Farm economic thinking and the genetic improvement of fertility in northern beef herds

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Abstract

Low levels of reproduction efficiency have been considered a key constraint of the economic performance of beef herds grazing the rangelands of northern Australia. Considerable effort has been directed at resolving the issue and beef geneticists have developed technologies to allow the selection of animals with superior traits for fertility. It has been shown that incorporating selection for these traits with other herd management strategies will lead to herds with higher reproduction efficiency. However, modifying rates of reproduction efficiency will impact herd structures and output over time, making prediction of the economic value of the genetic improvement of fertility a relatively complex task. Consideration of alternative management strategies available to improve herd performance is also necessary to understand the relative value of improving reproduction efficiency. This analysis evaluated the profitability of genetically changing fertility in two regions of northern Australia: the Katherine region of the Northern Territory and the Fitzroy Natural Resource Management (NRM) region of central Queensland, using property-level, regionally-relevant property models that determine whole-of-business productivity and profitability over a 30-year investment period. We assessed the value of the genetic improvement of fertility by comparison to baseline production systems with typical reproduction efficiency for each region and to alternative management strategies available to the property manager. We demonstrate that appropriately assessing the biological, financial and economic components is critical to estimating the value of genetically improving the reproduction efficiency of a beef herd in northern Australia. An alternative approach of generating $Indexes represents a flawed approach to identifying the value of genetically improving fertility in northern beef herds giving potentially misleading and incorrect results. Our analyses indicated that purchasing bulls with different genes for fertility is likely to have variable impacts and unexpected outcomes on the profitability and riskiness of beef enterprises in northern Australia. Furthermore, there are alternative investments available to beef producers that can produce better economic outcomes. Good quality science in the area of genetic improvement of fertility needs to be paired with equally sound economic methods to ensure appropriate conclusions are reached about value to beef producers and the industry.

Keywords

Beef cattle, beef herd models, farm management economics, genetic improvement, breeder fertility, rangelands, Breeding objective, $Index

Introduction

Investigation of the performance of breeding herds across northern Australia identified that realistic targets for weaning rates were not being met (O'Rourke *et al.* 1992) and that there was a marked variation in herd performance (McCosker *et al.* 2011). The causes of poor reproduction performance in beef breeding herds are multifactorial and have been comprehensively reviewed (Burns *et al.* 2010). A population-based epidemiological study of the factors affecting the reproduction performance of commercial breeding herds in northern Australia has recently been completed (McGowan *et al.* 2014). That research together with other survey data that looked in more detail at mortality rates (Henderson *et al.* 2012) provides contemporary data for the level of performance of the breeder component of beef herds across regions of northern Australia.

The capacity to improve the reproduction performance of beef herds across northern Australia via the means of genetic selection has also been a focus of research activities. Burns *et al.* (2014) investigated the genetic control of traditional and novel measures of male reproduction performance and their genetic correlations with critically important female traits, including age at puberty, post-partum anoestrous and traits associated with female lifetime reproduction performance. They found new male traits that are heritable and genetically associated with scrotal circumference or female reproduction traits, and no antagonisms between these male reproduction traits and other production traits. They concluded that these male traits could be used for indirect selection to improve both male and female reproduction performance in northern Australia beef herds. They estimated that an Estimate Breeding Value (EBV) for sperm motility in Brahman cattle might lift lifetime weaning percentage by 6% in 10 years.

In a related project, Johnston *et al.* (2013) found early-in-life female reproduction traits are heritable and alternative measures (such as male reproduction performance, mating outcome, lactation status of first calf heifers and maiden cows) were capable of capturing genetic variation. They also identified large differences between sires for the early-in-life reproduction performance of their daughters and, although lifetime reproduction traits were lowly heritable, several traits measured early in life were highly genetically related. They found this to be a key result for the future development of genetic evaluation and performance recording and suggested that by focusing on these more heritable, early-in-life traits it would be possible to make significant genetic progress in lifetime reproductive rates.

Johnston *et al.* (2013) also investigated whether any genetic antagonisms exist with economically important steer production traits. They found that the generally low genetic correlations between steers traits and cow reproduction traits indicated that selection for improved steer performance (i.e. early growth, carcass and meat quality and feed efficiency) could occur without any major antagonisms with female reproduction. They identified this to be important for a breeding objective focussed on whole herd profitability. However, they concluded that if both steer and cow reproduction traits are to be improved then they would both need to be measured and selected appropriately according to their relative contribution to an overall breeding objective.

Herd fertility (weaning rate) is identified as a key "profit driver" in northern Australian beef herds. (Johnston *et al.* 2013, McLean *et al.* 2014, MLA 2015). The common method applied to support this claim is summarised in Table 1 and consists of comparing the impact of a small change in one factor while holding other factors constant. MLA (2105) states that "this provides an indication of how changes in each of these measures impact the productivity of the herd".

Table 1: Impact of changes to reproductive rate, mortality rate and sale weight on productivity (MLA 2015)

Variable	Change (percentage points)	Kg beef/AE response
Increase reproductive %	1%	1.50
Decrease mortality %	1%	2.28
Increase sale weight	1kg	0.18

Although this form of analysis has long been discredited by numerous agricultural economists, such production outputs often underpin /reflect the thinking of many in the beef research community. This is particularly so in the genetics community where the production value of increasing "reproductive %" - almost eight times that of increasing "sale weight" – appears to underpin the economic weightings applied when developing some breeding objectives.

A breeding objective or selection index is a tool designed to optimise bull selection by weighting the many genetic traits that may define profit in a particular production system. In theory, they are supposed to provide a single metric, associated with profitability, which meets the goals of the beef producer better than single trait selection or multiple trait selection via independent culling levels. The economic value placed on a trait is said to express to what extent improvement of genetic merit of that trait contributes to an improvement of economic efficiency of the production system. Smith (1983) identified that incorrect economic values and omission of important traits from the breeding goal may lead to losses in efficiency of improvement of animal production.

Melton *et al.* (1979) identify the determination of a trait's economic value as a "major difficulty" as "most traits are not marketed individually" and "their economic value cannot be observed directly". They identify:

- if the relative prices of either outputs or inputs change, the economic value of traits will change as well;
- if the average value of the trait changes, its economic value will change as well;
- to complete the index, the genetic and phenotypic variances and co-variances of the traits need to be obtained with some certainty;
- objectives may be as varied as producers themselves;
- the lack of well estimated production functions presents special problems for this type of analysis, most fall short of the complex formulation necessary to fully represent reality.

Malcolm *et al.* (2019) confirm that the shortcomings identified by Melton *et al.* (1979) remain evident. *"Regardless, progress in genetic identification has not been matched by progress in providing sound farm management economic information to farmers about investing in the animals with superior genetic potential. Indeed, it is almost a universal truth that geneticized advice about improving and fulfilling the genetic potential of livestock in animal farm systems is not grounded in the discipline and principles of farm management economics".*

Even so, breeding objectives (AGBU 2018; MLA 2018b) are seen by some a key part of a process to allow beef producers to capture the economic benefits of genetic research. MLA (2018b) state "a breeding objective describes characteristics that affect profit the most, as well as how important each trait is to profit”. AGBU (2018) identify BreedObject as a tool for formalising breeding objectives and $Indexes that can help beef producers “breed more profitable cattle”. Differences in $Index values are said to describe how animals are expected to benefit production system profitability when production is for the described purpose. AGBU (2018) states “the $Index is an EBV for profit for this production purpose”.

There is a large gulf between the view of the farm management economists (Malcolm *et al.* 2019) and the view of the others (AGBU 2018; MLA 2018b) about the capacity of selection indexes to measure the impact on profit of a bull selection decision.

UNE (2018) shows the calculation of a $Index as a combination of traits affecting profit with the economic values of those traits and identifies that the “economic value of a trait is the change in profit after changing the mean for that trait by one unit”. They provide the following example to illustrate the calculation of a Breeding Objective.

Objective = $a_1BV_1 + a_2BV_2 + \ldots + a_mBV_m$

Where BV represents different breeding values of a trait and ‘a’ represents the economic value of that trait.

UNE (2018) provide a simplified example of the use of a “profit function” in calculating the economic value of a 1 kg increase in fleece weight in sheep:

*Profit per ewe = FleeceWght * price/kg – cost per ewe*

*= 4 * 10 – 10 = $30*

Now increase FW by one unit:

*= 5 * 10 – 10 = $40*

Hence, the economic value of 1 kg increase in FleeceWght is $10.

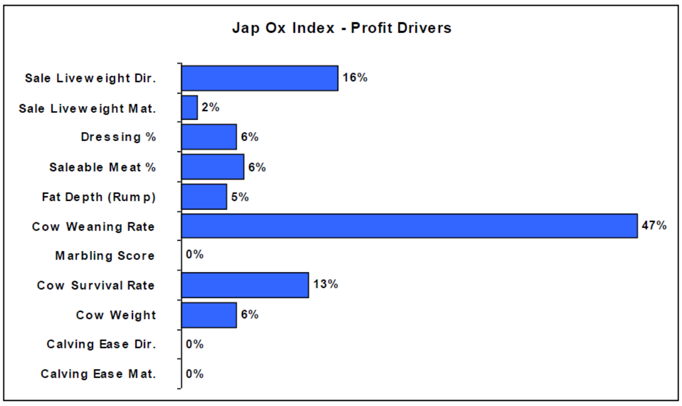
The Brahman Jap Ox index

The Brahman Jap Ox index is widely promoted by MLA and government agencies in northern Australia. It is constructed using BreedObject software and applies three key inputs (AGBU 2018):

1. Production and cost estimates for commercial beef production,
2. The EBV’s available through BreedPlan,
3. Description of the inheritance of all traits concerned, including the genetic correlations between all traits and measurements.

The BreedPlan website (http://breedplan.une.edu.au) describes the Brahman Jap Ox Index “as estimating the genetic differences between animals in net profitability per cow joined for an example commercial herd targeting pasture finished steers for export markets. Steers are assumed to be pasture grown and finished, weighing 600 kg live weight or 325 kg carcass weight at 32 months from a self-replacing herd run in a tropical environment. Daughters are retained in the industry for breeding”. The values assigned to each bull rely upon a matrix calculation that applies the economic weights (profit drivers), the various EBV’s and their correlations. The key economic traits identified by Breedplan (2019) and their weightings in the Index are shown in Figure 1.

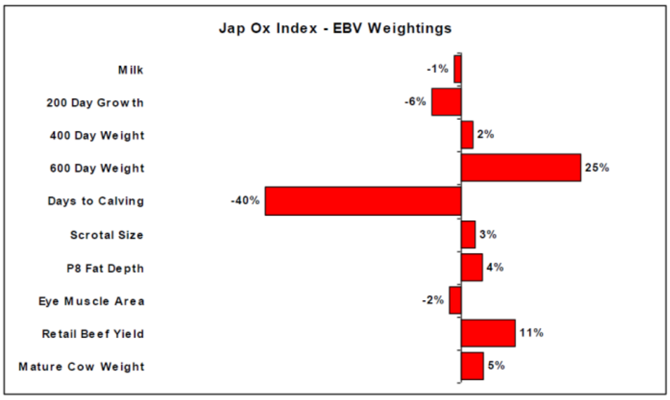
Figure 1 Jap Ox Index – Profit Drivers



The derivation of the weighting for each profit driver is not provided but the weighting applied to Cow Weaning Rate suggests the persons developing the weightings believed that the biggest impact on profit (by far) for a Jap Ox producer could be gained by focussing on improving female reproduction efficiency.

The construction of the index also includes weightings applied to the EBVs. (Figure 2) BreedPlan (2019) considers the genetic relationship between the key profit drivers and the EBVs that are available and produces the EBV emphases shown. The sign indicates the direction of the emphasis. For example, greater 600 Day Weight EBVs and shorter Days to Calving EBVs are favoured.

Figure 2 Jap Ox Index – EBV weightings



Once again, the derivation of the weightings is not provided but the EBV weightings again heavily concentrate on the EBV for Days to Calving. This EBV is reported as being related to fertility (Upton 2018) even though no trial results or analysis can be found providing evidence that selecting for reduced days to calving in northern Australia will improve the weaning rate of a beef herd run under commercial conditions.

The BreedObject website (BreedObject 2019) provides a Jap Ox Index calculation for all sires listed with the Australian Brahman Breeders Association that have the necessary objective measures recorded with BreedPlan. Table 2 compares the recoded EBV's for the top ranked bull and the breed average EBV's. The EBV values showing the critical differences between the top ranked bull and the breed average are highlighted. Table 2 also shows that the top ranked bull produces a Jap Ox Index almost three times that of the breed average suggesting that bulls with these characteristics (or their genes) will have three times the impact on profit of the breed average bull.

Table 2 Brahman Jap Ox index and EBV's for the top rated bull and breed average (ABRI online catalogue (2019))

EBV	Top rated bull CBV 11-8851 (D)	Breed average	Difference Bull & Breed Av	Expected difference in progeny
BWt (kg)	-0.6	2.5	-3.1	-1.55
200D (kg)	15	19	-4	-2
400D (kg)	32	27	5	2.5
600D (kg)	37	37	0	0
MCW* (kg)	16	41	-25	-12.5
Milk (kg)	-3	-1	-2	-1
SS (cm)	3.1	0.7	2.4	1.2
DTC* (days)	-38.2	-0.9	-37.3	-18.65
CWt (kg)	17	23	-6	-3
EMA (sq.cm)	1	2.5	-1.5	-0.75
Rib (mm)	0.9	-0.4	1.3	0.65
Rump (mm)	0.6	-0.5	1.1	0.55
RBY (%)	0.3	0.6	-0.3	-0.15
IMF (%)	0.3	-0.1	0.4	0.2
PNS (%)	6.3	0	6.3	3.15
F.time (secs)	-0.06	0.01	-0.07	-0.035
SForce (kg)	0.41	0	0.41	0.205
Jap Ind ($)	105	28	77	38.5
Live Ex Ind ($)	101	25	76	38

*MCW – Mature cow weight, *DTC – Days to calving

Given that there are no real differences in any of the other EBV's reported in Table 2, the final estimate of economic value for the top ranked bull relies almost entirely on the substantial economic weighting placed on weaning rate (Days to Calving).

We can understand why beef geneticists and others were keen to develop such a thing as a selection index. The number, complexity and almost competitive nature of the EBV's available together with a desire to include some measure of the economic value of selecting bulls on objective criteria are the obvious factors behind their creation. The technical elegance of combining vectors of phenotypic and economic values, their variances and covariances in a profit optimising mathematical matrix is an attractive concept.

The rankings provided the Brahman Jap Ox index (and the Live Export Index) suggest selecting bulls expected to improve the weaning rate will have a significant impact on property profit in northern Australia. We will assess this by:

- modelling the level of improvement in weaning rate (fertility) claimed by Burns *et al*. (2014) to determine the marginal improvement in profitability potentially provided by the technology across two distinct regions, then
- identifying the value of the strategy of selecting bulls to improve weaning rate (fertility) relative to a range other relevant and alternative management strategies.

Methods

The implications of strategies aimed at the genetic improvement of fertility on the productivity and profitability of a beef enterprise were investigated for a representative beef cattle property in the Katherine region of the NT and the Fitzroy NRM region of central Qld using production economic principles. Hypothetical properties were constructed where production responses to genetic improvement and other management strategies were determined with reference to existing data sets and published literature as well as the expert opinion of experienced Qld Department of Agriculture and Fisheries and NT Department of Primary Industry and Resources staff. The economic and financial effect of a strategy was assessed by comparison to a base production system with no change in herd fertility.

Property-level herd models were used to determine whole-of-business productivity and profitability over a 30-year investment period. Change was implemented by altering the herd performance and inputs of the base scenario to construct the new scenario. The comparison of the two scenarios, one of which reflected the implementation and results of the proposed change from a common starting point, was the focus of the analysis. Partial discounted cash flow (DCF) techniques were applied to calculate the marginal returns associated with additional capital or resources invested within property operations. Positive marginal returns indicated that marginal costs were likely to be lower than marginal revenue and therefore additional investment was worth further consideration. The DCF analysis was compiled in real (constant value) terms, with all variables expressed in terms of the price level of the present year (2018). It was assumed that future inflation would affect all costs and benefits equally. The Breedcow and Dynama herd budgeting software (Version 6.02; Holmes *et al.* 2017) was used to apply investment analysis methods as described by Robinson and Barry (1996), Makeham and Malcolm (1993) and Campbell and Brown (2003). The models contain livestock schedules linked to DCF budgets, for the base scenarios and each alternative scenario, for an interval of 30 years.

Representative beef cattle enterprises

Katherine region, NT

The modelled herd and property in the Katherine region was based on data for the former ABARES Region 713 (ABS 2012) of the NT. The 2010 NT Pastoral Industry Survey (Cowley 2015) plus research relevant to the region (Henderson et al. 2012; McGowan et al. 2014) informed it. The region has a semi-arid monsoonal climate and experiences two distinct seasons: a wet season (October to April) and a dry season (May to September). The hypothetical property was located ca. 600 km from Darwin and ca. 300 km from Katherine. The property was a total area of 147,000 ha with a carrying capacity of 7,400 AE. Pastures on the property were primarily native tropical tall grasses growing on soil types considered to have a range of levels of phosphorus (P) deficiency status (marginal, deficient or acute, defined here as 6-8, 4-5 and 2-3 mg/kg bicarbonate extracted P (Colwell 1963) in the top 100 mm soil, respectively) with the majority of the property considered to have an acute or deficient P status. The enterprise was a self-replacing *Bos indicus* breeding and growing activity that relied on the production of weaners by the breeding herd. Steers and surplus heifers were sold to the live export market (steers 80% at 1-2 years, 20% at 2-3 years; cull heifers at 2-3 years) while cull cows and cull bulls were sold to the abattoirs. The price basis for each class of livestock was derived from Darwin live export markets and north Qld over the hooks markets (MLA 2018a) between July 2006 and November 2016, which were taken to be representative of expected prices expressed in current (real) terms. A detailed description of the herd structures and dynamics, and cattle management activities, treatments and cost assumptions required as inputs for the analysis are given in Chudleigh *et al.* (2019). The starting level of reproduction efficiency for this herd was a 55% weaning rate calculated as the ratio of weaners produced to cows mated. This level of efficiency is close to the median value given for the ‘contributed a weaner’ parameter as reported for the region by (McGowan *et al.* 2014). The mortality rates applied were the median for the region as described by Henderson *et al.* (2012).

Fitzroy NRM region, central Qld

The property and herd characteristics for the hypothetical property in the Fitzroy NRM region were informed by recent industry surveys and research relevant to the region (McGowan *et al.* 2014; Bowen *et al.* 2015; Barbi *et al.* 2016). The property was located centrally in the Fitzroy NRM region and considered to be a total area of 8,700 ha and to consist of a mixture of native and sown grass pastures, giving an assumed carrying capacity of 1,500 AE. The beef production system was a self-replacing *B. indicus* crossbred breeding and growing activity that relied on the production of weaners by the breeding herd. The breeding herd was considered to graze on less productive, non-arable land types (predominantly a mixture of open Eucalypt woodlands and better quality land types; Whish 2011). The steers and heifers were assumed to graze more productive and arable Brigalow land types (Whish 2011) supporting sown, buffel grass pastures. All livestock classes were considered to have sufficient access to land types with Adequate P status (defined here as >8 mg/kg bicarbonate extracted P (Colwell 1963) in the top 100 mm soil) and hence to require no P supplementation. The heifers were assumed to be mated whilst grazing buffel grass pastures and then to calve on breeder country. Feed-on (feedlot entry weight) steers were sold through the sale yards while surplus heifers and cull cows went to the abattoirs. The price basis for each class of livestock was derived from Roma store sale data and JBS Australia Dinmore abattoir (Ipswich, Qld) respectively, between July 2008 and November 2015, which were taken to be representative of expected prices expressed in current (real) terms. Freight costs for steers were calculated as described in Bowen *et al.* (2015). A detailed description of the herd structures and dynamics, and cattle management activities, treatments and cost assumptions required as inputs for the analysis are given in Bowen and Chudleigh (2018). The starting level of reproduction efficiency for this herd was a 77% weaning rate calculated as the ratio of weaners produced to cows mated. This level of efficiency is close to the median value given for the ‘contributed a weaner’ parameter as reported for the region by (McGowan *et al.* 2014).

Alternative production scenarios

Katherine region, NT

In the Katherine region a base herd with no selection for the genes associated with fertility that maintained its expected weaning rate over time was compared:

- firstly, to a herd that changed its breeding bull herd in the first year to bulls with genes expected to improve conception rates by 6% over time (Year 1 change; Scenario 1) and,
- secondly, to a herd that replaced the herd bulls as they came due with genetically different bulls - also expected to improve the breeder conception rates by 6% over time (Gradual replacement; Scenario 2)

- sub-scenarios were investigated within each of these two over-arching scenarios

A key assumption underlying the Scenario 1 was that the property manager converted all of the current breeding bull herd to one with different genes in the first year with the first group of calves with the different genes born in the second year. This was due to the calendar year being used in the herd budget and the first crop of calves after the changeover of bulls being born, on average, around November of the first year arising from the mating prior to the changeover of the herd bulls. On this basis, it was Year 4 before heifers with different genes were first mated as 2-3 year olds. Additional capital was required and more than a decade was taken to fully implement the change. The capital cost of the changeover was incorporated in the first year of the analysis and was due to the sale of the existing bull herd not covering the costs of the replacement bull herd.

- In **Scenario 1a** replacement bulls with different genes cost the same as the average cost ($2,500) used in the 'without change' herd but there was a net cost to change the bull herd over in the first year (Year 1 change, same cost; Scenario 1a). The net capital cost of the changeover of bulls at the beginning of the investment period was $257,500 (206 x $2,500 for the new bulls less 206 x $1,250 for the old ones).

- Whether a producer could pay more on average for replacement bulls with different genes was assessed by paying $500 more per bull (Year 1 change, $500 more; **Scenario 1b**). The changeover cost to establish the bull herd became $360,500 (206 x $3,000 for the new bulls less 206 x $1,250 for the old ones) and the ongoing cost of replacement bulls became $3,000 each.

- Additionally, the uncertainty around the paddock level change in conception rates likely to be achieved was considered by changing conception rates by 4% instead of 6%. This was tested at the same average purchase price for bulls as paid by the base herd (Year 1 change, 4% conception rate (CR); **Scenario 1c**).

Scenario 2 involved introduction of the different genes for fertility at a slower rate and without the additional capital costs as incurred by the Scenario 1.

- In **Scenario 2a** replacement bulls with the different genes for fertility were purchased at the same cost as the previous replacement herd bulls as herd bulls became due for replacement (Gradual replacement, same cost; Scenario 2a). Another assumption applied in this scenario was that no additional costs would be incurred in herd management. The heifers produced by the bulls with different genes for fertility were grouped with the heifers without the genes for fertility of the same age and all were subject to the same selection criteria as they moved through the age cohorts of the breeding herd. The constraint of no additional costs prevented the identification of the genetically different heifers and females with and without the different genes had the same chance of being culled. The bulls with the different genes were allocated to mature cow groups with the highest conception rates so that proportionally more heifers with the genes for fertility were likely to be mated in any age cohort as the different genes flowed through the herd. Whether this would be possible in an actual herd is difficult to determine but appears unlikely.

- Scenario 2 was also tested for the impact on risk and returns of paying $500 per head more for replacement herd bulls (Gradual replacement, $500 more; **Scenario 2b**).

For all Katherine scenarios, the starting level of reproduction performance prevented all females that did not show as pregnant from being culled. That is, the mature breeding females only had 5% of cows that showed as non-pregnant culled and only 50% of non-pregnant heifers were culled after their first mating. Most non-pregnant mature females had to be retained in the herd until they were last mated at 9-10 years of age to maintain the herd in a steady state. Increasing the maximum cull age would allow slightly heavier culling of non-pregnant younger females but this would reduce the economic performance of the herd given that the final mating age of 9-10 years was identified as the economic optimum for the Katherine herd.

Fitzroy NRM region, central Qld

For the Fitzroy NRM region four alternative scenarios were modelled (Scenarios 3-6) encompassing two starting herd fertilities, a different way of culling heifers to achieve more weaners and a gradual process of introducing the different genes for fertility.

The first Fitzroy NRM scenario followed the same implementation process as applied in the first Katherine scenario and immediately replaced the bull herd to provide a 6% improvement in conception rates over time (Year 1 change, same cost; **Scenario 3**). Heifer culling and mating strategies were maintained the same as the 'without change' Fitzroy NRM herd i.e. about 1/3 of replacement heifers were culled before mating with all non-pregnant replacement heifers culled after their first mating. The higher starting reproduction performance and relatively lower mortality rates applied in the Fitzroy NRM model also allowed all breeding females to be culled on the basis of their pregnancy status with all non-pregnant cows being culled. The increased pressure on female reproduction performance in this herd together with the expected sale weights and prices of the various classes of females produced an optimum herd structure that last mated cows at 12-13 years of age. Replacement bulls cost the same as the average ($5,000) used in the 'without change' herd. The net cost of the changeover of all of the herd bulls at the beginning of the investment period was $55,000. (22 x $5,000 for the new bulls less 22 x $2,500 for the old ones (50% of the existing herd bulls were sold on to industry; 50% went to the abattoirs).

Additionally, to address concerns raised by industry observers that the number of weaners should increase over time with investment to improve fertility, the herd model was altered to cull the additional heifers at weaning, thereby changing the herd structure to allow more weaners to be produced over time (Cull heifers for more weaners; **Scenario 4**). In Scenario 4 bull change-over occurred in Year 1, as for Scenario 3. In **Scenario 5**, to test the effect of the starting level of reproduction efficiency of the herd, a herd model was constructed at the level of performance representing the bottom quarter of herds surveyed by McGowan *et al.* 2014). The resulting herd had a starting weaning rate of 65% (cf. 77% as assumed for Scenarios 3-4). In this scenario (Lower starting reproduction rate; Scenario 5) bull change-over occurred in Year 1 as for Scenarios 3 and 4.

The final scenario for the Fitzroy NRM region property considered the economic impact of replacing the herd bulls as they came due with genetically different bulls (Gradual replacement, same cost; **Scenario 6**). This was implemented following the same process applied for the Katherine herd, although in the Fitzroy NRM region herd model all mated females that did not show as pregnant were culled. It was Year 8 before the first lot of heifers produced by a completely changed over bull herd were mated and produced calves in this scenario. Replacement bulls cost the same as the average ($5,000) used in the 'without change' herd.

Biological responses to the introduction of different genes for fertility

Biological responses to each of the production scenarios were assigned with reference to Burns *et al.* (2014); as well as the expert opinion of scientists and beef extension officers with extensive knowledge of the northern Australian cattle industry. There was little relevant data available to estimate the effect on breeder liveweight, mortality and weaner liveweight, of selecting for genes associated with fertility in northern Australia, so these factors were maintained at the same level in the alternative models. A key assumption was that the potential impacts of the genetic selection program were not limited by nutritional or other production constraints expected to be associated with land types and climate typical of each region. Each genetic change scenario was modelled to include the impacts of implementing the change. In scenarios where all herd bulls were changed in Year 1, the reproduction efficiency did not begin to change until the heifers produced by the initial and subsequent mating has entered the herd. Additionally, extra stock produced by the genetic change did not add to the returns of the property until they were sold as either cull females or sale steers. Where bulls with different genes for fertility were introduced to the herd as the existing bull herd became due for replacement (the 'gradual replacement' scenarios), the change in reproduction efficiency was apportioned according to the proportion of females with different genes in each females age class mated each year.

The herd model was reset to maintain constant grazing pressure each year in which the conception rate of an age cohort of females changed. This required a slightly different number of heifers to be retained each year to maintain the herd structure necessary to optimise economic returns. That is, all herds maintained the production targets (maximum age of culling cows, heifer culling age plus steer and cull heifer sale age) that were identified as the economic optimum for the base herd. Cull cows, cull bulls, steers and heifers were sold at the same age, weight and price ($/kg liveweight) regardless of the strategy and no other production parameters were changed.

Criteria used to evaluate genetic change scenarios

The economic criteria were net present value (NPV) of the net cash flows before tax at the required rate of return (5%; taken as the real opportunity cost of funds to the producer) and the internal rate of return (IRR). The NPV was calculated over the life of the investment, expressed in present day terms at the level of operating profit which was calculated as: operating profit = (total receipts – variable costs = total gross margin) – overheads. Operating profit was defined as the return to total capital invested after the variable and overhead (fixed) costs involved in earning the revenue were deducted. Operating profit represented the reward to all of the capital managed by the business and was calculated net of an allowance for the labour and management of the owner. Opening and salvage values for land, plant and livestock were applied at the beginning and end of the discounted cash flow analysis to capture the opening and residual value of assets. Plant replacement was incurred as a capital cost less a salvage value in the year it was expected to be incurred during the investment period. An amortised NPV was calculated at the discount rate over the investment period to assist in communicating the difference between the baseline property and the property after the management strategy was implemented. This amortised NPV measure is not the same as the annual difference in operating profit between the two strategies but is presented to identify the approximate annual average improvement in profit generated by the implementation of the genetic change strategy. The IRR was calculated as the discount rate at which the present value of income equals the present value of total expenditure (capital and annual costs), i.e. the break-even discount rate.

The financial criteria were peak deficit, the number of years to the peak deficit, and the payback period in years. The beef enterprise started with no debt but accumulated debt and paid interest as required by the implementation of a genetic change strategy. Peak deficit in cash flow was calculated assuming interest was paid on the deficit and compounded for each additional year in the investment period. The payback period was calculated as the number of years taken for the cumulative present value to become positive.

Results and Discussion

Katherine region

Replace the bull herd in the first year (Year 1 change, same cost; Scenario 1a)

Table 3 indicates the change in weaning rate and other factors as the selected genes flowed through the breeding herd.

Table 3 Modelled steps in genetic change of conception rate (6% change) and herd structure, bulls exchanged first year (Year 1 change, same cost; Scenario 1a)

Factor	Base herd	Year 4	Year 5	Year 7	Year 8	Year 9	Year 10
Total adult equivalents	7,400	7,400	7,400	7,400	7,400	7,400	7,400
Total cattle carried	9,372	9,359	9,361	9,365	9,367	9,368	9,370
Weaner heifers retained	1,412	1,428	1,444	1,470	1,480	1,490	1,498
Total breeders mated	5,145	5,095	5,067	5,023	5,005	4,988	4,974
Total breeders mated & kept	4,872	4,869	4,846	4,809	4,793	4,779	4,766
Total calves weaned	2,825	2,856	2,888	2,939	2,961	2,980	2,996
Weaners/total cows mated (%)	54.9	56.1	57.0	58.5	59.2	59.7	60.2
Weaners/cows mated and kept (%)	58.0	58.7	59.6	61.1	61.8	62.4	62.9
Overall breeder deaths (%)	9	9	9	9	9	9	9
Female sales/total sales (%)	39.9	40.1	40.4	40.7	40.9	41.0	41.1
Total cows and heifers sold	816	834	851	879	891	902	911
Maximum cow culling age	9	9	9	9	9	9	9
Heifer joining age	2	2	2	2	2	2	2
One year old heifer sales (%)	8.2	12.5	14.0	16.5	17.4	18.5	18.9
Two year old heifer sales (%)	16.5	13.5	13.5	13.5	13.5	13.5	13.5
Total steers and bullocks sold	1,229	1,243	1,257	1,279	1,289	1,297	1,304
Maximum bullock turnoff age	2	2	2	2	2	2	2

Table 3 indicates that the weaning rate for the overall breeding herd lifts by about 5.34% over 10 years when conception rates are incrementally increased by 6%. Change of more than this in the weaning rate is unlikely as all age groups of females have the different genes for reproduction efficiency by the end of the decade. The average weaning rate does not change by 6% due to a change in herd structure causing a proportional increase in the number of first calf heifers in the herd. This group of females has lower conception rates, and even though these low rates are increased by 6%, they are still relatively low and cause the 6% increase in herd weaning rate target to be missed. It can be seen that the breeding herd with the changed reproduction efficiency in Year 10 after the implementation of the change sells 75 more steers and 95 more cows and heifers after mating about 170 fewer breeders at the same grazing pressure.

Table 4 indicates the marginal returns arising from incurring the bull changeover costs ($257,500) at the start of the investment period and then continuing the analysis for three decades. The property is likely to be better off over the three decades if the investment in genes to change conception rates by 6% was implemented as predicted. The beef enterprise takes some time to recoup the investment (15 years) but the marginal return on funds invested by Year 30 is sufficient to earn an average of about 9% on the capital invested in changing the bull herd. It appears that if bulls capable of providing the level of gains applied in the scenario analysis were available at the same price as bulls currently purchased, their introduction would improve economic performance over the three decades after the first use of the bulls.

Table 4 Marginal returns of genetic change of conception rate in the Katherine region (Year 1 change, same cost; Scenario 1a)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
Marginal NPV of "Change" advantage	$345,322
Annualised NPV	$22,464
Peak deficit (with interest)	-$225,425
Years to peak deficit	5
Payback period (years)	15
IRR of ‘change’ advantage	9.38%

What if the genetically different bulls cost more? (Year 1 change, $500 more; Scenario 1b)

Table 5 shows the investment returns where $500 more per bull on average was paid to achieve the genetic change. The investment generated a positive return of about 5% per annum and the investment did not breakeven for 19 years. Paying a premium for the genetically different bulls halved the return on funds invested and significantly extended the payback period. Hence, seed stock producers would need to be careful about incurring significant extra costs to identify the genetically different bulls if they wanted to recoup those funds when the bulls were sold.

Table 5 Marginal returns of genetic change of conception rates with $500 more paid for bulls (Year 1 change, $500 more; Scenario 1b)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
Marginal NPV of "Change" advantage	$247,226
Annualised NPV	$16,082
Peak deficit (with interest)	-$356,882
Years to peak deficit	5
Payback period (years)	19
IRR of ‘change’ advantage	5.32%

What if the change in conception rates was 4%, not 6% (Year 1 change, 4% CR; Scenario 1c)

Table 6 shows the incremental change in herd reproduction efficiency over time if a 4% improvement in conception rates was achieved, not 6%.

Table 6 Modelled steps in genetic change of conception rate (4% change) and herd structure, bulls exchanged first year (Year 1 change, 4% CR; Scenario 1c)

Factor	Optimised	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Total adult equivalents	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400
Total cattle carried	9,372	9,363	9,365	9,366	9,367	9,368	9,369	9,371
Weaner heifers retained	1,412	1,423	1,434	1,443	1,451	1,458	1,465	1,470
Total breeders mated	5,145	5,108	5,090	5,075	5,061	5,048	5,037	5,027
Total breeders mated and kept	4,872	4,870	4,855	4,842	4,830	4,819	4,810	4,801
Total calves weaned	2,825	2,846	2,867	2,886	2,902	2,916	2,929	2,940
Weaners/total cows mated (%)	54.90	55.71	56.33	56.86	57.34	57.77	58.15	58.49
Overall breeder deaths (%)	9	9	9	9	9	9	9	9
Female sales/total sales (%)	39.9	40.1	40.2	40.4	40.5	40.6	40.7	40.7
Total cows and heifers sold	816	828	840	850	859	867	874	880
Maximum cow culling age	9	9	9	9	9	9	9	9
Heifer joining age	2	2	2	2	2	2	2	2
One year old heifer sales (%)	8.2	11.1	12.2	13.1	13.9	14.5	15.1	15.6
Two year old heifer sales (%)	16.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Total steers and bullocks sold	1,229	1,239	1,248	1,256	1,263	1,269	1,275	1,280
Maximum bullock turnoff age	2	2	2	2	2	2	2	2

Table 6 indicates that a 4% change in conception rates brought about by genetically different bulls changed the weaning rate by 3.59% (54.9 to 58.49%). The number of females sold increased by 64 and the number of steers sold increased by 51. Table 7 indicates that reducing the change in conception rates from 6% to 4% significantly reduced the economic performance of the investment.

Table 7 Marginal returns of genetic change of conception rate in the Katherine region (4% change); (Year 1 change, 4% CR; Scenario 1c)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
Marginal NPV of ‘change’ advantage	$165,219
Annualised NPV	$10,748
Peak deficit (with interest)	-$258,062
Years to peak deficit	5
Payback period (years)	19
IRR of ‘change’ advantage	5.06%

What if the bull change-over costs were not incurred? (Gradual replacement, same cost; Scenario 2a)

This scenario replaced the herd bulls as they came due, at the same cost as for the ‘without change’ herd, and required that no additional costs be incurred to identify heifers produced by the new bulls. Table 8 shows the incremental change in conception rates over the first 5 mating’s as the genetically different bulls replace the current bull herd. All heifers had the different genes from the sixth mating and it was year 13 before the breeder herd is converted.

Table 8 Incremental steps in genetic change of conception rate with bulls replaced over time (Gradual replacement, same cost; Scenario 2a)

Parameter	First mating	Second mating	Third mating	Fourth mating	Fifth mating
Total herd bulls	205	205	205	205	205
Bulls with different genes	41	82	123	164	205
Mature cows mated to different bulls	1,027	2,055	3,082	4,110	
Number that conceive	699	1,397	2,096	2,767	
Number that wean a calf	616	1,232	1,849	2,441	
Heifer weaners produced	308	616	924	1,220	

Yearling heifers	266	532	797	1,053	
Two year heifers pre culling	250	500	749	989	
Heifers with different genes mated	250	500	749	989	
Total heifers mated	1,145	1,145	1,145	1,145	
Percentage of heifers with different genes	21.8%	43.6%	65.4%	86.4%	100%
Improvement in conception rate of mated heifers	1.3%	2.6%	3.9%	5.2%	6.0%
Improvement in conception rate of 3-4 year heifers		1.3%	2.6%	3.9%	5.2%
Improvement in conception rate of 4-5 year cows			1.3%	2.6%	3.9%
Improvement in conception rate of 5-6 year cows				1.3%	2.6%
Improvement in conception rate of 6-7 year cows					1.3%
Year of impact	Year 4	Year 5	Year 6	Year 7	Year 8

Table 9 shows the change in herd structure over the 13 years taken to fully implement the strategy.

Table 9 Modelled steps in genetic change of weaning rate and herd structure with bulls replaced over time (Gradual replacement, same cost; Scenario 2a)

Parameter	Base	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Total adult equivalents	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400
Total cattle carried	9,372	9,369	9,367	9,365	9,363	9,363	9,365	9,367	9,368	9,369	9,366
Weaner heifers retained	1,412	1,416	1,423	1,433	1,445	1,458	1,470	1,481	1,489	1,494	1,492
Total breeders mated	5,137	5,128	5,112	5,092	5,068	5,043	5,022	5,004	4,990	4,981	4,975
Total breeders mated & kept	4,872	4,872	4,866	4,856	4,842	4,825	4,808	4,792	4,781	4,773	4,768
Total calves weaned	2,825	2,832	2,846	2,865	2,890	2,917	2,941	2,962	2,977	2,988	2,997
Weaners/total cows mated (%)	54.99	55.22	55.66	56.27	57.03	57.84	58.56	59.19	59.66	59.99	60.24
Weaners/cows mated and kept (%)	57.98	58.13	58.48	59.01	59.69	60.45	61.17	61.81	62.28	62.60	62.86
Overall breeder deaths (%)	9	9	9	9	9	9	9	9	9	9	9
Female sales/total sales (%)	39.90	39.95	40.06	40.21	40.39	40.58	40.75	40.89	41.00	41.07	41.13
Total cows and heifers sold	816	820	828	839	852	867	880	892	900	906	911
Maximum cow culling age	9	9	9	9	9	9	9	9	9	9	9
Heifer joining age	2	2	2	2	2	2	2	2	2	2	2
One year old heifer sales (%)	8.24	9.18	10.47	12.03	13.80	15.40	16.52	17.46	18.14	18.59	18.59
Two year old heifer sales (%)	16.50	15.85	15.20	14.55	13.90	13.50	13.50	13.50	13.50	13.50	13.50
Total steers & bullocks sold	1,229	1,232	1,238	1,247	1,258	1,269	1,280	1,289	1,296	1,300	1,304
Maximum bullock turnoff age	2	2	2	2	2	2	2	2	2	2	2
Average female price	$494.09	$492.74	$490.73	$488.21	$485.32	$482.59	$480.55	$478.85	$477.65	$476.86	$475.26
Average steer/bullock price	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88	$681.88

Table 10 indicates that the strategy may generate sound economic benefits over the 30-year investment horizon.

Table 10 Marginal returns for investment in genetically different bulls to improve breeder fertility with no additional costs (Gradual replacement, same cost; Scenario 2a)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
NPV of "Change" advantage	$712,184
Annualised NPV	$46,329
Peak deficit (with interest)	n/a
Payback year	n/a
Payback period (years)	n/a

What if the genetically different bulls cost more? (Gradual replacement, $500 more; Scenario 2b)

Table 11 shows the investment returns where $500 more per bull on average was paid with the strategy of replacement of bulls as they come due. The investment generated a positive return of about 18% per annum and the investment did not breakeven for 7 years. Paying a $500 per head premium for the genetically different bulls halved the return on funds invested and produced an extended payback period. (The purchase price of the bulls was increased by 20%) Hence, seed stock producers would need to be careful about incurring significant extra costs to identify the genetically different bulls if they wanted to recoup those funds when the bulls were sold. Producers purchasing the bulls still can achieve very acceptable returns at low risk on the funds invested when it costs slightly more to access herd bulls with different genes.

Table 11 Marginal returns of genetic change of conception rates with $500 more paid for bulls (Gradual replacement, $500 more; Scenario 2b)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
Marginal NPV of "Change" advantage	$401,842
Annualised NPV	$26,140
Peak deficit (with interest)	-$109,365
Years to peak deficit	7
Payback period (years)	11
IRR of ‘change’ advantage	18.56%

Fitzroy NRM region

Replace the bull herd in the first year (Year 1 change, same cost; Scenario 3)

Table 12 indicates the change in weaning rate and other indicators of herd performance as the genes flowed through the breeding herd. The key points to recognise about the values in Table 12 are:

- The optimal culling strategy was maintained at each step to maintain the profitability of the herd. This caused increasing numbers of 2 year old heifers to be culled prior to mating to maintain the herd structure and grazing pressure.

- The reduced number of cows mated over time to achieve the same number of weaners reflects the impact of the strategy on the efficiency of the herd.

- Therefore, as the number of weaners produced did not really change, the total number sold from the property did not change but the average value of the females sold increased over time. This reflected the increased proportion of younger, more valuable females in the sale mix as the change was implemented.

- It took 13 years for the predicted increase in the percentage of weaners produced from cows mated to reach the target.

Table 12 Modelled steps in genetic change of weaning rate and herd structure in the Fitzroy NRM region (Year 1 change, same cost; Scenario 3)

	Base herd	Year 4	Year 5	Year 7	Year 9	Year 10	Year 12	Year 13
Total adult equivalents	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total cattle carried	1,537	1,537	1,538	1,538	1,539	1,539	1,539	1,540
Weaner heifers retained	249	249	249	250	250	250	250	250
Total breeders mated	642	633	625	615	608	605	601	599
Total breeders mated & kept	535	535	535	535	535	535	535	535
Total calves weaned	498	499	499	500	500	500	500	500
Weaners/total cows mated (%)	77.60	78.83	79.86	81.26	82.24	82.64	83.27	83.53
Weaners/cows mated and kept (%)	93.19	93.19	93.24	93.32	93.38	93.41	93.44	93.45
Overall breeder deaths (%)	4.53	4.53	4.52	4.52	4.54	4.56	4.58	4.59
Female sales/total sales (%)	47.79	47.79	47.80	47.80	47.79	47.78	47.77	47.77
Total cows and heifers sold	210	210	211	211	211	211	211	211
Maximum cow culling age	13	13	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2	2	2
Two year old heifer sales (%)	58.48	56.77	60.06	64.12	66.56	67.39	68.40	68.65
Total steers & bullocks sold	230	230	230	230	230	230	231	231
Maximum bullock turnoff age	2	2	2	2	2	2	2	2

Table 13 indicates the marginal returns arising from incurring the bull changeover costs ($55,000) at the start of the investment period and continuing the analysis for three decades.

Table 13 Marginal returns for an investment to improve fertility through better genes (Year 1 change, same cost; Scenario 3)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
Marginal NPV of "Change" advantage	-$50,196
Annualised NPV	-$3,265
Peak deficit (with interest)	-$126,309
Years to peak deficit	n/a
Payback period (years)	never
IRR of "Change" advantage	-11.65%

The beef property was worse off with the investment to change the average conception rate by 6% when changeover costs were incurred. The extended period of time to the peak deficit and the lack of a payback year in the first 30 years suggests that investment returns would not significantly improve with further extension of the analysis. It appears that if bulls capable of providing the level of change applied in the scenario were available and a changeover cost was incurred, their introduction would reduce economic performance.

What if heifers were culled differently to provide more weaners? (Cull heifers for more weaners; Scenario 4)

One of the outcomes that has caused concern with industry commentators was that the Fitzroy NRM herd improved its reproduction efficiency but only produced about the same number of weaners when the optimum heifer culling strategy was maintained. Although the number of weaners produced by a herd (or the weaning rate) provides no indication of economic efficiency, the herd model was altered to cull additional surplus heifers at weaning, thereby changing the herd structure to allow more weaners to be produced over time. Table 14 shows the steps required to implement the strategy and the time taken for the benefits taken to flow through the herd.

Table 14 Modelled steps in genetic change of weaning rate and herd structure with weaner heifers culled (Cull heifers for more weaners; Scenario 4)

	Base herd	Year 4	Year 6	Year 8	Year 10	Year 12	Year 13
Total adult equivalents	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total cattle carried	1,537	1,527	1,514	1,506	1,502	1,500	1,499
Weaner heifers retained	249	236	217	207	200	197	196
Total breeders mated	642	643	642	642	640	638	637
Total breeders mated & kept	535	544	555	562	566	569	569
Total calves weaned	498	507	518	525	529	531	532
Weaners/total cows mated (%)	77.60	78.83	80.62	81.79	82.64	83.27	83.53
Weaners/cows mated and kept (%)	93.19	93.19	93.28	93.35	93.41	93.44	93.45
Overall breeder deaths (%)	4.53	4.53	4.52	4.53	4.56	4.58	4.59
Female sales/total sales (%)	47.79	47.92	48.08	48.16	48.20	48.22	48.22
Total cows and heifers sold	210	215	221	225	227	228	228
Maximum cow culling age	13	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2	2
Weaner heifer sale & spay (%)	0.00	6.98	16.03	21.17	24.23	25.87	26.29
One year old heifer sales (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Two year old heifer sales (%)	58.48	52.48	52.48	52.48	52.48	52.48	52.48
Total steers & bullocks sold	230	233	239	242	244	245	245
Maximum bullock turnoff age	2	2	2	2	2	2	2
Average female price	$750.50	$710.13	$659.64	$631.26	$614.35	$605.28	$602.99
Average steer/bullock price	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62

The key points to recognise about the values in Table 14 are:

- The optimal culling strategy (i.e. the most profitable strategy) was replaced with one that culls additional surplus heifers as weaners. This caused about the same number of 2 year old heifers to be culled prior to mating over time but increased the number of weaner heifers to be culled to maintain the same grazing pressure as herd reproduction efficiency improved.

- The impact on the reproduction efficiency of the herd of this strategy is shown by roughly the same number of cows mated over time achieving an increasing number of weaners.

- The total number of cattle sold increased over time but the average value of the females sold is reduced. This reflects the increased proportion of less valuable weaners in the female sale mix.

- It still took 13 years for the predicted increase in the percentage of weaners produced from cows mated to reach the target.

- Even though more cattle were sold, and the number of weaners produced increased, the economic efficiency of the herd was significantly reduced. This demonstrates that strategies that do not maintain the optimum herd structure often reduce economic performance compared to the 'without change' scenario.

Table 15 indicates the marginal returns arising from incurring the bull changeover costs ($55,000) at the start of the investment period and selling weaner heifers to increase weaner numbers.

Table 15 Marginal returns for investment in genetically different bulls to improve fertility with the sale of surplus weaner heifers (Cull heifers for more weaners; Scenario 4)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
NPV of "Change" advantage	-$191,866
Annualised NPV	-$12,481
Peak deficit (with interest)	-$528,080
Years to peak deficit	n/a
Payback year	n/a
Payback period (years)	n/a

What if the herd had lower reproduction efficiency? (Lower starting reproduction rate; Scenario 5)

The starting level of reproduction efficiency impacting the potential benefits has been raised as an issue by industry commentators. Some breeding herds have a lower starting reproduction efficiency than the median identified in the CashCow project for the Fitzroy NRM region (McGowan *et al.* 2014). This was addressed by constructing a herd model for the Fitzroy NRM region that applied the 25th (or 75th) percentile performance identified in the CashCow project to represent a breeding herd that performed at about the level of performance of the bottom quarter of herds surveyed. Table 16 shows the 25th (75th) percentile data applied in the models. This was used to construct a herd model with lower reproduction efficiency with all other parameters maintained at the same level in the base herd model.

Table 16 25th (75th) percentile reproduction performance for Central Forest data (McGowan et al. 2014)

Factor	Heifers	First lactation cows	Second lactation cows	Mature	Aged	Overall
P4M* (%)		33	56	55	55	52
Annual pregnancy (5)	75	67		79	71	79
Foetal / calf loss# (75th Percentile) (%)	17.7	11.3		8.5	11.8	10.2
Contributed a weaner (%)	48	67		70	68	69
Pregnant missing (%)		16.6		10.7	9.2	11.2

*P4M - Lactating cows that became pregnant within four months of calving
** Percentage of cows in a management group (mob) that became pregnant within a one-year period. For continuously mated herds, this included cows that became pregnant between September 1 of the previous year and August 31 of the current year
***Calf loss percentages were determined in the Cash Cow project if a heifer or cow was diagnosed as pregnant in one year and was recorded as dry (non-lactating) at an observation at least one month after the expected calving month the following year. By definition, foetal and calf loss as it was derived excludes cow mortality.
^Females were recorded as having successfully weaned a calf if they were diagnosed as being pregnant in the previous year and were recorded as lactating (wet) at an observation after the expected calving date.
#pregnant animals that fail to return for routine measures, but not including irregular absentees. It comprises mortalities, animals whose individual identity is lost, and those that permanently relocate either of their own accord or without being recorded by a manager.

Foetal/calf loss was retained at the 75th percentile value identified by the CashCow project although no relationship between low conception rates and high rates of calf loss was identified in the CashCow project report. Therefore, the starting weaning rate calculated by our model (65%) is substantially lower than the 'contributed a weaner' value (69%) identified by the CashCow project for the 25th percentile level of herd performance. Our model is likely to have a significantly lower starting level of reproduction performance than that indicated for the 25th percentile by the CashCow data for the region.

The herd model produced a weaning rate from cows mated of about 65% and maintained the same overall culling and sale strategy when optimised. In this case only 4% of 2 year old heifers were culled prior to mating, a reflection of the lower starting reproduction efficiency of the herd. All empty cows were still culled on pregnancy status at weaning plus the same age of final culling was retained. Table 17 indicates the change in herd structure as the conception rate was changed for each female cohort.

Table 17 Modelled steps in genetic change of weaning rate and herd structure with 25th percentile starting point (Lower starting reproduction rate; Scenario 5)

Factor	25th base	Year 4	Year 6	Year 8	Year 10	Year 12	Year 13
Total adult equivalents	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total cattle carried	1,522	1,525	1,527	1,528	1,528	1,528	1,528
Weaner heifers retained	238	242	242	243	243	243	243
Total breeders mated	738	719	700	690	685	681	680
Total breeders mated & kept	552	550	550	550	550	550	550
Total calves weaned	485	484	485	485	485	486	486
Weaners/total cows mated (%)	65.78	67.24	69.27	70.32	70.91	71.26	71.37
Weaners/cows mated and kept (%)	87.89	87.89	88.14	88.24	88.26	88.26	88.26
Overall breeder deaths (%)	4.47	4.47	4.45	4.46	4.48	4.49	4.50
Female sales/total sales (%)	47.69	47.66	47.68	47.68	47.67	47.66	47.65
Total cows and heifers sold	204	203	204	204	204	204	204
Maximum cow culling age	13	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2	2
Weaner heifer sale & spay (%)	2.07	0.00	0.00	0.00	0.00	0.00	0.00
Two year old heifer sales (%)	28.71	31.69	40.27	44.33	46.41	47.38	47.59
Total steers & bullocks sold	224	223	223	224	224	224	224
Maximum bullock turnoff age	2	2	2	2	2	2	2

Table 18 indicates that, due to the trade-offs occurring between value of the herd sales and the increasing number of weaners produced, economic performance was not improved with investment in genetic improvement of fertility in a Fitzroy NRM herd with lower starting reproduction efficiency: 65% weaning rate cf. 77% as assumed for Scenarios 3-4.

Table 18 Marginal returns for investment in genetically different bulls to improve breeder fertility with 25th percentile reproduction performance for Central Forest data (McGowan et al. 2014); (Lower starting reproduction rate; Scenario 5)

Factor	Value
Period of analysis	30
Interest rate for NPV	5.00%
NPV of "Change" advantage	-$48,857
Annualised NPV	-$3,178
Peak deficit (with interest)	-$131,101
Years to peak deficit	n/a
Payback period (years)	n/a
IRR of "Change" advantage	-6.47%

What if the bull change over costs were not incurred? (Gradual replacement, same cost; Scenario 6)

Table 19 shows the incremental increase in conception rates over the first five mating's as the genetically different bulls were introduced. Heifers with and without the different genes had the same chance of being culled prior to mating. All mated females that did not show as pregnant at weaning were still culled. It was Year 8 before the first lot of heifers produced by a completely changed over bull herd were mated and produced calves.

Table 19 Incremental steps in genetic change of conception rate with bulls replaced over time (Gradual replacement, same cost; Scenario 6)

Parameter	First mating	Second Mating	Third mating	Fourth mating	Fifth mating
Total herd bulls	22	22	22	22	22
Bulls with different genes	4	9	13	18	22
Mature cows mated to different bulls	126	251	377	503	
Number that conceive	109	219	324	423	
Number that wean a calf	103	206	305	398	
Heifer weaners produced	51	103	153	199	
Yearling heifers	50	100	148	193	
Two year heifers pre culling	48	97	143	187	
Heifers with different genes mated	30	60	88	115	
total heifers mated	144	144	144	144	
Percentage of heifers with different genes	20.6%	41.3%	61.2%	80.0%	100%
Improvement in conception rate of mated heifers	1.2%	2.5%	3.7%	4.8%	6.0%
Improvement in conception rate of 3-4 year heifers		1.2%	2.5%	3.7%	4.8%
Improvement in conception rate of 4-5 year cows			1.2%	2.5%	3.7%
Improvement in conception rate of 5-6 year cows				1.2%	2.5%
Improvement in conception rate of 6-7 year cows					1.2%
Year of impact	Year 4	Year 5	Year 6	Year 7	Year 8

Table 20 shows the change in herd structure over the 17 years taken to fully implement the strategy. The same impact on herd structure as shown in Table 12 was repeated in Table 20, but at a slower rate.

Table 20 Modelled steps in genetic change of weaning rate and herd structure with bulls replaced over time (Gradual replacement, same cost; Scenario 6)

	Base	Year 4	Year 5	Year 6	Year 7	Year 8	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17
Total adult equivalents	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total cattle carried	1,537	1,537	1,537	1,537	1,538	1,538	1,539	1,539	1,539	1,539	1,539	1,540	1,540
Weaner heifers retained	249	249	249	249	249	250	250	250	250	250	250	250	250
Total breeders mated	642	640	637	632	626	620	608	605	603	601	599	598	598
Total breeders mated & kept	535	535	535	535	535	535	535	535	535	535	535	535	535
Total calves weaned	498	498	499	499	499	499	500	500	500	500	500	500	500
Weaners/total cows mated (%)	77.60	77.86	78.33	78.94	79.68	80.50	82.19	82.59	82.93	83.23	83.46	83.61	83.70
Weaners/cows mated and kept (%)	93.19	93.19	93.20	93.22	93.24	93.28	93.38	93.41	93.42	93.44	93.45	93.45	93.46
Overall breeder deaths (%)	4.53	4.53	4.53	4.53	4.52	4.53	4.55	4.56	4.57	4.58	4.58	4.59	4.59
Female sales/total sales (%)	47.79	47.79	47.80	47.80	47.80	47.80	47.79	47.78	47.78	47.77	47.77	47.77	47.76
Total cows and heifers sold	210	210	210	210	211	211	211	211	211	211	211	211	211
Maximum cow culling age	13	13	13	13	13	13	13	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2	2	2	2	2	2	2	2
One year old heifer sales (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Two year old heifer sales (%)	58.48	58.18	58.59	59.43	60.56	61.89	66.33	67.18	67.79	68.24	68.52	68.67	68.75
Total steers & bullocks sold	230	230	230	230	230	230	230	230	230	231	231	231	231
Maximum bullock turnoff age	2	2	2	2	2	2	2	2	2	2	2	2	2
Average female price	$750.50	$750.50	$750.66	$750.93	$751.28	$751.70	$752.75	$752.95	$753.10	$753.21	$753.27	$753.31	$753.33
Average steer/bullock price	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62	$812.62

Table 21 indicates that even though no additional costs were incurred, the strategy only produced a minimal $685 annualised NPV over the 30 year investment horizon. If additional costs were incurred, no more that the equivalent of $2.50 per retained weaner heifer could be spent for a positive NPV to be maintained.

Table 21 Marginal returns for investment in genetically different bulls to improve breeder fertility with no additional costs (Gradual replacement, same cost; Scenario 6)

Factor	Value
Period of the analysis (years)	30
Interest rate for NPV	5.00%
NPV of "Change" advantage	$10,537
Annualised NPV	$685
Peak deficit (with interest)	-$898
Years to peak deficit	6
Payback period (years)	9

Summary and discussion of results

Table 22 summarises the scenario results for the two regions.

Table 22 Profitability and financial risk of implementing genetic improvement of fertility strategies for 1) the Katherine region and 2) the Fitzroy NRM region

Strategy	NPV of change[A]	Annualised NPV[B]	Peak deficit (with interest)[C]	Year of peak deficit	Payback period (years)[D]	IRR (%)[E]
Katherine region, NT						
Scenario 1a. Year 1 change, same cost	$345,322	$22,464	-$225,425	5	15	9.38
Scenario 1b. Year 1 change, $500 more	$247,226	$16,082	-$356,882	5	19	5.32
Scenario 1c. Year 1 change, 4% CR	$165,219	$10,748	-$258,062	5	19	5.06
Scenario 2a. Gradual replacement, same cost	$712,184	$46,329	n/a*	n/a*	n/a*	n/c*
Scenario 2b. Gradual replacement, $500 more	$401,842	$26,140	-$109,365	7	11	18.56
Fitzroy NRM region, central Qld						
Scenario 3. Year 1 change, same cost	-$50,196	-$3,265	-$126,309	n/a	never	-11.65
Scenario 4. Cull heifers for more weaners	-$191,866	-$12,481	-$528,080	n/a	never	n/c *
Scenario 5. Lower starting reproduction rate	-$48,857	-$3,178	-$131,101	30	never	-6.47
Scenario 6. Gradual replacement, same cost	$10,537	$685	-$898	6	9	n/c*

[A] NPV is the net present value of an investment, referring to the net returns (income minus costs) over the 30-year life of the investment and represents the extra return added by the management strategy, i.e. it is the difference between the baseline, case study property with no genetic change and the same property after the genetic change strategy is implemented.
[B] The annualised NPV represents the average annual change in NPV over 30 years, resulting from the genetic change strategy and can be considered as an approximation of the change in profit per year.
[C] Peak deficit is the maximum difference in cash flow between the genetic change strategy and the base scenario over the 30-year period of the analysis. It is a measure of riskiness.
[D] Payback period is the number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment.
[E] IRR is the internal rate of return on the extra capital. This is the discount rate at which the present value of marginal income from a project equals the present value of marginal expenditure, i.e. the break-even discount rate.
*n/c – not calculable, n/a – not applicable or not available

Immediately and completely replacing the current bull herd with bulls that change reproduction efficiency in the Katherine herd model appeared unlikely to improve economic performance within the first two decades after the investment due to the 15-year payback period. Herd managers may improve economic performance over three decades if they fully replaced their current bull herd with bulls showing strong indicators for fertility but paid no more for them. Converting to a herd with different genes for fertility, by replacing all bulls in Year 1 of the analysis with bulls that cost the same amount, resulted in a positive annualised NPV of 22,464 but increased financial risk as indicated by the peak deficit of -$225,425.

Replacing the bulls over the first 4 years in the Katherine region improved the profitability of the property at low risk when incurring no additional costs. Incurring an additional $500 per head to access bulls with different genes almost halved the returns compared to the scenario that replaced bulls over time at no additional cost.

The Live Export Index compiled for the top ranked Brahman bull (Table 2) suggests producers in the Katherine region could pay up to $7,500 (+$38 per cow mated x 40 cows x 5 years) more for bulls with those characteristics and still breakeven on the investment. We assessed the higher bull price of $10,000 in the Katherine scenario (2b) to test the benefits of paying that amount extra to achieve an almost 6% change in weaning rate over time. Paying an extra $7,500 per bull, a value suggested as payable by the Brahman Live Export index, would produce an NPV for the investment of - $3,942,949 equivalent to reducing the annual profit of the property by more than $250,000. Paying a premium of $750 per bull above the average purchase price of $2,500 to access the different genetics produced a marginal return on investment of about 10%.

The marginal returns from the genetic change of fertility in the Fitzroy NRM region were negative where additional capital was required to replace the bull herd. Annualised NPV for the net cash flow for the genetic change of fertility of the breeder herd was -$3,265 at a starting weaning rate of 77% and -$3,178 at a starting weaning rate of 65%. Gradually introducing bulls with different genes for fertility with no additional costs produced a negligible change in returns. It is possible in the Fitzroy NRM region that some minor benefits may be gained by a reduction in the cow culling age as the conception rates change due to a freeing up of some livestock capital. Given that, the sale of more valuable cull heifers would need to be forgone for this to happen, and any anticipated benefits may prove illusionary.

For the Fitzroy NRM region, any costs incurred to segregate and select heifers produced by the genetically different bulls would need to be negligible, as the benefits associated appear unlikely to be large. For example, the herd gross margin in Year 17 for the genetically different herd was improved by about 1.3% or $3,156 per annum compared to the base herd. This benefit was partly offset by the herd asset value falling by $3,597 in the same year due to the structural change in the herd. Bringing forward a less than 2% improvement in gross margin by a couple of years, that is largely offset by a fall in the asset value of the herd, and incurring costs in doing so seems unlikely to significantly change the outcome.

The economic and financial analysis reported here indicated that selecting bulls with different genes for fertility is likely to have variable impacts and unexpected outcomes on the profitability and riskiness of beef enterprises in northern Australia. Even the most profitable scenario is very sensitive to a relatively small increase in the amount paid to access the bulls with different genes. An example of an unexpected outcome was the fact that the breeding herd located in the Fitzroy NRM region did not produce more weaners while gradually improving reproduction efficiency but reduced the number of cows mated to produce the same number of weaners over time. This outcome was related to maintaining the most profitable culling strategy as the reproduction efficiency of the herd improved. When the heifer culling strategy was changed to produce more weaners, herd profitability fell even though reproduction efficiency improved by the same amount as previously. Another unexpected outcome was the increase in risk associated with the genetic improvement of fertility. Any strategy that required upfront capital to gain the benefits significantly increased risk.

There is often a temptation, based on limited analysis, to suggest a rule of thumb concerning the level of herd reproduction efficiency where chasing genetic improvement in fertility is unlikely to provide economic benefits. We have not been able to discern a clear break-even point in our analyses between the level of herd reproduction efficiency and the level of economic benefit. For example, when the weaning rate of the Fitzroy NRM herd was reduced from 77% to 65%, and there was still capacity to cull all non-pregnant females, economic benefits were still negative: -$3,265 cf. -$3,178, respectively.

After having considered the current analysis and similar exercises undertaken as part of unpublished departmental project work in earlier times, we have identified what we think are the key factors underpinning the differences in the economic results for the Katherine and Fitzroy NRM herds:

- Where there is a requirement to retain non-pregnant females to maintain breeder numbers, improving herd reproduction efficiency will likely improve herd production and profitability as each additional pregnant breeder effectively replaces a non-pregnant breeder held to maintain breeder numbers. However, it is important to consider the following points:-
  - This improvement is on the basis that it is (genetic) fertility and not herd nutrition that limits the capacity of cows to reconceive on a more regular basis.
  - The assumption that the herd mortality rate will not change with the change in the calving percentage is also very important to the results. Increasing the number of females that calve closer to an annual basis in difficult production environments is likely to increase the herd mortality rate. Each manager will need to incorporate an assessment of whether the mortality rate will change in any analysis undertaken.
  - The other complicating factor is that many northern breeding herds have their performance limited by the level of phosphorus deficiency of the land types being grazed. Appropriate management of the phosphorus status of the herd needs to be implemented if genetic gains for fertility are to be fully realised.
  - A minor increase in the price paid to access the bulls with the different genetics significantly influences the potential benefits.
- Once herd performance is at a level where culling all non-pregnant breeders is possible, measureable economic benefits appear unlikely for even the most beneficial implementation scenarios. Any improvement in reproduction efficiency above this level of performance causes replacement of cull cows with cull heifers or vice versa in the sales mix due to the limit placed on total grazing pressure by the AE cap.
- The point where all non-pregnant cows can be culled in any breeding herd can be determined by expected mortality rates, the final age of culling breeders, the optimal age to cull replacement heifers or the optimum age to sell steers. The optimum culling or selling age can also be determined by the relative sale values of the various classes of sale stock and these relativities can change over time.

We know these factors will vary between properties so would suggest that only appropriate farm economic methods, as used in this study, can provide sufficient insight to assist decision making at the property level. However, despite this qualifier, many beef properties located in northern Australia with the nutritional attributes to produce "Jap Ox" are already likely to have a level of reproduction efficiency above that expected to benefit from further genetic improvement in the weaning rate. The application of the Live Export Index to select bulls for use in herds in the Katherine region with similar attributes to the modelled herd is expected to produce economic benefits, although not at the level predicted by the application of the BreedObject software.

The range of information produced (Table 22) when assessing the genetic improvement of fertility using farm management economics does reveal significantly more about the nature of the investment than the application of a very limited $index. Even so, a beef herd manager in northern Australia faces many more management choices than how to select bulls.

The real power of farm management economics is its capacity to compare a wide range of alternative management strategies relevant to any beef production system. Including other strategies in the assessment allows identification of the absolute and relative value of investing in genetic improvement; something even properly constituted Selection Indexes cannot do.

We have (separately) compiled analyses for a range of production strategies for these two regions. Full description can be found in Chudleigh *et al.* (2019) and Bowen and Chudleigh (2018). A summary of results is provided here (Table 23 and 24) to demonstrate the point that selection indices do not add value in the real world of farm management decision making when there are a number of alternative management strategies and technologies to be considered and assessed for their effect on business profitability. The results provided in Table 22 are highlighted green within Tables 23 and 24.

Table 23 - Profitability and financial risk of implementing alternative strategies to improve profitability in the Fitzroy NRM region, Queensland (from Bowen and Chudleigh 2018)

Strategy	NPV of change	Annualised NPV	Peak deficit (with interest)	Years to peak deficit	Payback period (years)
Converting from weaner steers to bullocks	$822,777	$53,523	-$105,693	4	4
Improving steer performance					
Leucaena	$840,725	$54,690	-$465,728	6	12
Leucaena + purchased breeders	$910,120	$59,205	-$532,242	6	11
Other perennial legumes	$458,395	$29,819	-$436,067	7	14
Forage oats for feed on steers	-$539,079	-$35,068	-$1,482,018	never	never
Forage oats for bullocks	-$36,729	-$2,389	-$131,523	never	never
Feedlotting steers	-$1,085,730	-$70,628	-$2,988,831	never	never
HGP bullocks - same price, heavier weight	$30,529	$1,986	-$49,529	8	17
Improving breeder performance					
Production supplements for breeders	-$503,826	-$32,826	-$1,411,054	never	never
Better genetics for fertility					
Replace all bulls first year	-$50,196	-$3,265	-$126,309	never	never
Cull additional heifers as weaners	-$191,866	-$12,481	-$528,080	never	never
Lower starting weaning rate	-$48,857	-$3,178	-$131,101	never	never
Gradual replacement of bulls	$10,537	$685	-$898	6	9
Wet season spelling for breeders	-$21,375	-$1,715	-$56,715	never	never
Benefit of reducing foetal/calf loss in young females by 50%					
$5/head	$7,289	$474	-$1,829	5	6
$7.50 /head	-$6,427	-$418	-$17,502	never	never
$10/head	-$20,142	-$1,310	-$55,927	never	never
$20,000 capital	$15,672	$1,019	-$20,000	2	12
$30,000 capital	$6,148	$400	-$30,000	2	n/a
$40,000 capital	-3,376	-$220	-$40,451	4	never
Pestivirus, high prevalence, vac all	$15,750	$1,025	-$21,219	7	15
Pestivirus, high prevalence, vac heifers	$56,614	$3,683	-$3,276	6	6
Pestivirus, naïve herd vaccination	-$37,446	-$2,436	n/a	n/a	n/a
Inorganic supplements for breeders					
Marginal P herd, P wet season	$86,137	$5,603	-$7,185	3	3
Marginal P herd, N+P dry season	-$3,578	-$233	-$34,107	15	n/c
Marginal P herd, N+P dry, P wet	-$18,434	-$1,199	-$61,210	20	n/c
Deficient P herd, P wet season	$96,874	$6,302	-$26,907	3	3
Deficient P herd, N+P dry season	$56,247	$3,659	-$37,094	3	4
Deficient P herd, N+P dry, P wet	$36,655	$2,384	-$57,965	3	14
Acute P herd, P wet season	$695,035	$45,213	-$38,866	3	3
Acute P herd, N+P dry season	$435,778	$28,348	-$56,453	3	4
Acute P herd, N+P dry, P wet	$630,094	$40,989	-$87,535	3	4
Feeding first calf heifers	-$148,860	-$9,684	-$416,285	never	never
Marketing options					
Organic beef	$37,445	$2,436	n/a	n/a	n/a
EU slaughter and feed on	-$134,464	-$8,747	-$373,606	never	never
EU feed on only	-$123,566	-$8,038	-$339,795	never	never
Wagyu beef, price premium maintained	$506,411	$32,943	-$269,104	4	12
Wagyu beef, price premium reduces from year 20	$49,471	$3,218	-$269,104	4	n/a
Wagyu beef, price premium reduces from year 10	-$646,738	-$42,071	-$1,927,459	never	never

Table 24 - Profitability and financial risk of implementing alternative strategies to improve profitability and resilience of beef enterprises in the Katherine region, Northern Territory

Strategy	NPV of change	Annualised NPV	Peak deficit (with interest)	Years to peak deficit	Payback period (years)	IRR (%)
Improving herd performance						
Fixing a P deficiency	$5,106,316	$332,345	-$328,345	1	2	152
Herd Segregation $100,000 capital	$2,843,406	$184,968	-$100,000	1	1	235
Herd Segregation $500,000 capital	$2,462,454	$160,186	-$500,000	1	3	39
Herd Segregation $1,000,000 capital	$1,986,263	$129,209	-$1,000,000	1	7	19
Herd Segregation $2,000,000 capital	$1,033,882	$67,256	-$2,000,000	1	15	7.5
Home bred herd bulls	$424,620	$27,622	-$78,400	2	3	40
Improving breeder performance						
Cull more heifers before mating	-$703,386	-$45,756	-$1,969,428	never	never	n/c
Feeding first calf heifers	-$1,075,723	-$69,977	-$3,001,513	never	never	n/c
Feeding first calf heifers (half cost)	-$482,392	-$31,380	-$1,339,387	never	never	n/c
Better genetics for fertility						
Replace all bulls first year	$345,322	$22,464	-$225,425	5	15	9.4
Replace all bulls, pay more	$247,226	$16,082	-$356,882	5	19	5.3
Replace all bulls, lower conception	$165,219	$10,748	-$258,062	5	19	5
Gradual replacement of bulls	$712,184	$46,329	n/a	n/a	n/a	n/c
Gradual replacement, higher cost bulls	$401,482	$26,140	-$109,365	7	11	18.5
Benefit of reducing foetal/calf loss by 50%						
$5/head	$593,451	$38,605	-$26,575	1	1	162
$10 /head	$192,142	$12,449	-$87,635	4	9	19
$15/head	-$209,167	-$13,607	-$560,431	never	never	n/c
$100,000 capital	$899,522	$58,515	-$100,000	1	2	60
$200,000 capital	$804,284	$52,320	-$200,000	1	5	30
$400,000 capital	$613,806	$39,929	-$400,000	1	9	15.7
$800,000 capital	$232,855	$15,148	-$800,000	1	19	7.3
Benefit of reducing female mortality by 50%						
$5 per head	$979,326	$63,707	-$33,020	1	1	266
$10 per head	$477,289	$31,048	-$66,040	1	2	60
$20 per head	-$526,785	-$34,268	-$1,445,342	never	never	n/c
$100,000 capital	$1,386,125	$90,169	-$100,000	1	1	114
$500,000 capital	$1,005,173	$65,388	-$500,000	1	7	19.8
$750,000 capital	$767,078	$49,899	-$750,000	1	11	13
$1,250,000 capital	$290,887	$18,923	-$1,250,000	1	n/c	7
Improving steer performance						
Benefit of reducing steer mortality by 50%						
$5 per head	$471,420	$30,667	-$19,215	1	3	83.8
$10 per head	$168,885	$10,986	-$65,871	3	6	22.1
$20 per head	-$436,185	-$28,374	-$1,207,973	never	never	n/c
$50,000 capital	$726,337	$47,249	-$50,000	1	2	73.7
$100,000 capital	$678,717	$44,152	-$100,000	1	3	42.4
$500,000 capital	$297,765	$19,370	-$503,493	2	14	9.7
Stylo augmentation (1000 ha paddock)						
15% utilisation, May sale	$17,066	$1,110	-$116,654	4	n/c	2.7
15% utilisation, September sale	$122,482	$7,968	-$97,717	4	11	13.75
30% utilisation, May sale	$254,814	$16,576	-$189,841	4	11	14.27
30% utilisation, September sale	$473,571	$30,806	-$149,218	4	7	27.28
Stylo augmentation (all steers)	$2,282,461	$148,477	-$506,055	8	11	n/c
Feeding the steer tail concentrates	-$479,121	-$31,168	-$1,344,287	never	never	n/c
Feeding the steer tail concentrates high price	-$304,844	-$20,026	-$867,521	never	never	n/c
Agisting the steer tail on the floodplains	$915,695	$59,567	n/a	n/a	n/a	n/c
Agisting all steers on the floodplains	$1,783,765	$116,036	n/a	n/a	n/a	n/c

Although the values shown in Tables 23 and 24 fail the test of "which property do they apply to", just as the Brahman Jap Ox index, they are a much better place to start when looking at the opportunities available to northern beef producers to improve efficiency than any other method.

In the Fitzroy region, it is evident that even the relatively simple strategy of targeting the optimum age to sell steers will likely produce more benefits for Fitzroy producers than targeting the genetic improvement of fertility.

Many of the strategies developed for each region can be implemented simultaneously while some are alternatives. For example, a manager in the Katherine region is unlikely plant a large area of stylo if reliable agistment is available on the floodplains due to the riskiness of planting stylo. Unreliable agistment on the flood plains may be less favoured than planting stylo for steers. A very low cost strategy such as gradually replacing the herd bulls with bulls more likely to improve the weaning rate over time would be favoured but once costs were incurred in achieving the changeover, other strategies may rank higher. Even so, introducing bulls with different genes would not change anything if the property was acutely P deficient and the P deficiency had not been appropriately treated. Liebig's Law of the Minimum would still apply.

Looking at strategies in isolation does not identify the cumulative benefit potentially arising to property managers of implementing complementary strategies. For example, the combination of appropriate P supplementation, objective selection of home bred bulls and planting sufficient stylo for the steers makes a significant difference to the economic performance of our example property in the Katherine region over the 30 year investment period. Complementary strategies can also be found and combined for the Fitzroy region property and for most specialist beef properties in northern Australia. The only framework capable of applying this sort of wide ranging, all-encompassing analysis of the choices available is the Farm Management Economics framework.

General discussion

There appear to be a number of misconceptions about modelling the value of genetic improvement of beef cattle in general and the genetic improvement of fertility in particular. The first issue arises with the selection of the framework. The framework should be decided by the question under consideration; namely, what are the costs, benefits and risks over time to a beef production system of selecting bulls expected to change the fertility of their female progeny?

The only framework that can satisfactorily answer this question is farm management economics, in particular that component of farm management economics that looks at situations where the farm production system is already in place and faces the need to improve productivity. Here, marginal analysis is applied at the property level. Appropriately linking an effective livestock production model to an economic model at the farm level that can follow the impacts of change over a number of decades is the critical component that provides insight into the value of an alternative beef production strategy. This insight cannot be derived from a less capable framework that does not capture all aspects of performance and costs relating to each component of the herd and the trade-offs that occur over time when the performance of one component of the herd is changed. The livestock model also needs to be able to balance the various activities within the herd to identify a likely economic optimum for the productions system.

It must be remembered that typical self-replacing beef production systems in northern Australia are likely to have (at least):

- a breeding activity that produces weaners,
- heifer growing activities that supply replacement breeding females and cull heifers for sale,
- a number of steer growing and finishing activities, and
- a cull cow activity that may or may not hold cull cows for a season or longer periods of time

The suitable age to cull breeding females and replacement heifers, or sell steers, or the period of time to hold cull cows prior to sale, are some of many factors that have to be considered prior to estimating the value of changing the performance of part of the herd. That is, the starting herd performance and the herd structure that optimises returns both need to be carefully identified prior to modelling the value of genetically changing the conception rates of the breeding component of the herd. The modelling process also needs to be able to accurately follow the changes in herd structure and herd numbers that occur as a change in herd management is implemented. This is critically important where change takes decades to flow through a herd. Failure to incorporate the aspects of time and risk in an analysis of the costs and benefits of changing the performance of a breeding herd in northern Australia largely negates the value of the analysis.

The construction of Breeding Objectives and Selection Indexes, as recommended by MLA (2018b, 2018c) and AGBU (2018), cannot reflect the range of economic and financial outcomes of genetic selection for fertility. One of the key components of herd modelling and farm management economics is that the entire herd is modelled. That is, the modelling is done at the level of the property so that the full impacts of changing reproduction efficiency (or other factors affecting herd performance) can be appropriately estimated within the constraints applied by the optimum production system for the property. Isolating one component of a herd and pretending that changing the performance of that component will not impact overall herd structure or the performance of other components of the herd is a serious error.

Geneticists and others have applied significant rigour and skill to their science over many decades to identify accurate means of selecting beef cattle likely to improve the efficiency of beef production systems in northern Australia. Using an inappropriate framework to estimate economic value will not help adoption of the technology. It would be better to apply similar rigour to both science and economics, thereby providing an accurate insight for beef producers as to where to target investments or selection pressure. Most Fitzroy region beef producers using the Brahman Jap Ox index to calculate the extra amount they can pay to access top ranking bulls appear likely to reduce property profitability, not improve it.

The issue of ill-informed investment decisions arising from the use of Breeding Objectives and Selection Indexes is not limited to beef producers. The publication of $Indexes has led others to apply them to estimate a wider range of economic values. Fennessy *et al.* (2014) applied the method underpinning the construction of $Indexes with the BreedObject software to the evaluation of the impact of animal genetics and genomics RD&E investment made by MLA. They identified "the value proposition behind the purchase of a superior bull from a BREEDPLAN-recorded herd is derived by comparing the genetic merits of candidate bulls. For example, if bull A has an economic index $20 greater than bull B for 600 days weight, then the average offspring of bull A are predicted to differ in profitability realised through growth rate, relative to bull B, by $10". They reported "the estimated contribution of reduction in days to calving is based on the assumption that 1 day is equivalent to 1.60 kg in terms of 600 day (live) weight based on 1 day earlier being valued at $2.00 and carcass weight being valued at $2.32 per kg ($1.24 per kg of 600-day weight)". This approach was applied to suggest that the value of MLA's investment in animal genetics and genomics RD&E had a present value of $1.122 billion. Identifying the value of a fertility trait as equivalent to a change in the age of turnoff is an error. Applying a faulty method to estimate the farm level change in profit due to genetic gain cannot produce a reliable estimate of the value of this area of RD&E. As identified by Malcolm *et al*. (2019), such things as $Indexes cannot be used estimate change in farm profit.

Edwards *et al.* (2013) applied a similarly inappropriate method to calculate a value they termed 'genetic profit'. They set out to investigate the potential return on investment of implementing a genetic improvement program in a self-replacing commercial Brahman breeding herd. They used the Jap Ox Index to quantify the economic value of genetic gain and improvements were made using a Brahman sire with a top 10% Jap Ox Index ($45).The cows mated in each strategy were all assumed to have a breed average Jap Ox Index ($20). Genetic gain was calculated for each strategy using the following equations: [(Sire Jap Ox Index) – ($20)]/2 = Calf Genetic Improvement. They found "this model supports the return on investment in genetic improvement in Brahman cattle in northern Australia, and demonstrates the potential value of Fixed Time AI in both disseminating improved genetics and improving rate of genetic gain." Unfortunately, this finding is likely to be less reliable when assessing the decision to invest than the toss of a coin.

It would take time and space to list the errors made by Fennessy *et al.* (2014) and Edwards *et al.* (2103) in their respective analyses. Both papers have value in so far as they present text book quality examples of how not to identify the economic value of the genetic improvement of livestock at both the level of industry and property. The overriding concern is that both were funded and supported by significant research organisations responsible for the allocation of large amounts of industry and government (taxpayer) funds to beef research activities.

We would reinforce the message that looking at components of herd management in isolation (such as genetic improvement) will not reveal a true picture of the nature of the problem. Gaining a full appreciation requires a 'whole of property management' or farm management economics approach to be effective, an assertion also made by Foran *et al.* (1990) and Henderson *et al.* (2012).

The critical component of this analysis is the use of an effective herd model capable of balancing the trade-offs required to maintain the economic optimum while incorporating a change in the performance of a component of the herd. This model needs to be integrated with suitable farm level economic and financial models to identify the additional costs, benefits and risks associated with changing a production strategy. This framework incorporates a whole farm approach, the with and without comparison, diminishing marginal returns, equal-extra return, opportunity cost, the law of the minimum plus the time and risk associated with the change.

It is also critical to remember that Farm Management Economic thinking is more about the range of choices available than one particular technology. The range of values summarised in Tables 23 and 24 reveal the inadequacy of focussing on the genetic improvement of reproduction efficiency to the exclusion of other strategies in northern Australia yet inordinate amounts of public funds and producer levies are spent on this goal to the exclusion of research activities likely to produce (at least) positive economic benefits.

The production of "score sheets" like Tables 23 and 24 is a better starting point for a discussion about economic improvement than a Selection Index but there are problems with this approach as well. The potential benefits need to be examined on a property by property basis to account for the property-specific details in terms of location, operational scale, land capability, climate, herd performance and existing management practices. The usefulness of any particular change in management or investment to an individual beef producer, therefore, completely depends upon the relative value of a change within their enterprise. That is, the *marginal* return on the investment needs to be assessed within the constraints of each particular beef enterprise considering change.

It needs to be clearly recognised:

- Key to success is the ability of management to apply an appropriate framework to assess the trade-offs, responses, costs and benefits likely from the implementation of any opportunity for their property under their circumstances.
- The ultimate decision criteria to judge a potential change to a beef enterprise is the extra return on extra capital invested (marginal return) that is likely to result, weighed up in the context of the extra risk – both enterprise risk and financial risk - associated with the change.
- Applying an appropriate framework to decision making and understanding the reasoning behind the process will point roughly which direction to go, not the "answer".
- Opportunities for improving enterprise performance are specific to the unique resources, management system and managers of each property. This means that an investment that improves the performance of property A may or may not improve the performance of property B even though they are both found in the same region and have similar production characteristics.

In conclusion, we have demonstrated using case study herds in two regions of northern Australia (the Katherine and Fitzroy NRM regions) that a sound farm management economics approach is critical to identifying the relative and absolute value of genetically improving fertility of northern beef herds. The alternative approach of generating $indexes represents a flawed approach giving potentially misleading and incorrect results. Good quality science in the area of genetic improvement of fertility needs to be paired with equally sound economic methods to ensure appropriate conclusions are reached about value to beef producers and industry.

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