviation of the length of the oestrous cycle was taken as 1.5 days (Williamson and Payne, 1965). A conception rate at each oestrous occurring during mating of 0.7 was used, since this was the average conception rate found in the Massey herd.

The calculation of the definite integrals of the normal distribution was carried out numerically using the algorithm ALNORM (Hill, 1973). The maximization of conception rate for each of the 10 years under the constraints detailed above was carried out by the

Complex Method of Box (1965). A description of this method and a BASIC computer program is given by Bunday (1984).

TABLE 3 Herd conception rates (%) for different anoestrous periods at different values of the regression between calving date and anoestrous period

Year	Anoestrous (days)	Regression of Anoestrous -0.3	Period on Calving Date 0.0
1970	60	93.0	89.9
	70	91.2	87.0
	80	85.7	80.7
	90	76.8	86.2
1971	60	93.3	90.2
	70	90.8	86.9
	80	85.4	80.0
	90	75.4	68.0
1972	60	94.1	92.9
	70	92.1	90.2
	80	88.2	85.1
	90	76.9	73.7
1973	60	93.3	92.2
	70	93.9	92.0
	80	91.8	90.2
	90	88.2	83.9
1974	60	94.1	92.9
	70	93.7	92.5
	80	91.9	89.9
	90	87.1	83.9
1975	60	94.7	94.1
	70	93.3	92.3
	80	90.6	88.9
	90	83.8	80.8
1976	60	94.3	93.4
	70	93.3	91.8
	80	89.0	86.9
	90	81.4	77.5
1977	60	94.6	93.7
	70	93.5	92.5
	80	91.2	89.6
	90	83.9	80.8
1978	60	94.0	94.1
	70	93.5	92.7
	80	88.3	87.2
	90	76.5	75.8
1979	60	94.2	93.3
	70	92.1	90.3
	80	86.9	84.8
	90	74.6	71.0

The optimization was carried out in two ways.

First by finding the optimum herd-in-calf rate, maximizing over the average herd post-partum anoestrous interval, and the regression coefficient between calving date and the post-partum anoestrous interval. [that is p and b]. Second by setting the regression coefficient to zero, and optimizing in calf rate over the average herd post-partum anoestrous interval only.

RESULTS

The numbers of cows involved in each of the 10 years of calvings and the cumulative distribution of calving dates at 10-day intervals is shown in Table 1. The results of maximizing the conception rate in the herd for each of the years for the parameters of the anoestrous period (herd mean p and regression coefficient b) are shown in Table 2. The optimum average herd anoestrous period lies between 60 and 70 days, with a regression coefficient of between -0.3 and -0.48. None of the constraints are violated. The maximum conception rate in the herd remains remarkably stable between years at about 94%.

The results of setting the value of the regression coefficient between the anoestrous period and calving date to zero and then performing the optimization of herd conception rate for the anoestrous period only is also shown in Table 2. This resulted in lower anoestrous period, with the collapse of the anoestrous period to the constraint in years 1970, 1971 and 1979. Notably these were the years when less than 90% of the herd had calved by day 40. However, the change in herd conception rate was not affected very much by this (Table 3), though the herd conception rate was affected more when the anoestrous period increased above 70 days in those years than in the other years.

Extending the mating period by beginning mating 7 days, or one third of an average oestrous cycle earlier, consistently increased the herd conception rate by about 1% over all 10 years considered.

Table 3 shows the relationship between conception rate in the herd and the average herd anoestrous period for regression coefficients between anoestrous and calving date of 0 and -0.3, for each of the 10 years analysed. The change in herd conception rate with change in anoestrous period remains small for anoestrous periods shorter than 70 days. Above 70 days

the effect of anoestrous period on herd conception rate is more marked.

DISCUSSION

A high conception rate in the herd is an aim which is important to achieve. In pursuit of this goal it has been suggested that the period of anoestrous should be as short as possible, Wiltbank *et al.*; (1962). However, the analysis carried out here suggests that such a policy will capture few gains in terms of herd conception rate once the anoestrous period falls below 70 days.

The other factor revealed by this analysis is that when herds fail to have more than 90% of cows calved by 40 days after the expected onset of calving the subsequent herd conception rate becomes highly sensitive. The best way to reduce the negative effects of this sensitivity is to aim to obtain a high conception rate at each oestrous of cows in the herd.

It is suggested the anoestrous period in beef cows has assumed an overrated importance in the goal of increased productivity. Management practice should be adopted to ensure that the average anoestrous period in the herd remains above 70 days, but there seems to be little point in attempting to reduce this figure in order to achieve high herd conception rates. These analyses support the view that conception rate at each oestrous is the parameter most deserving workers' attention to optimize in calf rates in beef cows.

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