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Culling Dairy Cows as a Response to Drought in Northern Victoria

by

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Culling dairy cows as a response to drought in northern Victoria

Marnie Griffith[1]

Abstract

Conditions for the dairy industry in northern Victoria over the past decade have been tough. High prices for feed inputs, especially when combined with low farmgate milk prices, have seen situations where dairy farmers are losing money feeding cows. In this environment, it is natural to consider whether culling in response to drought followed by replacement as conditions return to normal would leave farmers better off.

This working paper develops a methodology to quantitatively evaluate culling during drought conditions for the northern Victorian dairy industry. The methodology is applied to two recent years of drought, 2002-03 and 2007-08. While higher feed costs provide reason to cull, this is largely offset by lower cull prices and higher replacement heifer costs. Farmgate milk prices also play an important role.

The methodology was extended to consider a two-year drought. It was found that duration of the drought has a potentially large impact on optimal culling response.

JEL Classifications: C61; Q15; Q25

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1 Introduction and background

This working paper develops a quantitative framework to analyse the culling of dairy cows in response to a drought. Conditions for the dairy industry in northern Victoria over the past decade have been tough. Prices for feed inputs have reached historical highs. The situation is especially dire when these high input prices are combined with low farmgate milk prices. There have been times over the past decade when dairy farmers have lost money feeding cows. In this environment, it is natural to consider whether reducing feed costs by temporarily reducing the herd size (followed by replacement as conditions return to normal) would leave farmers better off.

This decision is relatively complex, as dairy cows might be thought of as a 'capital asset', producing milk over a number of lactations. A decision to cull a greater than usual number of cows in response to drought would have an effect on age structure of the herd and hence net revenues for years to come. A framework which is capable of considering this must be employed.

Culling as a response to drought takes place against the background of the farmer's normal replacement strategy. Thus, in this paper, the first step in the modelling of culling as a response to drought conditions is to determine an optimal replacement policy under normal conditions.

The replacement problem is an important one for dairy farmers, and optimal replacement strategies and tools to support this decision have been extensively examined in the literature.[2]

Replacement rates in northern Victoria are higher than those in other areas of Australia, at around 25 per cent (Ausvet Animal Health Services 2005). Dairy cows are replaced for a variety of reasons. These are loosely split into voluntary versus involuntary culling, with voluntary replacement mostly occurring for low production and involuntary culling usually for ill-health (e.g. persistent mastitis) or accidents. Failure to conceive is also a major reason for culling a cow: this is sometimes classed as involuntary and sometimes as voluntary replacement – in this paper, we will consider it as grounds for involuntary replacement.

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[2] This paper examines optimal replacement assuming all other decisions are fixed. While the replacement problem is important, it is worth noting that dairy systems are incredibly complex. As an example, an earlier working paper (Griffith 2010) looks at the complex minimum cost feed budgeting problem.

The two main approaches to modelling optimal replacement have been dynamic programming and the marginal net revenue formulation (Groenendaal et al. 2004), with van Arendonk (1985) an example of the former and Burt (1965) an example of the latter. Dynamic programming is more flexible (in particular, it can handle variation in parameters such as net revenues and genetic progress in future replacements), but it is much more complex and data-intensive. We apply the marginal net revenue approach, as developed by Faris (1960) and extended by Burt (1965).

At the base of the asset replacement problem is the idea that the farmer is not just optimising net revenues from a single cow but maximising over an infinite stream of revenues from the current cow and all its subsequent replacements. A general result from the theory is that the optimal time to replace an asset is when the marginal net revenue from the asset in question is equal to the average net revenue of future assets (assuming identical replacements) (Faris 1960). Burt (1965) extends this methodology to the case where there is a risk of involuntary replacement (in the case of dairy cattle, probability of involuntary culling due to illness, accident or failure to conceive).

This framework is well-established in the literature (see for example, Groenendaal et al. (2004)). However, we have been unable to find an application in the Australian context. Indeed, we have been unable to find much discussion of replacement at all for the Australian dairy industry.

The response of the dairy industry to drought (or a period of extremely high feed prices) also appears to be relatively understudied. In related work in Australia, Armstrong *et al.* (2005) evaluate culling as a response to drought, although their methodology is very different to that used here. They evaluate a given level of culling (rather than deriving an optimal amount), have a different measure of performance (peak debt levels and time to break even rather expected value of future stream of net revenues) and are much less explicit about herd dynamics. In their modelling of the 2002-03 drought, they find that culling 40 per cent of the herd and rearing replacements had the least impact on debt and the shortest time to recovery for the family farm, relative to other options including culling only 15 per cent of the herd; culling 40 per cent but buying replacements; and agisting cows elsewhere.

The remainder of the paper is structured as follows. Section 2 outlines the theory of the optimal replacement model while Section 3 details assumptions regarding data. Results for optimal replacement under normal conditions are presented in Section 4, before culling as a response to drought is assessed in Section 5. Section 6 offers some conclusions.

2 Optimal replacement under risk of asset failure

Burt (1965) considers optimal replacement age for capital assets when there is a risk of involuntary replacement. The modelling framework is based on several assumptions necessary to make the model simple enough to solve analytically. These include the assumptions that:

- replacement is the only option, and that the cow is always replaced with a heifer;
- net marginal productivity with respect to age is diminishing beyond some point;
- an infinite planning horizon;
- revenue, cost and probability parameters do not change over time.

Total revenues depend on the starting age of the current cow, but not the optimal time to replace the cow, so the problem is defined without loss of generality for a first lactation cow.

The following notation is defined:

p_t	the probability that a cow of age t will reach age t+1
H_t	net revenue associated with a cow of age t
$D_t = M - 0.8 \times S_t - 0.5 \times H_t$	cost of replacement caused by random factors
S_t	salvage value for a cow age t
M	replacement heifer cost
C_t	voluntary replacement cost (replacement cost minus salvage value)
$R_t = p_t H_t - (1 - p_t) D_t$	conditional expected value of net revenue for an asset age t (excluding the cost of planned replacement)
T	planned replacement age
$\beta = \dfrac{1}{1+i}$	where i is the interest rate
$w_t = \beta^{t-1} p_1 p_2 \dots p_{t-1}$	
$V(T)$	the expected value of discounted net revenues from a series of identical replacements over an infinite planning horizon.

The analysis is based on the following relationship:

$$V(T) = q(T) + E\left\{\beta^{L(T)} V(T)\right\}$$

Where

$$q(T) = R_1 + \beta p_1 R_2 + \beta^2 p_1 p_2 R_3 + \cdots + \beta^{T-2} p_1 p_2 \ldots p_{T-2} R_{T-1} + \beta^{T-1} p_1 p_2 \ldots p_{T-1}(R_T - p_T C_T)$$

is the expected total revenue for a planned replacement age of T. This equation states that the expected value of discounted net revenues is the expected stream of net revenues from the current cow, plus the expected value of discounted net revenues from its replacement. Note that this discount factor is random, due to the risk of unplanned replacement, but a function of planned replacement age.

Burt (1965) then derives the following equation:

$$V(T) = \frac{\sum_{t=1}^{T} w_t R_t - w_T p_T C_T}{(1-\beta)\sum_{t=1}^{T} w_t}$$

The aim is then to choose the T which maximises $V(T)$.[3]

Note that cows are defined entirely by age – net revenues, survival probabilities and saleyard value all depend on age and nothing else. In reality, these characteristics can differ between cows of the same age. In addition, other characteristics that may be important in the culling decision, such as temperament and ease of milking, are also excluded from consideration.

The timeframe for this analysis is one lactation. We assume that this is one year (that is, each year cows spend nine months lactating, then three months dry before giving birth to a calf and commencing another lactation). In reality, lactation cycles can vary in length, and decisions to cull may be taken multiple times through the year, rather than just at the end of a cycle, as assumed here.

3 Data

This modelling is driven by three pieces of data: net revenues by age, salvage value by age and probability of involuntarily culling by age. The work of van Arendonk (1985) will be used to add detail to these broad variables.

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[3] Burt (1965) includes a sufficient conditions for V(T) to have a single relative maximum.

Net revenues are comprised of milk receipts plus calf receipts minus feed costs minus other variable costs (mostly vet and insemination costs). First lactation cows tend to have the lowest whole-of-lactation milk production. Milk production then increases, peaking around the third lactation, before falling. We assume that milk production falls by 10 per cent each lactation from the seventh onwards. The milk receipts in Table 1 below are calculated assuming a farmgate milk price of 32 cents per litre.

As noted above the timeframe for this analysis is one year. We assume for simplicity that mating and culling decisions are made once a year, with all cows who fail to conceive culled, in line with the traditional spring-calving herds of the region. In reality, there is an increasing trend for cows who fail to conceive to be retained and milked through an extended lactation. These cows may be given another chance to conceive, to calve for example in autumn.[4] The assumption that all non-pregnant cows are culled implies all surviving cows will produce a calf. We assume that this calf is worth $100, following Groenendaal et al. (2004).

Feed costs move with milk production, as feed intake, body weight and milk production are all related. An earlier working paper considered minimum cost feeding of dairy cows as the price of feed inputs changed (Griffith 2010). Feed budgets were derived based on the methodology of Armstong *et al.* (2000). Despite the changing mix of pastures, hay and grain as prices changed, in all scenarios, approximately 6 tonnes DM per cow per year were provided. We calculate feed costs of around $1075/year for cows between their third and sixth lactations inclusive, based on a rough diet of 3.5 tonnes of bought-in feed (a mix of grain and hay) at $200/tonne and 2.5 ML of water, assumed to cost $150/ML. To calculate feed costs for cows with lower milk production, we follow van Arendonk (1985), who found an increase in feed costs of 40 per cent of the increase in milk revenue. Other variable costs also increase with age, increasing quite sharply past about six years, as cows become more vulnerable to injury and illness. We assume other variable costs start at $300/year in the first lactation and increase at a rate of 5 per cent per lactation.

Saleyard (or salvage) value depends on the age and productivity of the cow. In the first few lactations, highly productive cows can be sold for dairy purposes, and so prices reflect value in dairy production. Otherwise, older and less productive cows are sold for beef, and price depends on weight – as well as weighing more, price per kilogram tends to be higher for heavier cows. Prices for dairy cows sold for beef are volatile, depending on the

[4] Thanks to Bill Malcolm for pointing this out.

supply-demand balance in the global beef market. Dairy Australia (2007) includes a historical chopper price of around $600-$700 a head for the period June 2003 to June 2007. We assume the saleyard value of dairy cows is $1,000/cow up to the seventh lactation, after which value declines by 10 per cent per lactation.

The probability of involuntary culling increases with age, as older cows are more vulnerable to illness and injury and also failure to conceive. On the other hand, first-time calvers also have lower conception rates (DRDC 2000). Madgwick and Goddard (1989) include survival scores of around 85 per cent for lactations 1-4, then falling approximately as follows: from 82 per cent to 80 per cent, 75 per cent, 70 per cent and finally, to 65 per cent for the ninth lactation. These are similar to those we take from Groenendaal et al. (2004), shown in Table 1.

Cost of involuntary disposal will be defined as the cost of a replacement heifer (assumed to be available at $1,500/head) minus the saleyard value of the cow to be replaced minus half the usual net revenue earned during that period. It will be assumed that animals sold for involuntary reasons will only command 80 per cent of what the same cow would sell for if the sale were planned (because reasons for the disposal, for example mastitis or injury, are likely to be related to a lower sale price).

Other data are an assumed discount rate of 10 per cent.

Table 1: Data for the base case

Lact. number	1	2	3	4	5	6	7	8	9	10	11	12
Survival prob.	0.86	0.85	0.82	0.80	0.77	0.75	0.73	0.71	0.68	0.65	0.62	0.59
Milk receipts	1,799	2,006	2,143	2,143	2,143	2,143	1,929	1,736	1,562	1,406	1,265	1,139
Calf receipts	100	100	100	100	100	100	100	100	100	100	100	100
Feed costs	937	1,020	1,075	1,075	1,075	1,075	1,032	994	959	928	899	874
Other variable costs	300	315	331	347	365	383	402	422	443	465	489	513
Net revenue	661	771	837	821	803	785	595	420	260	113	-23	-148
Salvage value	1,000	1,000	1,000	1,000	1,000	1,000	1,000	900	810	729	656	590

4 Optimal replacement for the northern Victorian dairy industry

4.1 Base case

Figure 1 shows how V(T), the expected value of the discounted net revenue stream, changes with T. The function V(T) reaches its maximum at T = 6, and hence the optimal time to replace the cow according to this modelling is following the sixth lactation. This accords well with the reality of the Australian dairy industry: a 2005 report to the Australian Department of Agriculture, Fisheries and Forestry found that only approximately 10 per cent of the herd in the northern Victoria region were older than eight years old (Ausvet Animal Health Services 2005).

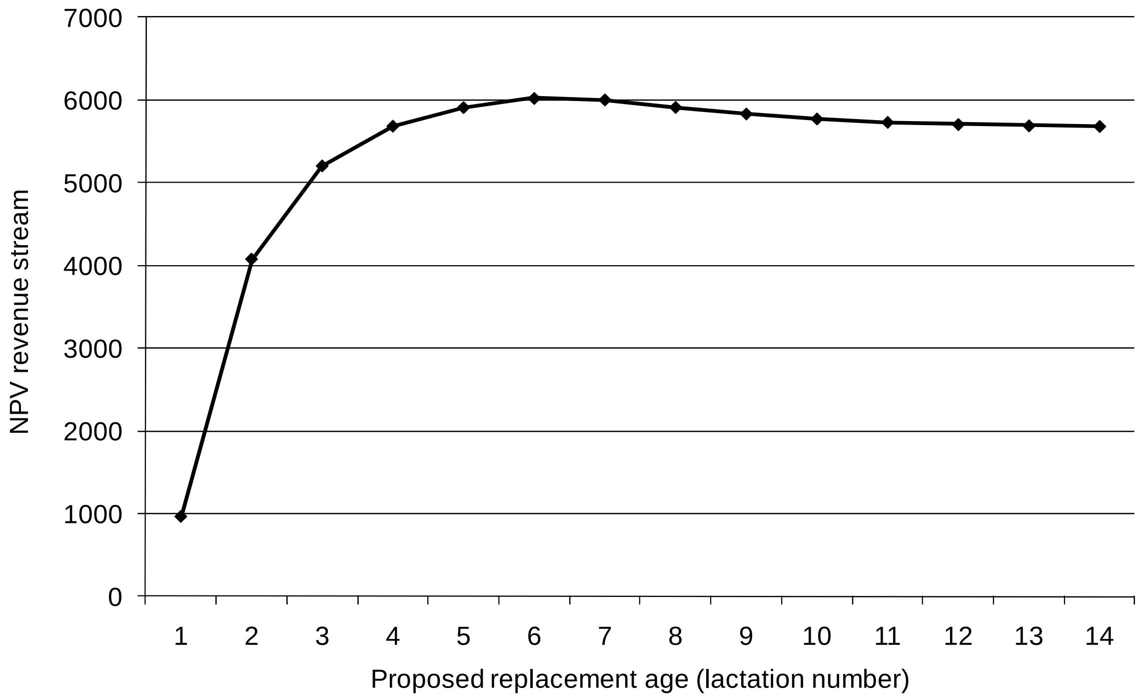

Figure 1: V(T) for different proposed lactation numbers

One point of interest in Figure 1 is that though the function attains its maximum at T = 6, it is very flat from that point on. It seems there is not that much difference in culling a cow at seven years of age, and waiting till it is fourteen. This result seems relatively robust to assumptions regarding the data.

If we assume that for every age group, an average number of cows are culled involuntarily (that is, multiplying the number of cows at every age by (1 - survival rate) from Table 1 above and assuming that that number of cows exit the herd each year), and that all sixth-lactation cows are replaced at the end of that lactation, we can derive the average age structure for a 250-cow herd (Figure 2).

On average, 25 per cent of the herd are on their first lactation, and the average age of the cows is just under four years old. This accords well with Neal *et al.* (2007), who assume a replacement rate of 25 per cent and an average age of 3.5 years for dairy cows in eastern Australia.

According to the modelling results, on average, just over a quarter of the culled cows are culled voluntarily (when they have finished their sixth lactation), while the rest are replaced involuntarily.

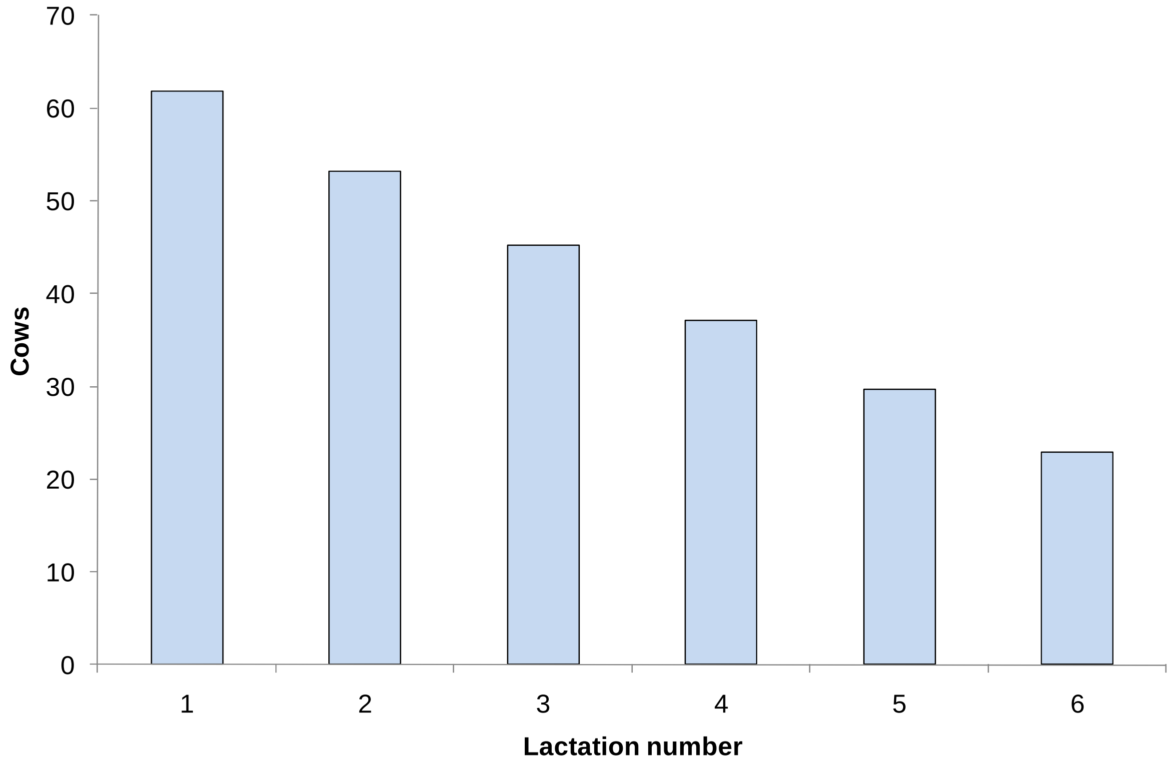

Figure 2: Predicted average age structure (by lactation number)

Figure 1 above calculates V(T) for a two-year old heifer as a function of T. Conversely, to assess the relative worth of cows of different ages, we can fix T at six and calculate V(6) for each lactation.

The equation $V(T) = q(T) + E\left\{\beta^{L(T)}V(T)\right\}$ is applied for our given T (= six) but for different starting ages. For older cows, the $q(T)$ component will be less than for a first-lactation cow, but $E\{\beta^{L(T)}V(T)\}$ will be greater, as the expected time to replacement is less, and hence $E\{\beta^{L(T)}\}$ is greater.

Figure 3 below shows that the most valuable cows in the herd are the three-year olds (on their second lactation). In general, a herd with a younger age structure is more valuable than a herd with an older age structure. This information will be used to help model culling as a response to drought in Section 5.

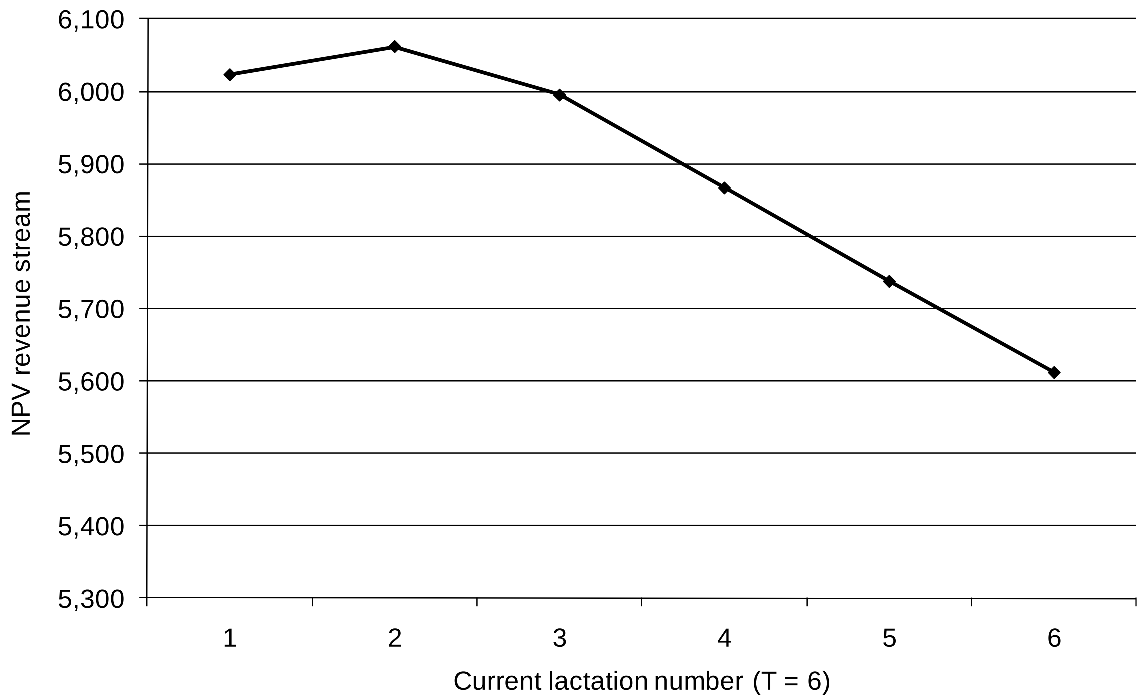

Figure 3: Expected value of cows of different ages (with planned replacement at T = 6)

4.2 Sensitivity analysis

Data for the base case were in many cases a best guess. A sensitivity analysis may help assess how robust the results are to the assumed data.

Four sensitivity analyses are conducted. In the first one, the saleyard values of cows were changed. Our assumption that cows can be sold for dairy purposes up to and including the seventh lactation might have been too generous. In addition, a value of $1,500 for replacement heifers might be too high. In the first sensitivity analysis, we assume replacement heifers, two and three-year old cows are all valued at $1,100/head. Salvage value per head thereafter declines by 5 per cent per lactation. The effect of this change is to reduce the optimal planned replacement age from the sixth to the fourth lactation (Figure 4).

The second sensitivity analysis was to change the discount rate from 10 per cent to 5 per cent. This markedly increased the future stream of profits, but had no effect on the optimal age of replacement (Figure 4).

It might be the case that this model overpredicts involuntary culling relative to voluntary culling. In the third sensitivity analysis, the chance of involuntary culling was decreased by 0.05 percentage points for all lactations after the first one. This also lead to a slight increase in V(T) relative to the base case, but did not change the optimal replacement age (Figure 4).

The fourth sensitivity analysis involved changing the pattern of net revenues. Net revenues for lactations one and two were left as in the base case, but net revenues for lactations three to seven were increased to a constant $900. Thereafter, net revenue per lactation was assumed to decline by 10 per cent per lactation. This different set of assumptions for net revenue increased the optimal T from six to seven.

All up, it seems the results are reasonably robust to minor changes in the data.

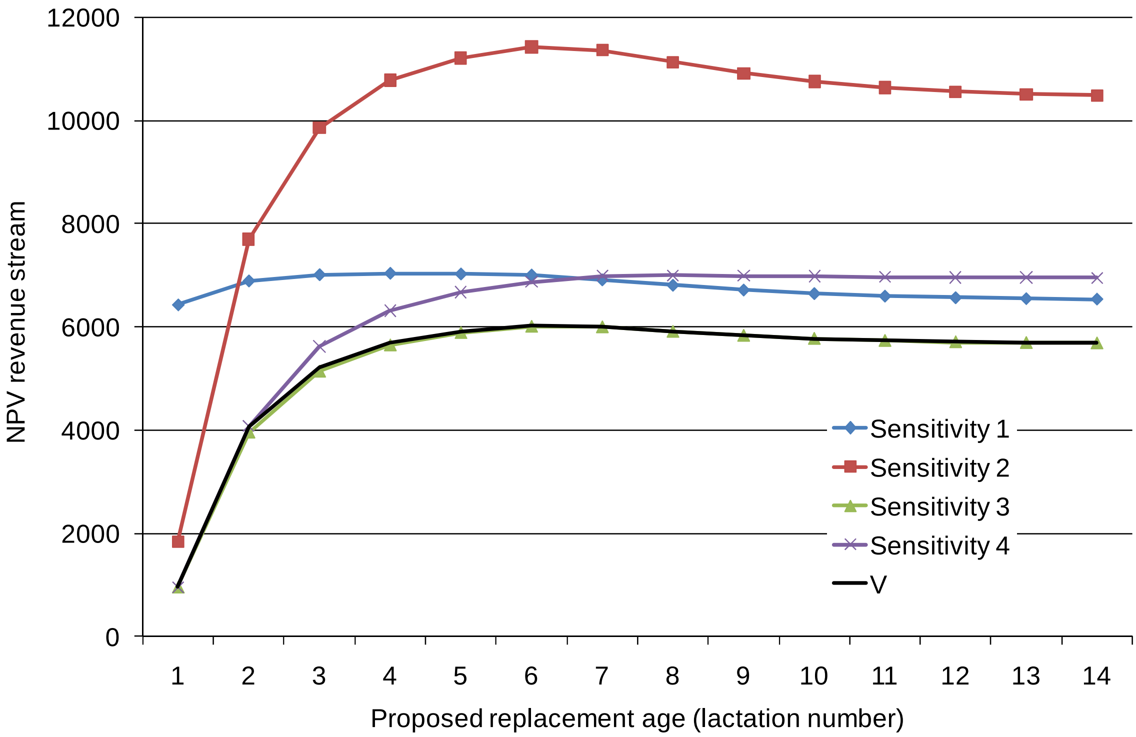

Figure 4: Sensitivity analysis for optimal planned replacement age

5 Culling as a response to drought

The interest behind this modelling was not so much in determining the optimal replacement age as in quantitatively evaluating culling as a response to drought. In times of drought, the cost of feeding cows can be higher than the value of their milk.[5] For example, in 2007, an ABARE survey revealed that 45 per cent of dairy farms Australia-wide were expected to record a negative farm income (Dairy Australia 2007). In northern Victoria, the hardest-hit region, this percentage would have been much higher. Farmers may see culling higher than normal levels of cows as necessary to avoid rapidly accumulating debt. The decision to cull cows must be weighed against the longer run costs in terms of the future productivity of the farm and the cost of purchasing replacements when conditions return to normal.

Although the whole of the last decade could be considered a drought in northern Victoria, two years in particular stand out: 2002-03 and 2007-08 (Figure 5). Drought is reflected in the peaks in feedgrains and in particular the pool price for temporary water in these years.

Farmgate prices for milk and seasonal conditions in the southern Murray-Darling Basin are not strongly linked, as milk prices are driven mostly by the world price for dairy products and the exchange rate. Note that in 2002-03, farmgate milk prices were low, while in 2007-08, although input prices were very high, so were milk prices. We will model the implications of these changes in input and output prices for the herd culling decision in this section.

[5] We assume that the effect of the drought is to increase feed costs, while all other components of net revenue stay the same. In particular, it is assumed that drought has no impact on involuntary culling (thanks to Andrew Alford for pointing this out).

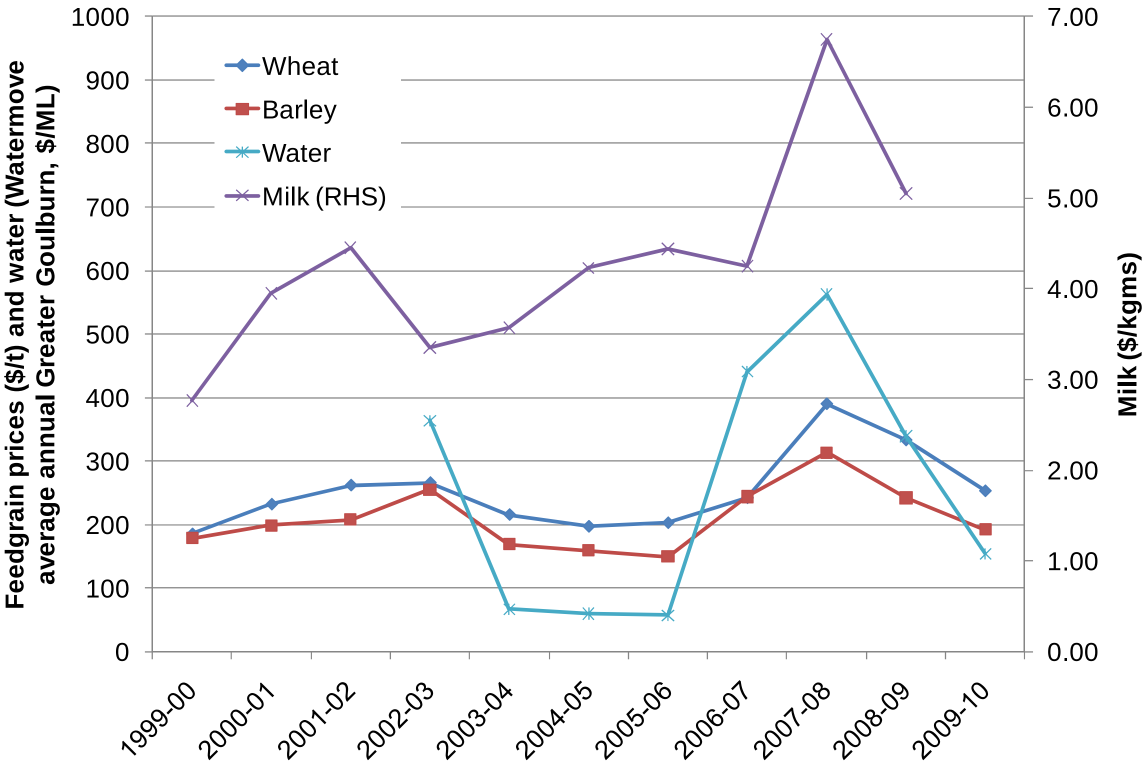

Figure 5: Grain, temporary water and milk prices

Sources: Prices for wheat and barley were taken from ABARE *Australian Commodities* publications for various years; water market price was derived as a volume-weighted average from Watermove weekly pool prices for trading zone 1a (Greater Goulburn); and prices for milk were taken from Dairy Australia's *Situation and Outlook* publications for various years. All are available on the respective websites.

5.1 A one-year drought

We develop a methodology to evaluate whether to cull a cow to avoid escalating feed costs which draws on the results presented in Section 4 above; in particular, the expected net present value of cows of different ages (assuming the optimal replacement policy), NPV_t, shown in Figure 3. In this scenario, we assume that the drought is known with certainty to endure for one year, after which all conditions return to normal (that is, the data contained in Table 1 applies).

We assume farmers can choose from two options: cull at the beginning of the year and replace with a heifer at the beginning of the following year (when conditions have returned to normal); or retain the cow through the drought year, feeding as normal. In both cases, when conditions return to normal at the beginning of the second year, the optimal replacement policy derived in Section 4 applies (that is, cows are culled voluntarily following their sixth lactation).

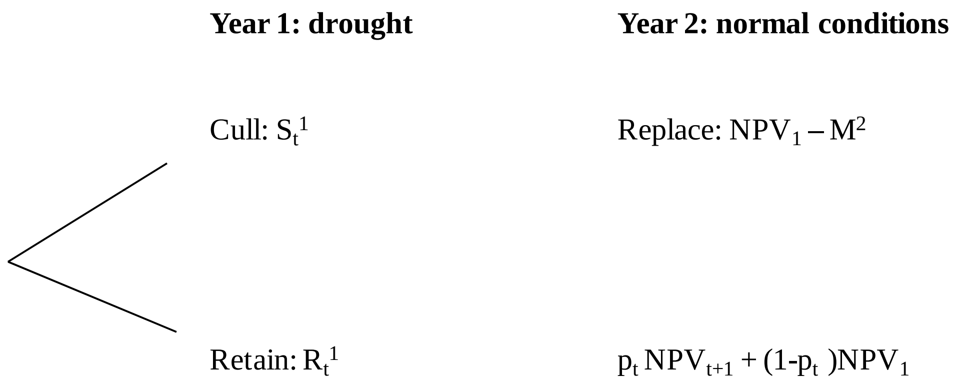

Figure 6: Schematic for the cull decision for a one-year drought

The benefit of culling cow at the beginning of the drought year is $S_t^1 + \beta(NPV_1 - M^2)$, the salvage value of the cow at the start of the year, plus the discounted value of a heifer from the start of the next year, minus the purchase cost of the heifer. Note that relative to the modelling in Section 4, salvage value, expected net revenue and replacement heifer costs might all vary due to the drought – this is captured through the use of the superscripts for time. The NPV terms are taken from the modelling above, and reflect (infinite) net present value streams of cows of different ages assuming average conditions and the optimal replacement policy.

The benefit of keeping the cow is the expected revenue stream over the drought year, plus the discounted weighted average of the net value of the cow if it survives and the net value of a replacement heifer if the cow doesn't survive (due to accidental death), $R_t^1 + \beta(p_t NPV_{t+1} + (1-p_t)NPV_1)$.[6] For a sixth-lactation cow (that is, one that is planned to be replaced at the end of the season anyway), the benefit of retaining the cow through the drought is $R_6^1 - \beta(p_6(M^2 - S_6^2) - NPV_1)$.

We assume the farmer chooses to cull the cow earlier than the planned replacement age if the total expected benefit of culling the cow is greater than the total expected benefit of keeping the cow through the drought conditions.

Note that while it might seem counterintuitive to use a long run methodology such as optimal replacement age in the context of a short-run event such as a drought, we have only used values from this modelling when conditions return to normal.

[6] Note that R_t includes the possibility of involuntary culling, and a term for the cost of a replacement heifer in this event.

5.1.1 Scenario 1: 2002-03

In this scenario, we assume that drought has caused the price of dry matter to increase to around $300/tonne, similar to levels in 2002-03 (Figure 5). We assume farmers produce their normal volumes of milk[7], implying a requirement of approximately 6 tonnes dry matter and a feed bill of around $1,800 per cow per year. We first assume milk prices remain at average levels of around 32 cents/litre, implying milk income of around $2,150 (as in Table 1).

Figure 7 shows the values of culling versus retaining cows of all ages. The value of culling the cows is shown by the straight line: it is the same no matter how old the cow is as we assume all cows have the same salvage value. The value of keeping the cow depends on the age of the cow (the columns).

With higher feed costs alone, dairy farmers would be best off to retain cows on their fourth lactation and younger, and cull the older cows, replacing them with heifers at the start of the following year (Figure 7.1). Note that higher feed prices affect the value of retaining but not the value of culling a cow, relative to a base case.

During times of drought, as farmers seek to offload stock, saleyard prices fall. In Figure 7.2, the higher feed prices of above are coupled with lower salvage values: we assumed cows are able be sold for $700 rather than $1000. The main impact of this change is to lower the value of culling immediately (that is, the line in Figure 7.2 has shifted down). Changes in the values of keeping the cow are marginal. As a result, dairy farmers should now only cull the sixth lactation cows at the beginning of the drought year.

Another factor which may deter culling is the fact that replacement costs in the following year are likely to be higher than average. We assume Year 2 replacement heifers are priced at $2,000, rather than $1,500. As for Figure 7.2, a change in replacement heifer costs are felt more on the culling than on the retaining side of the equations. Higher replacement heifer costs increase the value of retaining relative to the value of culling, except for the sixth lactation cows, as these cows will be replaced at the higher replacement costs at the end of the season anyway (Figure 7.3). Again, the sixth-lactation cows are culled at the beginning of the season.

Milk prices in northern Victoria are driven to a large extent by world markets, and thus, price movements are largely independent of seasonal conditions. In 2002-03, milk prices were low,

[7] The options of under-feeding or drying-off early are not considered here.

at around 24 cents/litre (rather than the 32 cents of Table 1). Higher feed costs coupled with lower milk prices mean dairy margins are squeezed from both directions.

Lower milk prices act through net revenues, as do higher feed costs. Thus, the value of culling line does not shift in response to lower milk prices, but the benefits of retaining cows are lower and farmers have a stronger incentive to cull. Again, cows on their sixth lactation should be culled at the beginning of Year 1 (Figure 7.4).

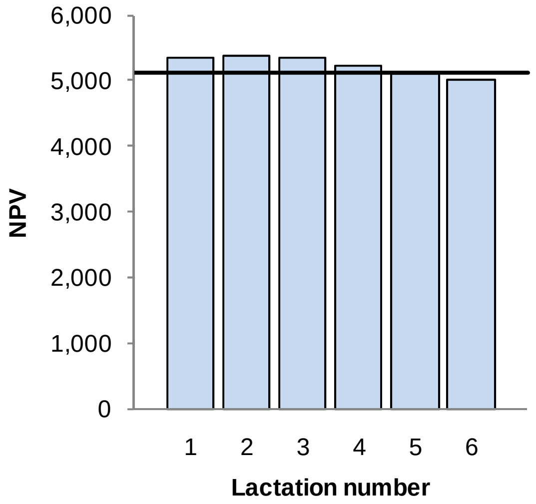

Fig 7.1: Higher feed prices

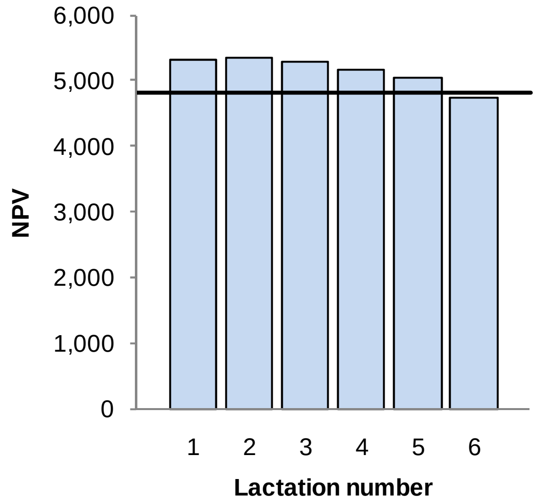

Fig 7.2: With lower salvage values

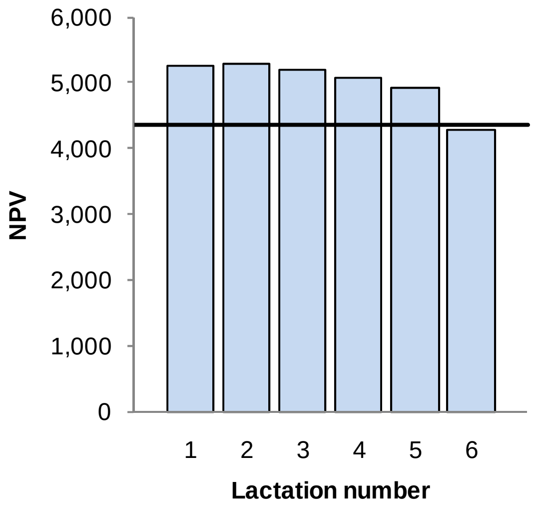

Fig 7.3: With higher replacement costs

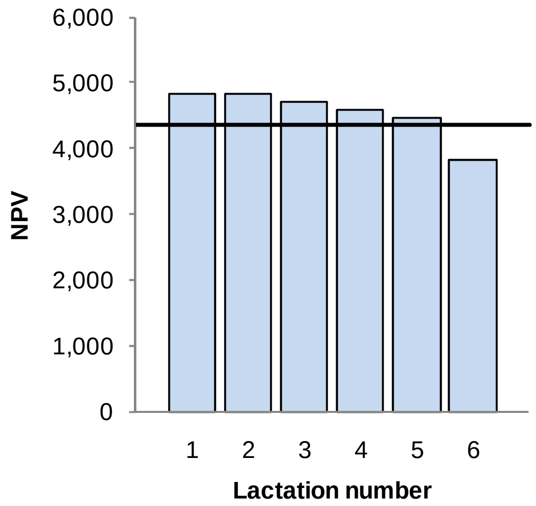

Fig 7.4: With lower milk prices

Figure 7: Cull versus retain for the 2002-03 drought

To put this into perspective, the sixth-lactation cows represents 9 per cent of the herd, 23 cows in the typical 250-cow herd. On average, six of these cows would have been culled involuntarily through the year, and all surviving cows would have been culled at the end of the year. Thus, the replacement rate stays the same as under normal conditions at 25 per cent. However, as these culled cows are not producing milk through the year, milk volumes decrease from 1.6 million litres to 1.4 million litres for the farm as a whole, about 9.7 per cent (slightly greater than the decline in cow numbers as these are relatively high producing cows).

In that year, milk production fell by around 20 per cent (albeit from a high 2001-02 base), and then fell further through 2003-04 as high feed prices continued. This was the first year of such severe conditions, and many cows were parked elsewhere in the state rather than culled. We do not evaluate agistment as an option in this paper, and indeed, this is less likely to occur now than it did in 2002-03.

5.1.2 Scenario 2: 2007-08

In 2007-08, feed costs were even higher than in 2002-03. For the purposes of this modelling, we assume cows need 6 tonnes of dry matter per head per year, available at $400/tonne, for a total feed bill of $2,400 per cow (Figure 5). For the first three cases, milk prices are at their rough average levels of around 32 cents per litre.

Figures 8.1 and 8.2 show the dire straits the industry could have been in with the feed prices of 2007-08. With higher feed costs alone (8.1), and even higher feed costs coupled with lower salvage values (8.2), farmers would have been better off to cull all cows (although admittedly this is very close for the first-third lactation cows in Figure 8.2).

As before, in Figure 8.3, we consider the effect of higher prices for replacement heifers at the start of Year 2. When the price of replacement heifers increases from $1,500 to $2,000, farmers choose to retain all but the sixth lactation cows.

Actual milk prices in 2007-08 were at record high levels, supported by pre-GFC world growth. Despite the extremely high feed prices, the value of retaining cows far exceeds the benefits of culling (Figure 8.4). In fact, it would be interesting to assess using this methodology, whether in this environment, farmers might have chosen to delay normal culling, keeping older cows for an extra year.[8]

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[8] Bill Malcolm notes that in 2008, farmers retained “everything that could walk and chew”.

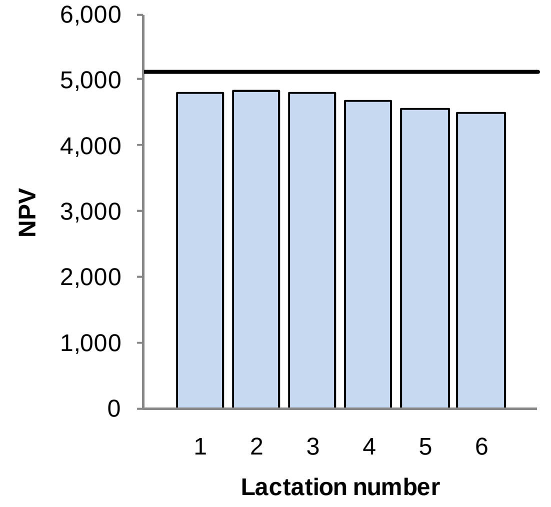

Fig 8.1: Higher feed prices

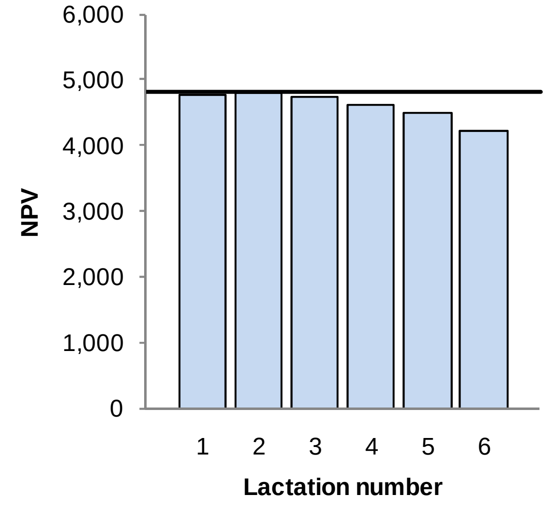

Fig 8.2: With lower salvage values

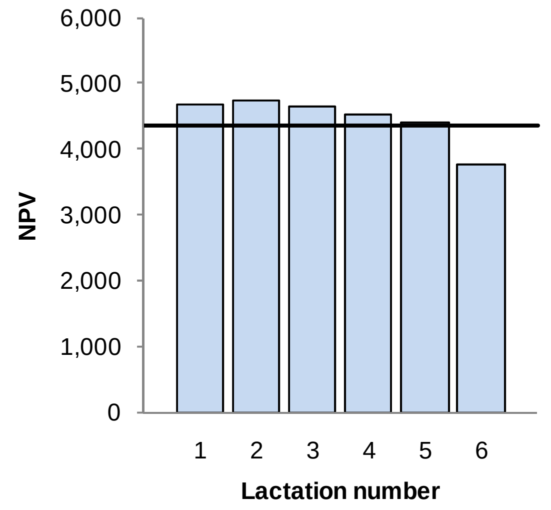

Fig 8.3: With higher replacement costs

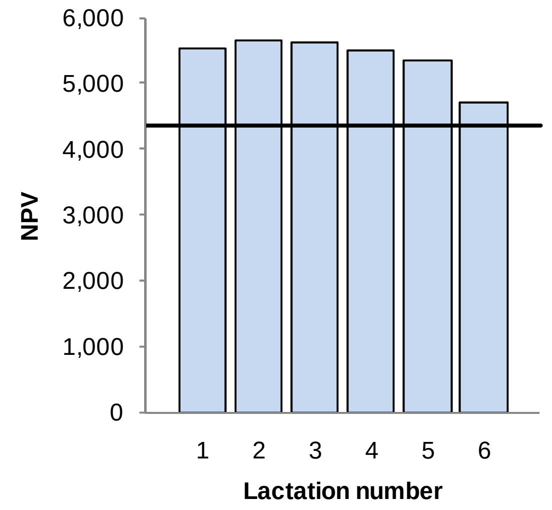

Fig 8.4: With higher milk prices

Figure 8: Cull versus retain for the 2007-08 drought

5.2 A two-year drought

Drought often extends beyond a single season. Farmers may be worried not just about the cost of feeding cows through the current season, but through a second year of drought and associated high feed prices.

We assume farmers face two years of drought, with the second year a repeat of the first. Again, we restrict the number of choices facing farmers to two: they can choose to feed cows through the drought, following normal herd replacement strategy, that is, replacing cows voluntarily after six lactations or before that if required; or they can choose to cull cows at the start of the drought, and replace all culled cows with replacement heifers at the start of year three when conditions return to normal.

	Year 1: drought	Year 2: drought	Year 3: normal conditions
	Cull: S_t^1		Replace: $NPV_1 - M^3$
	Retain: R_t^1	$p_t R_{t+1}^2 + (1-p_t) R_1^2$	$(p_t(1-p_{t+1}) + (1-p_t)(1-p_1))NPV_1$ $+(1-p_t)p_1 NPV_2 + p_t p_{t+1} NPV_{t+2}$

Figure 9: Schematic for the cull decision for a two-year drought

Given our assumptions about saleyard values, the revenue stream associated with culling immediately is the same for all cows, that is, farmers receive immediately the salvage value of the cow sold, no further income for two years, then the discounted net present value of a replacement heifer, minus her purchase price, or more formally, $S_t^1 + \beta^2 (NPV_1 - M^3)$.

This must be contrasted against the benefits associated with feeding a cow through the drought. For a cow on their fourth lactation or younger (that is, a cow that would not normally be culled voluntarily over this period), these benefits are

$$\begin{aligned} &R_t^1 + \beta(p_t R_{t+1}^2 + (1-p_t)R_1^2) \\ &+\beta^2((p_t(1-p_{t+1}) + (1-p_t)(1-p_1))NPV_1 + (1-p_t)p_1 NPV_2 + p_t p_{t+1} NPV_{t+2}) \end{aligned}$$

In other words, the expected value of revenue obtained through the two drought years, accepting that there is a chance the cow will die and be replaced anyway, plus the discounted net present value of the revenue streams when conditions return to normal. As can be seen from this expression, by Year 3, the relevant cow may be two years older than prior to the drought, or have been replaced, by a first lactation cow (if death occurred in Year 2) or a second-lactation cow (if death occurred in Year 1).

For cows on their fifth lactation, the farmer's normal replacement strategy would have them replaced by the time normal conditions return anyway. The benefit of culling these cows immediately must be weighed against the following expression for the benefit of keeping them.

$$\begin{aligned} &R_5^1 + \beta(p_5 R_6^2 + (1-p_5)R_1^2) \\ &+\beta^2((p_5(1-p_6) + (1-p_5)(1-p_1))NPV_1 + p_5 p_6 (NPV_1 - C^3) + (1-p_5)p_1 NPV_2) \end{aligned}$$

For cows on their sixth lactation, the revenue stream associated with retaining rather than culling them immediately is $R_6^1 - \beta(p_6 C^2 - R_1^2) + \beta^2(p_1 NPV_2 + (1-p_1)NPV_1)$.

For the purposes of assessing a scenario, we will use the same base scenarios as in 7.3 and 8.3 above: that is, leave milk prices at average levels, and assess feed prices at 2002-03 and 2007-08 levels respectively. As in 7.3 and 8.3, we assume drought means that salvage values fall to $700/head over Years 1 and 2, and the price of replacement heifers once the drought is over is $2,000/head rather than $1,500/head for Years 1 and 2 and the beginning of Year 3.

The return from culling is the same in these two scenarios (that is, the line is drawn at the same value), as cost of feeding through the drought is not an issue if cows are culled prior to the beginning of the drought-affected seasons. This value is lower than in the one-year scenarios above as farmers now wait two years rather than one year to recommence normal dairy operations.

For feed prices similar to 2002-03, this modelling predicts that if the drought lasted for two years rather than one, farmers would do best to cull fifth and sixth-lactation cows at the beginning of the drought period (Figure 10.1). This would imply a loss of herd numbers and milk production of just over 20 per cent for these two years. Extending the drought by one year has more than doubled drought-induced culling: when an identical drought was expected to last only one year, only the sixth-lactation cows were culled prematurely (Figure 7.3).

If prices were similar to 2007-08 levels (around $2,400/head), farmers would do better to sell all cows and restock once the drought is over (in Year 3) (Figure 10.2).[9] This is radically different than if this level of feed prices were only expected to persist for one year, where only the sixth-lactation cows are culled prematurely (Figure 8.3). Given the modelling assumptions, farmers expect to lose around $700-$800 per cow per year: they are willing to bear this for one year, but not two.

This highlights the importance of expectations regarding the duration of the drought. We assume that farmers know in advance whether the drought conditions will persist for one or two years. In fact, this is not the case. Given the widely differing optimal responses

[9] Of course, if widescale destocking occurred, salvage values might be much lower and replacement heifer costs much higher than assumed here. In addition, although we have assumed there is not a strong correlation between seasonal conditions and milk prices in northern Victoria, this might no longer hold given such a dramatic supply response, and milk prices might rise substantially. All these factors would tend to deter culling.

depending on the duration of the drought, future work incorporating uncertainty would appear to be justified.

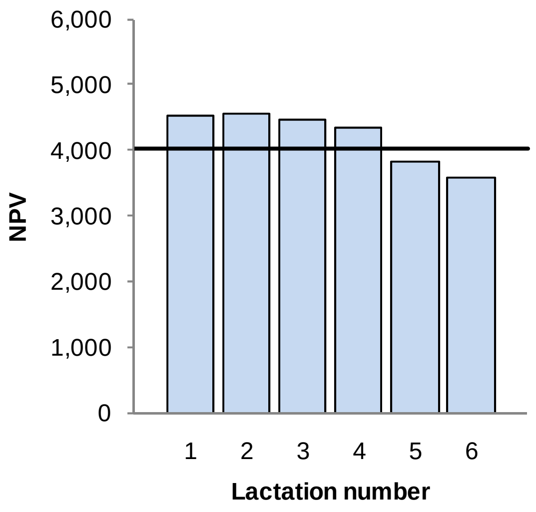

Fig 10.1: As per Fig 7.3, but 2-yr drought

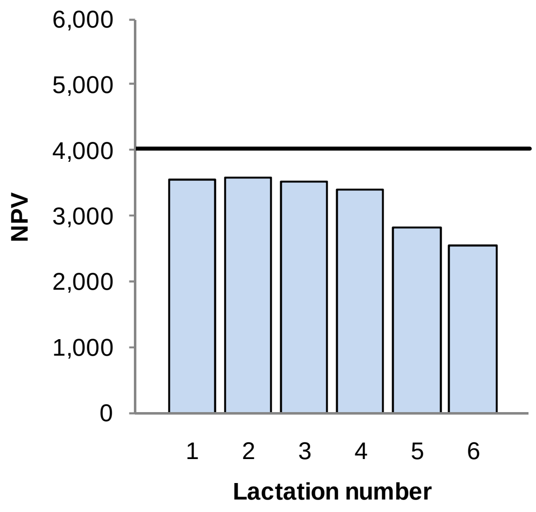

Fig 10.2: As per Fig 8.3, but 2-yr drought

Figure 10: Cull versus retain for a two-year drought

6 Conclusions

Recent years have seen severe drought in the southern Murray Darling Basin, resulting in little water available for irrigation. This has had a huge impact on the dairy industry in northern Victoria, traditionally based on irrigation of pastures. While dairy farmers in the region have substituted away from irrigated pastures towards bought-in feeds, these are also often expensive in times of drought. Dairy farmers have found themselves in situations over the past decade where they are losing money feeding dairy cows. It seems logical in this situation that they would consider culling higher than usual numbers of cows as a means of containing losses. The optimal decision depends on the cost of feeding cows through a drought versus the longer run costs of culling a greater than usual number of cows.

The first section of this working paper was devoted to applying the framework of Burt (1965) to the problem of finding an optimal replacement strategy for dairy cows under normal conditions in northern Victoria. This framework is relatively crude in that cows are classified just by age and the timescale is one year. The issues of genetic merit and genetic progress inherent in replacement heifers are not considered. Other assumptions (for example, a constant stream of future net revenues) are also stringent. Other approaches capable of capturing these factors might have been employed, such as stochastic dynamic programming (van Arendonk 1985) or hierarchic Markov processes (Kristensen 1987), but these are substantially more complex and have heavy data requirements. This approach, while simple, is at least rigorous with respect to its treatment of the long-run nature of the replacement problem.

Given our assumptions regarding survival probabilities, net revenues and saleyard values, it was found the optimal age to replace a dairy cow in northern Victoria is following the sixth lactation.

The framework is extended to consider a situation where a drought means that net revenues and salvage values are temporarily below average, while the cost of a replacement heifer increases. When the drought is over, conditions return to normal. Farmers are given the option of culling immediately and replacing culled cows with heifers when conditions return to normal, or following their normal replacement strategy and feeding cows through the drought.

Scenarios based on two recent years of drought (2002-03 and 2007-08) were constructed. In general, lower saleyard prices available at the start of the drought combined with higher prices for replacement heifers once conditions returned to normal seemed to offset in large part the effect of higher feed prices. In real life, milk prices were also low in that year. For the drought of 2002-03, the model predicts minor additional culling given the interaction of these factors, with farmers better off culling sixth-lactation cows at the start of the drought. These cows would have been culled at the end of the season anyway, and thus this decision does not have long-run implications for the herd although it implies that the season's milk production would be down about 10 per cent on normal.

Feed prices in 2007-08 were even higher than in 2002-03. Depending on assumptions regarding the interaction of feed prices, cull prices and replacement heifer costs, culling might have been extensive. However, fortuitously, world milk prices in that year were exceptionally high, and this provided strong incentives to retain all cows.

The simulation was then extended to the case of a two-year drought. The first scenario was based on 2002-03 feed prices, drought-induced reductions to saleyard prices and increases to replacement heifer costs, and average farmgate milk prices. The second scenario increased feed costs to reflect 2007-08 conditions.

In both cases, the extension of the drought led to increased drought-induced culling; for 2007-08, dramatically so. While farmers might be able to cope with one year of 2007-08 level feed prices, if these conditions persist for longer, a severe supply response might ensue (assuming, unlike 2007-08, that milk prices are average). Thus uncertainty regarding the duration of the drought becomes an important issue.

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