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NONLINEAR ECONOMIC VALUE FOR NUMBER OF LAMBS BORN IN NEW ZEALAND SHEEP INDEXES

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SUMMARY

A new non-linear economic value for number of lambs born (NLB) was developed for implementation in the New Zealand (NZ) SIL selection indexes. The function consists of a quadratic relationship between NLB EBV and dollar value at below-optimum commercial NLB levels, and a flat value above the optimum. This caps the reproduction dollar values of individuals with above-optimum NLB EBV that may be over-valued with a linear economic value. When incorporated into the NZ Maternal Worth index, the non-linear reproduction economic value mitigates the risk of very prolific genetics driving individuals' total index.

INTRODUCTION

A typical linear selection index used in genetic evaluation programs is calculated as $I_{linear} = \sum(EBV_i \times b_i)$, where for each trait *i* in the index, individuals' EBV_i (trait unit) are multiplied by a constant weight b_i. In this way, diverse traits including growth, reproduction, product yield and quality are incorporated to a single overall estimate of an individual's total genetic merit. In the NZ national sheep genetic evaluation, the New Zealand Maternal Worth (NZMW) index includes traits for reproduction (DPR), survival (DPS), growth (DPG), adult size (DPA) and wool (DPW). Each of these traits are weighted in indexes by linear economic values of $/trait unit (Byrne *et al.*, 2012)

However, there is concern that the current linear economic valuation for reproduction, defined as number of lambs born (NLB), risks overweighting this trait within the NZMW for highly prolific commercial flocks. The current economic weight b_{NLB}=2231 cents/lamb was derived from national population mean NLB of approximately 1.5 lambs. But due to the wide range of breeds and farm conditions across the country, many flocks experience much higher NLB. While increasing NLB in less prolific animals will increase revenue per ewe, at high NLB ewes may not be able to rear all lambs and feed and labour required to rear additional lambs reduces profit per lamb. Therefore, in practice profit per lamb per ewe decreases with increasing NLB and there is an optimum NLB above which production becomes unprofitable. This can be defined within the NZMW total merit index by replacing the current linear reproduction valuation DPR=($EBV_{NLB} \times b_{NLB}$) by a non-linear function that describes the relationship between EBV_{NLB} and profit per ewe for a typical NZ commercial sheep farm. A previous investigation (Martin-Collado *et al.*, 2016) determined that a non-linear then flat function is the most efficient approach to value NLB within the context of a multi-trait selection index.

The objective of this study was to develop a non-linear then flat index weighting for NLB to be applied within NZMW indexes, and evaluate its effect on ram rankings for reproduction and total merit.

MATERIALS AND METHODS

Non-linear function for NLB value. First, the relationship between EBV_{NLB} and commercial phenotype was defined. This is necessary because economic values must reflect what occurs at the commercial level, but breeder flocks are approximately two generations ahead of commercial flocks, and managed differently. Commercial phenotypes were predicted as $y_{NLB}=EBV_{NLB}+1.43$, based on average difference in NLB phenotypes between breeders and commercial producers due to management, genetic lag between breeder and commercial flocks, and NLB genetic trend.

The non-linear function was defined in two parts: a quadratic function $v_q = a + by_{NLB} + cy_{NLB}^2$ describing the relationship between NLB and farm profit up to the optimum NLB phenotype, then a flat constant value at and above the optimum NLB. Coefficients b and c were defined from the existing model for deriving linear economic values for commercial NLB in the NZ sheep industry (Byrne *et al*. 2012). In the range of NLB values of 1.5 to 2.0, the relationship between NLB and marginal economic value (MEV, cents/lamb) can be described by a linear function $MEV = -5899NLB + 10904$ (Figure 1a). The optimal NLB occurs at MEV=0 where y_{NLB}=1.848 lambs. This relationship reflects the first derivative of the quadratic function describing the relationship between NLB and farm profit per ewe.

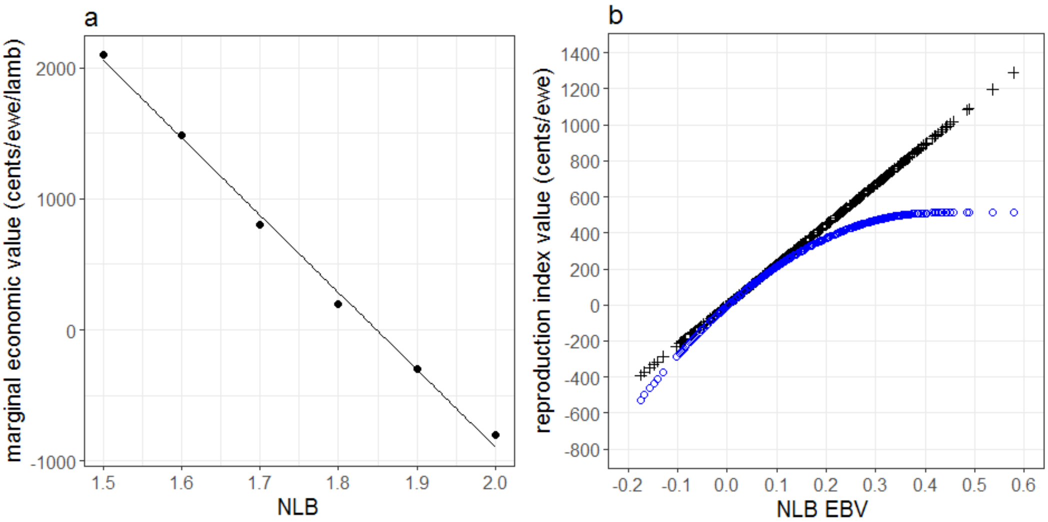

Figure 1. (a) Relationship of marginal economic value with population mean NLB. (b) Relationship of individual proven rams' EBV_{NLB} with profitability according to linear economic value b_{NLB}=2231 cents/ewe/lamb (crosses), or non-linear quadratic then flat function (circles)

Coefficients of the implicit quadratic function were calculated with simple algebraic integration of MEV, so that b=10904 and c=-5899/2=-2949.5. The constant a was calculated to make mean non-linear values similar to the current mean linear values achieved with DPR=($EBV_{NLB} \times b_{NLB}$). If the current national mean EBV_{NLB}=0.043 lambs, then the current mean value is (0.043×2231)=95.3 cents. Setting the quadratic equation to obtain this value for a predicted commercial mean NLB phenotype y_{NLB}=1.473 lambs, a=-9566.7. The optimum of this equation occurs at y_{NLB}=1.848 where value=511 cents. The function was then modified to give flat pattern of response as predicted commercial NLB exceeds the optimum y_{NLB}. The final non-linear reproduction value (DPRnl) function was therefore:

$$DPRnl = \begin{Bmatrix} -9566.7 + 10904y_{NLB} - 2949.5y_{NLB}^2, \text{if } y_{NLB} < 1.848 \\ 511, \text{if } y_{NLB} \geq 1.848 \end{Bmatrix}$$

With this function, the economic weighting applied to NLB for an individual depends on its EBV_{NLB}. Figure 1b illustrates the difference in individual reproduction profitability values calculated with linear DPR vs. the non-linear DPRnl.

Comparison of linear and non-linear values. The effects of non-linear economic value of NLB were evaluated by comparing ram index values and rankings calculated with current linear DPR and NZMW with those calculated with DPRnl. National evaluations for rams born in 2010-2014 were extracted from the SIL database in September 2016. Individuals' predicted commercial phenotype y_{NLB}, reproduction index values DPR and DPRnl, and total merit values NZMW and NZMWnl were calculated. NZMW was the sum of DPR plus DPG, DPA, DPW, and DPS subindexes; NZMWnl was the sum of DPRnl, DPG, DPA, DPW and DPS. Comparisons were done within breed for young rams defined as those born in 2014, and proven rams defined as those with EBV_{NLB} accuracy≥60. Values for DPR vs. DPRnl, and for NZMW vs. NZMWnl were compared with Pearson and Spearman rank correlations.

RESULTS AND DISCUSSION

Results presented here are for one breed only, but are representative of major breed groups tested. Proven rams' DPR and DPRnl (Figure 1b) illustrate how for individuals with near-average EBV_{NLB}, reproduction index values were similar, but above this values diverged. At the highest EBV_{NLB}=0.58, reproduction value dropped from DPR=1291 cents/ewe to DPRnl=511 cents/ewe (the capped maximum value). The non-linear NLB economic value reduced young and proven rams' average reproduction value by 88 and 109 cents/ewe, respectively; these reductions carried through in average total index values (Table 1).

Table 1. Ram group mean values for NLB EBV and predicted commercial phenotype (y_{NLB}), linear and non-linear reproduction values (DPR, DPRnl), growth (DPG), adult weight (DPA), survival (DPS), wool (DPW), and total merit with linear and non-linear reproduction values (NZMW, NZMWnl)

	Young (N=10921)	**Proven (N=381)**	**Top Proven by NZMW (N=100)**	**Top Proven by NZMWnl(N=100)**
EBV_{NLB} (lambs)	0.18	0.17	0.26	0.21
y_{NLB} (lambs)	1.61	1.6	1.69	1.64
DPR (cents/ewe)	401	378	585	478
DPRnl (cents/ewe)	313	269	390	341
DPG (cents/ewe)	1122	1244	1541	1556
DPA (cents/ewe)	-321	-352	-251	-221
DPS (cents/ewe)	207	192	315	349
DPW (cents/ewe)	173	167	245	246
NZMW (cents/ewe)	1582	1629	2435	2408
NZMWnl (cents/ewe)	1493	1520	2240	2271
Corr. DPR-DPRnl	0.962	0.942	0.901	0.928
Corr. NZMW-NZMWnl	0.988	0.979	0.886	0.886
Rank corr. DPR-DPRnl	1	1	0.999	1
Rank corr. NZMW-NZMWnl	0.984	0.975	0.862	0.862

Pearson and Spearman correlations between DPR and DPRnl, and between NZMW and NZMWnl were very high (r>0.94; Table 1). However, these values are an incomplete view of ranking changes. The flat maximum value in the non-linear function reduced variance and skewed distribution of reproduction values (Figure 2a). For average rams, there is little change in value going from linear to non-linear economic value. However, as rams' EBV_{NLB} increases, there is greater loss in index value (Figures 1b, 2b). Rams that were high-ranking with linear NZMW mainly due to extreme high EBV_{NLB} dropped in rank. For the top 100 proven rams as ranked by linear NZMW, the correlations with non-linear values are weaker (Table 1). Effects on other index traits can be seen with means from the top 100 proven rams as ranked by NZMW or NZMWnl (Table 1). Top rams according to NZMWnl, had higher values for growth, adult weight and survival, compared to top rams according to the linear index (Table 1).

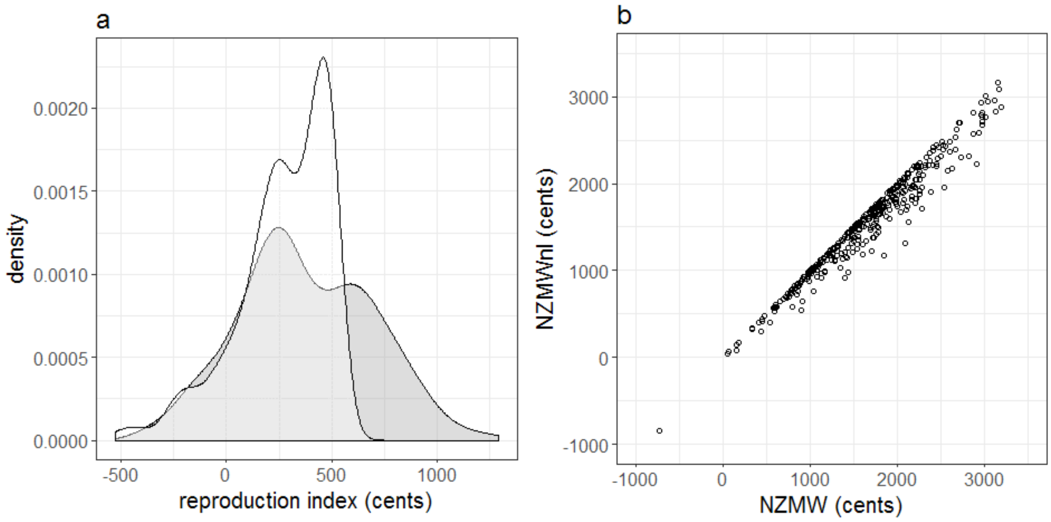

Figure 2. (a) Distributions of linear DPR (dark grey) and nonlinear DPRnl (white) reproduction index values for proven rams group. (b) Relationship of individual proven rams' total linear NZMW with NZMWnl that includes nonlinear NLB value

The results of this study show that there is a practical way to implement a non-linear function for NLB. The non-linear function tempers the risk of the more prolific genetics badly overshooting optimum NLB. Implementation of this non-linear index function is expected to reduce population-wide selection response for NLB, but increase in response for growth traits and ewe weight.

REFERENCES

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