An Age and Herd Structure Model for Beef Breeding Enterprises

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Abstract Beef cattle production in Australia is a complex business, with many options available for breeding, feeding and marketing. All of these will affect the profitability of a beef breeding enterprise. A decision support system, BEEF-N-OMICS (Dobos et al. 1992) has been developed to help beef cattle producers determine best management strategies to improve profitability. Central to this systemis an age and herd structure model. The breeding herd consists of a number of classes of animals; lactating and pregnant, empty and dry, pregnant and dry, lactating and empty and their progeny. Aspects of selling policy, culling, calving pattern and cow and calf mortality, impinge on the age structure and content of the herd. The evaluation of consequences resulting from changes in these policies requires a robust representation of subsequent age and herd structure. This paper describes the age and herd structure in a beef breeding herd from a set of 27 equations . It is these equations that form the core of an age and herd structure model for BEEF-N-OMICS.

1. INTRODUCTION

There are many options to consider in beef cattle production, involving breeding, feeding and marketing choices. Profitability of a beef breeding enterprise is affected by all of these choices. To improve herd productivity and profitability, information about these options must be integrated and the system evaluated as a whole. Central to this evaluation is the need to understand the effect of particular strategies on breeding herd age and structure (Clewett et al. 1988).

A breeding herd consists of several classes of animals including cows that are pregnant, empty and dry, empty and lactating and their progeny.

The aim of this paper is to report on a set of equations used to calculate beef breeding cow age and herd structure using a within-year static modelling approach. These equations form the basis of a decision support system called BEEF-N-OMICS which integrates aspects of feed availability, requirements and economic factors to test alternative beef production management strategies for southern Australia (Dobos et al. 1992). BEEF-N-OMICS aims to allow users to test the effects of changing management strategies on the whole beef herd. For example, aspects of nutrition, breeding policy, and buying and selling strategies can be assessed. At its core is an age and herd structure model which calculates the age and herd structure for a breeding cow enterprise using two algorithms. The first calculates the age structure, while the second calculates the herd structure. These are then linked to other modules within BEEF-N-OMICS to allow the user to investigate the impact of different management strategies on the whole herd.

2. AGE STRUCTURE ALGORITHM

2.1 Number of calves born, number of cows pregnant and pregnancy rate

The number of calves born (Ncb) are calculated using equation (1). The percentage of cows in the herd sold after calving for other reasons (Poc) is added to Ncb. However, their calves are included. The number of cows that are pregnant (Np) and the pregnancy rate (Pr) are then calculated using equations equations (2) and (3).

$$Ncb = Ncw*(1+Pcd/100*Mwa/My)+ (Poc/100*Hs) \quad (1)$$

$$Np = Ncb/(1-Pad/100*Gl/Dy) \quad (2)$$

$$Pr = Np/Hs \quad (3)$$

where Hs is herd size (user input, 0-2000); Ncw is number of calves weaned (user input, 0-2000); Pad is percentage of adult deaths (user input, 0-100); Gl is gestation length (282 days); Pcd is percentage of annual calf deaths (user input, 0-100); Mwa is minimum weaning age (user input, 0-12 months); My is the month of the year (1-12); Dy is the number of days in a year (365).

The algortihm does not allow for the birth of twins, therefore Pr is less than or equal to 1.0.

2.2 Proportion of breeding cows

The proportion of breeding cows (Pbc) of each age (1 to Mca, maximum cow age, user input, 1-15 years) in the herd is calculated using equation (4). It is based on adult cow death rate (Pad), the proportion of the herd sold for other reasons (Poc), pregnancy rate (Pr) and proportion of cows sold as dry (Pds).

$$Pbc_i = Pbc_{i-1} * [0.995 - Pad/100 - Poc/100 - \{(1-Pr)*Pds/100\} \quad (4)$$

where i is the age from Ar+1 to Ac (Ar is age of replacements and is 1 if Hh flag is set to true (heifer replacements kept) and joining age, Ja=15; 2 if Ja=27 and 3 if Ja=39; Ac is age at last joining before cows culled for age). For simplicity there are only three heifer joining ages in the model. If Hh is set to false (heifer replacements purchased), then Ar is greater (in years) of Ja or Rca (age at which replacements are purchased user input, 1-15 years).

2.3 Cumulative proportion of breeding cows

The cumulative total proportion of each Pca (Tpca) is then calculated using equation (5).

$$Tpca = \sum_{i=Ar+1}^{Ac} Pbc \quad (5)$$

2.4 Age structure

From equation (6), the cow age structure (Ca) is then calculated for each age, i, obtained from Ar to Ac.

$$Ca_i = (Cpa_i/Tpca) * Hs \quad (6)$$

At the conclusion of the iterative process, the number of culls to be sold (Cs) is set to the value of Ca when i=Ac. This value is used in the equations described in the herd structure algorithm.

Tables 2 and 4 below illustrate how the results from these equations report the breeding cow age structure.

3. HERD STRUCTURE ALORITHM

This algorithm is designed to generate numbers for 14 animal classes (8 cow and 6 progeny classes) between January and December. Numbers in each class are calculated based on death and pregnancy rates, the proportion culled for other reasons and the proportion of cows sold as dry. The algorithm begins at joining (user input) and there are eight cow classes on the property available from the previous year. These then become either another class or remain the same just after joining (this year). The type of class for last year, this year and the equivalent class for use in the algorithm are shown in table 1.

Table 1. Combinations of animals present at the start of joining. (* CFA cull for age)

Status of stock		
Animal class last year	Animal class this year	Animal class used in model
Lactating CFA*	Lactating	Lactating & empty
Lactating not CFA	Pregnant	Lactating & pregnant
Lactating not CFA	Empty	Lactating & empty
Empty CFA	CFA	Cull
Empty not CFA	Pregnant	Pregnant & dry
Empty not CFA	Empty	Empty & dry
Heifers	Pregnant	Pregnant & dry
Heifers	Empty	Empty & dry

The algorithm iterates over each month of the year (January to December) and checks if the current month is a calving month, if $Cp_j > 0$.

3.1 Number of heifers in a self replacing herd

The number of heifer replacements for a self-replacing herd (Hr) is calculated using equation (7). Any sales allocations are then made depending on the weaning month (user input). It is a function of those classes of stock that are removed from the herd because they are either empty and dry, sold for other reasons (Poc), died (Pad) or are classed as culls (Cs).

$$Hr_j = \{Hs*[Pad/100+((1-Pr)*Pds/100)+Poc/100]+Cs - (Cs*(1-Pr)*Pd/100)\}*Cp_j/100 \quad (7)$$

The number breeding replacements required for a self replacing herd is then Hr_j

3.2 Mating group size

The mating group size (Mgs_j) is calculated using equation (8). It decides how many cows will be available for joining.

$$Mgs_j = \{Hs*Pad_j/100*(1-Pad_{ij}/100)+Hr_{ij} - Pcd_j/12)\}*Cp_j/100 \quad (8)$$

3.3 Number of replacements to be purchased

If heifer replacements are to be purchased (Hh is false), then all heifers born are sold. Equation (9) calculates the number of replacements that need to be purchased and is a function of heifers that are required (Hr) and subtracting any calf deaths (Pcd) that may occur within the year.

$$Rn_j = Hr_j - (Pcd_j/My) \quad (9)$$

For each month of mating (k, 0-11), the number of animals in the first 5 classes of the herd structure are now calculated. Their physiological status is also checked at this point.

3.4 Pregnant and lactating (Pl)

This class consists of pregnant and lactating cows present on the farm at joining. Equations (10) and (11) are used to calculate the cow deaths between calving and joining (Cd) and cows that are to be culled because of age that are pregnant and lactating (Ccpl). Equation (12) calculates the number of cows that are pregnant and lactating.

$$Cd = Ncb*3*Pad_j/100 \quad (10)$$

$$Ccpl = Cs*Pr \quad (11)$$

$$Pl_{j,k} = [(Ncb-Cd-Ccpl)*Pr*Cp_j/100]*(1-Pad_j/100) \quad (12)$$

This class becomes pregnant and dry at weaning.

3.5 Pregnant and dry (Pd)

This class consists of pregnant and dry cows carried forward from the previous year that are now pregnant but not CFA. Equations (13), (14) and (15) are used to calculate those cows that were empty last year (Ely), cows that are culled because of age Ccpd) and the number of cows in this class that are dry (Dpd_k). The number of pregnant and dry cows is calculated using equation (16).

$$Ely = Hs*(1-Pr) \quad (13)$$

$$Ccpd = Cs*(1-Pr) \quad (14)$$

$$Dpd_k = (Ely-Ccpd-((Ely-Ccpd)*Pad/100)) \quad (15)$$

$$Pd_{j,k} = [(Hr_j + (Dpd_k - (Dpd_k * Pds/100))*Pr*Cp_j/100]*(1-Pad_j/100) \quad (16)$$

This class becomes lactating and empty when they calve.

3.6 Lactating and empty (Le)

This class consists of cows calving and surviving to joining but failing to become pregnant, and those lactating CFA cows with unweaned calves. The number of cows culled for age for this class (Cale) is calculated using equation (17). The number of cows in this class is calculated from equation (18).

$$Cale = Cs * Pr \quad (17)$$

$$Le_{j,k} = [(Ncb - Cd - Cale)*(1-Pr)*Cp_j/100]*(1-Pad_j/100) \quad (18)$$

This class becomes empty and dry at weaning.

3.7 Empty and dry (Ed)

This class consists of heifer replacements which failed to conceive (Hd), the surviving empty cows from the previous year which are not CFA (Dpd) less the proportion of cows sold as drys (Pds) (equation (19)). The number of cows in this class is calculated using equation (20).

$$Hd_k = Hr_j * (1-Pr) \quad (19)$$

$$Ed_{j,k} = [(Hd_k + (Dpd_k - (Dpd_k * Pds/100)))*(1-Pr)*Cp_j/100]*(1-Pad_j/100) \quad (20)$$

3.8 Culls (Cl)

This class consists of all CFA cows which were dry last year. For convenience they are sold with Pds (user input). Equations (21) and (22) calculate the weaning rate (Wr) and the number of dry cows sold (Dcs), respectively. The number of cows in this class is then calculated using equation (23).

$$Wr = Ncw/Hs*100 \quad (21)$$

$$Dcs_k = [Mgs_j * Pds/100*1.0055-Wr/100-Pad/100)*(1-Pad_j/100)]+[Mgs_j *Cs/Hs*(1-Pad_j/100)] \quad (22)$$

$$Cl_{j,k} = (Dcs_k + Cs) * Cp_j/100 \quad (23)$$

3.9 Number of progeny

Once the above classes have been calculated, the algorithm tests for weaning status of the progeny (Pg). If the weaning month is the same as the current joining month (k), then Pg is calculated using equation (24). There are eight classes describing progeny. The age (a, k+3), sex (f,m) and weaning status (w, Jan to Dec) at each iteration is checked and sales allocation determined.

$$Pg_{a,s,w} = Ncw * Cp_j/100 \quad (24)$$

The number of heifers available (Ha) for a self replacing herd (Hh is true) is calculated as the number of female progeny born to the herd ($Pg_{a,f,w}$, equation (25)).

$$Ha_j = Pg_{a,f,w} \quad (25)$$

$Pg_{a,s,w}$ within each of the eight classes are adjusted based on the following:

1. Hr_j are deducted at the end of the month joining begins, if Hh is true;
2. The number of male and female calves born are the same, ie 50% for each;
3. As stock are sold, the number in that month are reduced by the number sold;
4. If replacements are purchased (Hh is false), then the progeny numbers are adjusted as follows:

(a) when replacements are purchased as either heifers joined or heifers lactating and empty (user input), $Pg_{a,s,w}$ is increased after weaning by Rn_j;
(b) when replacement cows are purchased as lactating and pregnant, $Pg_{a,s,w}$ is increased after weaning by Rn_j*2.

3.10 Adjusting Pd and Le classes

After the herd structure algorithm has stepped through each month of the year, animals that are sold for any other reasons and because they are dry, are deducted from each monthly total for classes Pd, Le and Ed. These numbers are reduced between the nominated month of sale and the start of joining. That is, if Poc > 0, then equations (10) and (17) are adjusted after the sales month (user input) using equations (26) and (27), respectively.

$$nPd_{j,k} = [Pd_{j,k} - (Pd_{j,k}/(Pd_{j,k} + Le_{j,k}) *Poc/100*Hs)] \qquad (26)$$

$$nLe_{j,k} = [Le_{j,k} - (Le_{j,k}/(Pd_{j,k} + Le_{j,k}) *Poc/100*Hs)] \qquad (27)$$

If Pds > 0, equation (19) is adjusted by subtracting the proportion to be sold from each monthly total after the nominated month of sale.

Tables 3 and 5 illustrate how the results of these equations report the herd inventory.

The numbers generated from the above 27 equations are then stored in an array for use by other modules within BEEF-N-OMICS.

4. APPLICATION

To illustrate how the age and herd structure model works, two case studies are used. BEEF-N-OMICS requires the user to input data that relates to the farms current or "original" management (Case 1). The second case study (Case 2) is where the user tests management changes by reducing the calving spread and modifying sales policy from that of the "original" case.

4.1 Case study 1 - "original" management

The "original" herd management for this case study is as follows:

The breeding herd consists of 250 cows which are joined each year. The cows calve in July (20%), August (40%), September (20%), October (15%) and November (5%). Two hundred and thirteen (213) calves are weaned. The grazing area is 647 ha, which consist of 60 ha scrub, 304 ha fertilised native pasture and 243 ha of good improved pasture. Super phosphate fertiliser is applied to half the farm each year and pasture maintenance costs are A$14,800 per annum. No fodder crops are grown but supplements of hay are fed (100 tonne @ A$120/t) to the breeding herd in July and August. Death rates for calves and adults are 2% and 3% respectively, with all heifers born being kept. Seventy percent of dry cows are sold in May and no animals are culled for other reasons. Weaning occurs in March and the minimum weaning age of the calves is 7 months when they weigh 150kg. Cows are considered CFA at 10 years of age and heifers are joined at 27 months of age. The number of bulls per 100 cows is 4. Progeny are sold as follows:

40 % of males and 10% of females are sold at 9 months of age weighing 270 and 250 kg respectively. At 15 months of age 30% and 10% of males and females at 365 and 330 kg respectively. At 20 months of age 30% and 80% of the males and females are sold weighing 375 and 360 kg respectively.

The gross margin for the "original" management in this case study is A$49,599. Breeding cow age structure for the "original" management is shown in table 2. Note that the age structure starts at 2 years because joining age for "original" was 27 months. The herd inventory is shown in table 3.

4.2 Case study 2 - reducing calving spread and modifying selling policy

The user reduces the calving spread and modifies sales policy. Calving is now from July to September. All the dry cows are sold, vealer live weight is increased by 20 kg because of the extra feed available in spring and 50% more are sold. The heifers are kept in the herd and calve as two year olds. The breeding cow age structure is shown in table 4 and the herd inventory is shown in table 5. It can be seen that testing these changes in management, the breeding cow age structure changes and the number of animals within each class on the property alters. This could have major implications on the feeding management of the herd. The gross margin calculated in this case study was A$58,462. By testing these changes, the new gross margin is A$8,863 better than that of the "original" management. This indicates that the strategies of reducing calving spread and modifying selling policy is profitable.

5. DISCUSSION

This paper reports on 27 robust equations that are used to calculate the age and herd structure of beef breeding herds. They are utilised in a decision support system called BEEF-N-OMICS which aims to allow users to test the effects of changing management strategies on the whole beef herd.

The variables that influence age and herd structure are the number of dry cows, culling for other reasons, calf and adult death rates, pregnancy and calving rates, the number of cows to be joined and at what age, whether replacements are purchased or kept, progeny sales policy and the number of calves weaned. The effects of some types of management changes are illustrated in the case studies and in Dobos and Oddy [1993].

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Clewett, J.F., Taylor, W.J., McKeon, G.M., Neal, J.A., Howden, S.M. Young, P.D., Rickert, K.G. and Wilson, R. BEEFMAN: Computer systems for evaluating management options for beef cattle in northern Australia, *Proceedings of Australian Society of Animal Production* 17, 367, 1988.

Dobos, R.C., Sangsari, E., Carberry, P.C. and Johnston, B.D. BEEF-N-OMICS: A "what if" program for the beef industry, *Proc. Conf. Decision Support for Farming in southern NSW and northern Victoria*, July, pp 51-52, 1992.

Dobos, R.C. and Oddy, V.H. Beef production decision support systems and better feeding management, *Proc. Conf. Harnessing Information for a Smarter Agriculture*, Australian Institute of Agricultural Science, Launceston, Tasmania, pp 39-40, 1993.

Table 2. Breeding cow age structure for Case study 1.

Breeding cows: Age (yrs)	Number	Proportion (%)	Number empty		
1	.	.	.	Heifers available	107
2	44	17.7	4	Replacements required	44
3	38	15.3	3	Replacement rate (%)	17.7
4	34	13.5	3	Average cow age (yrs)	5.2
5	30	12.0	2	Average weaning age (m)	8.0
6	26	10.6	2	Bulls on hand	10
7	23	9.3	2		
8	21	8.2	2		
9	18	7.3	1		
10	16	6.1*	1		
11	.	.	.		
12	.	.	.		
13	.	.	.		
14	.	.	.		
15	.	.	.		
Total cows	250	100.0	20		

* Culls in herd structure model

Table 3. Breeding herd inventory for Case study 1.

All breeding enterprise stock												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PL	167	175	175	35	9	9	9	.	.	35	106	141
PD	44	46	46	185	211	210	166	87	44	20	28	37
LE	32	23	23	5	1	1	45	130	173	167	101	62
ED	7	6	6	25	28	9	9	10	10	10	8	8
CI	.	23	23	5	9	5	1	.	.	.	.	.
Pg												
4-5m	.	.	.	.	.	.	.	.	.	.	.	.
6-7m	.	.	.	32	32	.	.	.	.	.	.	.
8-9m	.	.	.	96	96	64	32	11	.	.	.	.
10-11m	.	.	.	.	32	95	95	63	42	6	.	.
1-2 y	98	98	77	76	76	76	93	126	143	97	99	98
2-3 y	.	.	.	.	.	.	15	44	59	62	.	.
3-4 y	.	.	.	.	.	.	.	.	.	.	.	.
4-5 y	.	.	.	.	.	.	.	.	.	.	.	.
Total	348	371	350	469	494	469	465	471	471	397	342	346

Table 4. Breeding cow age structure for Case study 2.

Breeding cows:					
Age (yrs)	Number	Proportion (%)	Number empty		
1	42	15.3	3	Heifers available	124
2	38	13.9	3	Replacements required	42
3	34	12.5	2	Replacement rate (%)	15.3
4	31	11.2	2	Average cow age (yrs)	4.6
5	28	10.1	2	Average weaning age (m)	8.5
6	25	9.1	2	Bulls on hand	11
7	22	8.1	2		
8	20	7.3	2		
9	18	6.6	1		
10	16	5.9*	1		
11	.	.	.		
12	.	.	.		
13	.	.	.		
14	.	.	.		
15	.	.	.		
Total cows	274	100.0	20		

* Culls in herd structure model

Table 5. Breeding herd inventory for Case study 2.

All breeding enterprise stock												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PL	217	216	216	.	.	.	.	.	.	43	130	173
PD	39	39	39	254	254	253	152	.	.	18	44	44
LE	15	15	15	.	.	.	101	252	251	157	15	15
ED	3	3	3	18	18	.	.	.	.	1	3	3
CI	16	16	16	5	.	.	1	.	.	.	16	.
Pg												
4-5m	.	.	.	.	.	.	.	.	.	.	.	.
6-7m	.	.	.	.	.	.	.	.	.	.	.	.
8-9m	.	.	.	174	104	.	.	.	.	.	.	.
10-11m	.	.	.	.	69	173	103	.	.	.	.	.
1-2 y	61	61	49	49	49	49	96	172	172	87	62	61
2-3 y	.	.	.	.	.	.	21	48	48	48	.	.
3-4 y	.	.	.	.	.	.	.	.	.	.	.	.
4-5 y	.	.	.	.	.	.	.	.	.	.	.	.
Total	351	351	338	495	494	475	473	472	471	398	358	357