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Changing the sex ratio at birth in lambs, calves and deer: Implications for productivity and genetic gain in breeding flocks and herds in New Zealand

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ABSTRACT

Survival rates to weaning in sheep, beef cattle and deer favour females by between 2 and 7 percentage units. Conversely, weaning weight favours males by 0.5 to 4.4 kg in sheep, 4 to 26 kg in beef calves and about 2-3 kg in red and fallow deer. Productivity at weaning time (ie weight of offspring per pregnant female) is increased by manipulating the sex ratio to all males, by only about 2% in each of the species.

In self-replacing ewe and beef breeding systems, within-herd genetic gain is maximal over the range of 25 to 55% of males born and reduces dramatically beyond this range.

Overall, there appears to be limited scope for reliably improving productivity to weaning and genetic gain in breeding flocks and herds by manipulating the sex ratio at birth. An analysis of the post weaning benefits is thus urgently required.

Keywords: sex ratio, sex effects, biological efficiency, sheep, beef cattle, deer.

INTRODUCTION

Controlling the sex of agriculturally important animals may have a significant impact on the economics and genetics of livestock production in New Zealand. Benefits may arise because agriculturally important traits are often expressed to differing degrees in each sex. For example, traits such as milk, eggs and antler velvet are limited to only one sex: such traits may be termed sex-limited traits. In the case of sex-influenced traits such as growth, carcass and survival, both sexes can express the trait but one sex outperforms the other. Sex-linked traits on the other hand are confounded with the X-and Y-chromosome, eg the Inverdale gene for fecundity in sheep.

Rates of genetic gain are influenced by changes in the proportion of potential parents that are actually selected as future parents (ie selection intensity). Changes in the sex ratio at birth in self-replacing breeding enterprises, through its effect on selection intensity, can potentially impact on annual rates of genetic gain.

SCOPE AND AIMS OF STUDY

Any full analysis of the implications of sex-control technology and therefore sex ratio changes at birth would need to take account of the multitude of relevant traits in sheep, cattle, deer, horses, goats, etc. However the current analysis is limited to the mixed livestock industries and in particular to sheep, beef cattle and deer. Furthermore, this analysis focuses on the implications in *breeding* flocks and herds. A sheep and beef cattle example have been chosen to illustrate the implications for genetic change, although the principles are expected to apply more generally.

An analysis was carried out to determine the effect on animal productivity and genetic gain, of changing the sex ratio at birth to either more males or more females.

Productivity at weaning time in flocks and herds

To permit the comparison of three contrasting sex-ratio scenarios, namely 100 vs 50 vs 0% males at birth, productivity has been defined as the ratio of total weight of offspring weaned per pregnant female. This index , although simple, recognises weight of offspring as an important output from breeding enterprises. The two components that make up weight of offspring at weaning are survival to weaning and weaning weight, both of which are sex-influenced. Estimates for these sex effects have been derived from published NZ data. The following productivity results are presented as a ratio of 100:50:0 per cent males at birth with 50% males at birth given an arbitrary productivity of 100 units.

The implications for productivity when a terminal sire is used over a portion of females in a self-replacing herd is also examined, using a beef herd as an example. In this scenario, 42% of the herd calved to straight-bred bulls so as to generate female replacements, the balance calved to a terminal sire. Data from the terminal sire breed giving the greatest weight of calf weaned per cow calving under NZ conditions, ie the French strain of Simmental, was used (Baker *et al.*, 1990). For the purpose of this analysis, the mean sex effect (male - female) for calf survival of -4.1 percentage units and for weaning weight of 11.6 kg was used (Baker *et al.*, 1990). The breeding cow herd was assumed to be Angus and all actual calf survival and weaning weights were taken from Baker's paper.

Genetic gain in self-replacing flocks and herds

Manipulation of the sex ratio has implications for genetic change in self-replacing flocks and herds through its effect on the proportion of males and females selected to become future parents. Under normal conditions about 1.5 rams (ie about 2% of rams born) and 3 bulls (ie about 3% of bulls born) are required as replacements per 100 breeding females, compared with a requirement for about 20 females (ie about 25% of ewe lambs born and about 45% of heifer calves born). By manipulating the sex ratio the proportions of offspring born which are retained as future parents will vary. This will in turn affect the selection intensity for each sex and consequently influence genetic gain according to the relationship shown in Equation 1.

Equation 1 $\Delta G = \frac{i.h.\sigma_g}{GI}$

Where ΔG = annual genetic change
i = average selection intensity for males and females
h = square root of heritability for trait
σ_g = genetic standard deviation for trait (kg)
GI = average generation interval for males and females (yr)

The trait considered in this analysis was yearling weight in sheep and cattle. Selection intensity for each sex was determined from tables depending on the number of selected parents and candidates for selection (Becker, 1975). Heritability of yearling weight was assumed to be 0.32 in both sheep and cattle with a genetic standard deviation of 2.7 and 14.3 kg respectively (Morris, CA pers comm). Mean generation interval in cattle was assumed to be 2.95 years (2.4 years in males, 3.5 years in females) in sheep and 3.25 years (2.0 years in male and 4.5 years in females) in beef cattle.

To assess the implications for genetic gain, sex ratios at birth ranging from 10% males at birth to a maximum of 70-80% males at birth (ie the maximum possible number of males born so as to provide all female replacements from the balance of offspring) were examined.

RESULTS

Ewe breeding flocks

1. Sex effects

Estimates for the sex effect (male - female) on survival to weaning range from -2 to -6 percentage units (Dalton *et al.*, 1980; Hight and Jury, 1970). On the other hand, male lambs are heavier than females lambs by 0.4 to 4.4 kg at weaning depending on flock and year (Jury *et al.*, 1979). For both traits, the sex effect appears very variable.

2. Productivity

Assuming average sex effects on survival and weaning weight of -3.5 percentage units and +2.1 kg respectively, relative productivity at 100:50:0 % males born is 102:100:98 units. Multiple birth rate has no effect on these relativities and neither are they influenced to any great extent by actual survival rates and weaning weights.

Under optimistic conditions for males, ie low survival penalty and high weaning advantage, relative productivity is 109:100:91. Conversely, under pessimistic conditions for males, ie high survival penalty and low weaning weight advantage, relative productivity is 98:100:102. Thus, under all male systems relative productivity can range from 98 to 109 units. Similarly, for all female systems it can range from 91 to 102 units.

3. Rate of genetic change

Between 25 and 55% of males born (or 45-75% females born), rates of genetic gain for yearling weight were similar and at a maximum. With only 10% of males (or 90% females) born, genetic gain had fallen to about 90% of maximum. The maximum proportion of males born which allowed *all* surviving females to be retained as future parents was about 85%. Annual genetic gain under these circumstances was about 75% of maximum.

Beef cow herds

1. Sex effects

Estimates for the sex effect (male - female) on survival to weaning range from -2 to -7 percentage units (Baker *et al.*, 1990; Morris *et al.*, 1986). On the other hand, male calves are heavier than females calves by 4 to 26 kg at weaning (Baker *et al.*, 1974). Sex effects on survival and weaning weight in cattle show a similar variability to those reported in sheep.

2. Productivity

Assuming average sex effects on survival and weaning weight of -4 percentage units and +15 kg, relative productivity at 100:50:0 % males born is 102:100:98 units. Under optimistic conditions for males, ie low survival penalty and high weaning advantage, relative productivity is 105:100:95. Conversely, under pessimistic conditions for males, ie high survival penalty and low weaning weight advantage, relative productivity is 97:100:103. Thus, under all male systems relative productivity can range from 97 to 105 units, while for all female systems the range is from 95 to 103 units.

3. Rate of genetic change

Between 30 and 55% of males born (or 45-75% females born), rates of genetic gain for yearling weight were similar and at a maximum. With only 10% of males (or 90% of females) born, genetic gain had fallen to about 80% of maximum. The maximum proportion of males at birth which allowed *all* surviving females to be retained as future parents was about 80%. Annual genetic gain under these circumstances was about 75% of maximum.

4. Productivity using a terminal sire

Productivity was 104 units in the herd with only straight-bred females born and only male cross-bred calves born compared with 100 units in the herd with a 50:50 sex ratio at birth in both straight-bred and cross-bred calves. If only female straight- and cross-bred calves were born productivity was 102 units.

Deer herds

1. Sex effects

Considerably less data are published for deer herds compared with sheep flocks and beef herds. Using the last 6 years data from one 11 year study in red deer (Moore *et al.*, 1988), survival was 5.2% lower and weaning weight 3.2 kg higher in males compared with females. No NZ data appear to have been published for sex effects on survival in fallow deer although males are 2-3 kg heavier at weaning than females (Asher and Adams, 1985; Morris *et al.*, 1992).

2. Productivity

For red deer, relative productivity is 101:100:99. If the sex effect reported for red deer for survival is assumed for fallow deer, the ratios in this species are 103:100:97.

3. Genetic gain

Insufficient published estimates on genetic parameters for deer in NZ are available for meaningful analyses to be carried out (Red deer: Rapley, 1990; Fallow deer: Morris *et al.*, 1992).

GENERAL DISCUSSION

The first major finding of this study was that changes from a 50:50 sex ratio to all males or all females at birth had, on average, relatively minor effects on the weight of offspring at weaning in sheep, beef cow, red deer and fallow deer breeding enterprises. This arises because some of the gains in weight of male progeny are offset by the lower survival rates in male progeny. Analyses which fail to take this into account would thus overestimate the likely benefits of more males born.

The sex effect on survival and weaning weight is unpredictable. For example, in the case of sheep and beef cattle, the sex effect on weaning weight is independent of actual mean weaning weight (Jury *et al.*, 1979; Baker *et al.*, 1974). As a result of the variable and unpredictable size of the sex effect on survival and weaning weight, the actual productivity outcome in any particular flock or herd could extend over a 10 unit range. Importantly, some of the outcomes could be counter productive. This uncertainty of outcome, coupled with the risk of some outcomes being counterproductive, may prove to be an important barrier to the widespread adoption of sex control technology in the mixed livestock breeding industry in NZ. As a consequence, much of the livestock raised for slaughter will continue to be females that are surplus for replacement purposes. If breeding enterprises are also engaged in finishing operations, there may be advantages to the finishing operation of more males that have not been accounted for in the current analysis. These relate to the biological as well as financial advantage of finishing males over females in our current meat industry (McCall, D.G and Parminter, T.G. unpublished results). Under circumstances where breeding and finishing enterprises are part of the same overall farming operation, sex control technology may be worth considering, although the risk of pessimistic sex-effect outcomes remains.

The second major, and apparently new, finding was that the rate of genetic gain, for live weight at least, is insensitive to sex ratio changes over the range 30-55% of males born. This finding was consistent in sheep and beef cow analyses and probably applies generally to sex-influenced traits. Clearly, gains in selection intensity in one sex were completely countered by losses in the other sex over this range. Beyond this range, the reduction in genetic gain was dramatic. For example, at about 80% males born, the maximum possible in a self-replacing flock or herd, rate of genetic gain was only 75% of the maximum. Manipulation of the sex ratio at birth thus provides no realistic opportunity for improving rates of genetic gain within a breeding herd or flock. Conversely, natural chance deviations from a 50:50 sex ratio at birth, especially against males, is unlikely to be any practical significance.

The implications for genetic gain in dairy cow herds with altered sex ratios at birth were not reported in this paper. The dairy industry is a special case because of its herd improvement structure and the fact that milk is a sex-limited trait. Thus, 'cows to breed cows' as well as 'cows to breed bulls' pathways are the important routes by which manipulation of the sex ratio can impact on genetic gain (Garrick and Rendel, 1992). Calculations show that annual rate of genetic gain in the dairy industry is likely to be realistically improved by about 3-5% (Rendel, J.M. pers. comm.). This would be well worthwhile in the long term, provided costs of implementation are low.

Using terminal sires over a greater proportion of the flock or herd is a new opportunity created by sex control technology. Terminal sire use could apply to sheep, beef cow and deer breeding enterprises. Although the productivity gain is a modest 4% when a high performance strain of beef terminal sire is used, financial premiums for terminal sire cross male weaner calves may enhance this advantage. Many producers may consider this worthwhile, although the risks of achieving more pessimistic outcomes would need to be assessed. Terminal sires could be used in dairy herds to supply male dairy cross beef cattle for finishing. Alternatively, female dairy cross beef heifers could be produced from dairy cows and used to establish and replenish breeding herds (ie terminal dam herds).

Limitations of study

The four major limitations of this study are: only one progeny trait is considered; weaning time is used as the end point; little economic analysis has been presented, and the dairy herd was not considered. Some other traits that could have been considered for all three species include carcass traits, subsequent live weights as well as management traits such as birth difficulty, animal health and animal behaviour. Some account would need to be taken of animal feed requirements so that comparisons could be made on a per hectare or per unit of feed required basis. For example, in the case of red deer in New Zealand, it has been estimated that biological efficiency (ie lifetime g carcass/MJ ME for the hind/calf unit) can be enhanced by about 15% if only red male progeny are born and up to about 40% if only hybrid (eg Canadian Wapiti cross) males are born (McMillan, 1993). For sheep, fleece traits would need to be include since they are an important source of revenue in this species. Similarly, velvet antler traits could be included in alternative deer analyses. Any full analysis would also take account of financial costs and returns as well as risk assessment. It would be for each producer to decide what action to take based on the outcomes of such analyses. Given the promising results from preliminary analyses on the implications of sex control in the dairy industry, more fuller analyses are urgently required. The implications for beef production from the dairy herd also require evaluation.

SUMMARY

On average, a sex ratio of 100% males at birth will increase productivity at weaning time by about 2% in sheep, beef cattle and deer breeding enterprises. Conversely, productivity is decreased by about 2% in systems with all females at birth. In the case of terminal sire use in self replacing breeding enterprises, productivity is increased by about 4%, at least in cattle, if a minimum of female replacements are born and the remainder are cross-bred males. The implications for rate of genetic change of altering the sex ratio at birth is minimal, provided the proportion of males is between 25 and 55%. Beyond this range rates of gain diminish rapidly. An analysis of the post weaning benefits, as well as the implications in dairy herds is urgently required.

CONCLUSIONS

Because of the wide variation in, and unpredictability of sex effects on survival and weaning weight, manipulation of the sex ratio of offspring at birth can result in highly variable effects on productivity. This uncertainty, coupled with the small productivity gain expected under average conditions, is likely to be a major limitation to the widespread adoption of sex control technology in sheep, beef cattle and deer breeding enterprises.

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