

## Population analysis of a purebred Hereford and a multibreed synthetic beef cattle herd

PF Arthur<sup>1</sup>, M Makarechian<sup>2</sup>, R Weingardt<sup>2</sup>, RT Berg<sup>2</sup>

<sup>1</sup> NSW Agriculture, Agricultural Research Centre, Trangie, NSW 2823, Australia;

<sup>2</sup> Department of Animal Science, University of Alberta, Edmonton, AB, T6G 2P5, Canada;

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**Summary** – Lifetime records of females born from 1966 to 1975 were used to estimate and compare population parameters of a purebred Hereford (HE) and a multibreed synthetic (SY1) beef cattle herd raised under a stringent culling policy whereby heifers and cows failing to wean a calf each year were culled. Population size averaged 118 cows, 39 heifers and 155 cows, 56 heifers a year for HE and SY1, respectively. The SY1 was a multibreed composite breed group with an average breed composition of 33% Charolais, 33% Angus, and 20% Galloway, and the remainder from other beef breeds. The 2 herds were raised under the same management. Nine life table statistics were studied: age-specific survivorship, age-specific survival rate, mortality rates ( $Qx$ ), expected herd life, age-specific birth rate, reproductive value, net reproductive rate ( $Ro$ ); instantaneous rate of population increase ( $r$ ) and generation interval ( $T$ ). Differences were obtained between the herds for the age-specific life table statistics, with SY1 having higher values (except for lower  $Qx$  values) than HE. SY1 had higher means than HE for  $Ro$  ( $1.57 \pm 0.11$  versus  $1.21 \pm 0.15$ ;  $p < 0.07$ ) and  $r$  ( $0.09 \pm 0.01$  versus  $0.03 \pm 0.02$ ;  $p < 0.04$ ), indicating a faster rate of population growth in SY1. The value of  $T$  for SY1 was higher ( $p < 0.01$ ) than that for HE ( $5.09 \pm 0.11$  versus  $4.25 \pm 0.19$  years). The results indicate that the same management and culling policy may result in different life table statistics, which in this study was possibly due to the influence of heterosis for calf survival in the multibreed composite SY1 herd. Over time the stringent culling policy had the effect of reducing  $Ro$ ,  $r$  and  $T$  values to the point where herd size in the HE herd could not be maintained ( $Ro < 1$  in the 1972 and later cohorts).

beef cattle / demography / longevity / survival / reproduction

**Résumé** – Analyse démographique d'un troupeau de race pure Hereford et d'un troupeau synthétique multiracial de bovins à viande. Les enregistrements des carrières des femelles nées de 1966 à 1975 sont utilisés pour estimer et comparer les paramètres démographiques d'un troupeau de race pure Hereford (HE) et d'un troupeau synthétique multiracial (SY1) de bovins à viande, soumis tous 2 à une politique de réforme rigoureuse

dans laquelle toute génisse ou toute vache ne produisant pas un veau sevré par an était éliminée. La taille moyenne instantanée de la population était de 118 vaches et 39 génisses dans le troupeau HE, de 155 vaches et 56 génisses dans le troupeau SY1. Le troupeau SY1 était un ensemble composite d'origine multiraciale comprenant 33% de Charolais, 33% d'Angus et 20% de Galloway, le reste provenant d'autres races bovines à viande. Les 2 troupeaux étaient conduits de manière identique. Neuf paramètres issus de l'analyse des carrières des femelles sont étudiés : la probabilité, à la naissance, de survivre jusqu'à un âge donné ; le quotient de survie  $P_x$  (probabilité, à un âge donné, de survivre jusqu'à la classe d'âge suivante) ; l'espérance de vie à un âge donné (nombre moyen d'années restant à vivre à une femelle atteignant l'âge  $x$ ) ; le quotient de fécondité (probabilité pour une femelle, à un âge donné, de produire une fille) ; la contribution relative d'une femelle d'un âge donné à la procréation des générations futures ; le taux net de reproduction  $R_0$  (nombre moyen de filles de remplacement produites par une femelle) ; le taux instantané d'accroissement de la population ( $r$ ) et l'intervalle de génération ( $T$ ). On observe des différences entre les 2 troupeaux sur les paramètres démographiques spécifiques de l'âge, le troupeau SY1 présentant des valeurs plus élevées que le troupeau HE. Le troupeau SY1 présente des valeurs moyennes plus élevées que le troupeau HE pour le taux net de reproduction  $R_0$  ( $1,57 \pm 0,11$  contre  $1,21 \pm 0,15$ ;  $p < 0,07$ ) et pour le taux instantané d'accroissement  $r$  ( $0,09 \pm 0,01$  contre  $0,03 \pm 0,02$ ;  $p < 0,04$ ), ce qui indique un taux d'accroissement de la population plus élevé dans le troupeau SY1. L'intervalle de génération  $T$  est plus élevé ( $p < 0,01$ ) dans le troupeau SY1 que dans le troupeau HE ( $5,09 \pm 0,11$  contre  $4,25 \pm 0,19$  années). Ces résultats montrent qu'une même conduite et qu'une même politique de réforme peuvent se traduire par des paramètres démographiques différents, phénomène résultant sans doute dans cette étude d'un effet d'hétérosis sur la survie des veaux dans le troupeau synthétique d'origine multiraciale SY1. Sur la durée, la politique rigoureuse de réforme entraîne une réduction des paramètres  $R_0$ ,  $r$  et  $T$  jusqu'à un point où la taille du troupeau HE ne peut plus être maintenue ( $R_0 < 1$  en 1972 et dans les cohortes ultérieures).

**bovin à viande / démographie / longévité / survie / reproduction**

## INTRODUCTION

Demographic analyses are used extensively in humans, wildlife and fisheries to characterize populations. They involve estimation of parameters such as reproductive and mortality rates, growth in numbers and biomass, age structure and other vital statistics of the population. Research reports in domestic animals using similar analyses were reviewed by Vu Tien Khang (1983). A comprehensive population analysis of a commercial beef cattle herd was made by Schons *et al* (1985) and some possible uses of the various parameter estimates discussed. In livestock, results of such analyses have been used to formulate strategies for culling and replacement (Turner *et al*, 1959; Hickey, 1960; Basu and Ghai, 1980; Greer *et al*, 1980), organize breeding schemes (Wiener, 1961; Lauvergne *et al*, 1973; Martin, 1975; Basu and Ghai, 1980) and as a check on management practices (Nadkarni *et al*, 1983). A similar analysis was used by Ahmad *et al* (1992) to characterize a herd of dairy buffalo.

The goal of faster genetic improvement in operations producing seed stock dictates that the generation interval should be shortened, and hence intense selection and/or stringent culling practices are usually employed. Arthur *et al* (1992) reported the reasons for disposal of cows from a purebred Hereford and 2 multibreed synthetic beef cattle herds managed at the same location and under a stringent culling policy. The longevity and lifetime productivity of the cows were reported by Arthur *et al* (1993). There is very little information available for beef cattle on the effect, over time, of such a stringent culling policy on population parameters and on the sustainability of herd numbers. The objective of this study was to construct age-specific and overall life tables to characterize and compare a purebred Hereford and a multibreed synthetic beef cattle herd under a stringent culling system.

## MATERIALS AND METHODS

### *Herd management and breeding plan*

The data used for the study were from the University of Alberta ranch at Kinsella, located 150 km south-east of Edmonton, Alberta, Canada. Two main breeding populations were established in 1960, namely the purebred Hereford (HE) and the Beef Synthetic. The history of the ranch and the formation of the breeding populations have been reported in detail by Berg (1980). The Beef Synthetic population was renamed Beef Synthetic #1 (SY1) in 1982, after another synthetic group composed of beef breeds was developed. To satisfy the criteria of relatively stable herd numbers, consistent management, detailed identification and production records required for such analyses, records on females born at the Kinsella ranch from 1966 through to 1975 and followed till disposal were used. The average herd size and standard deviation of the cow herd was  $155 \pm 6.7$  for SY1 and  $118 \pm 3.4$  for HE. The corresponding values for the heifers were  $56 \pm 3.0$  for SY1 and  $39 \pm 3.5$  for HE. All the females had left the herd at the time of data analyses.

The Beef Synthetic #1 (SY1) population is a multibreed composite group with mainly Charolais, Angus and Galloway breeding. The average breed composition of the SY1 females is presented in table I. The management and breeding plan of the herds were described in detail by Berg *et al* (1990). In summary, the 2 herds were treated as similarly as possible. The breeding herds were on the range year round and dependent on natural grazing, except for 3–4 months in winter when supplementary feed was provided. The level of supplementary feed depended on the pasture conditions and severity of the winter. Selection of sires was within each herd and was based on pre- and postweaning gain. On a few occasions, Hereford bulls from outside the HE herd were used for breeding. Sires were selected for breeding as yearlings and about 25% of these bulls were again used in the following year. All sound heifers were exposed to bulls as yearlings to calve as 2 year olds. Cows and heifers were exposed to bulls for 60 d in the breeding season which was July/August each year. Breeding occurred in single-sire groups of about 25 cows. To prevent reproductive failure resulting from poor serving capacity of a particular bull, mating groups were monitored during the first half of the breeding season. Any bull found to have poor serving capacity was replaced with a proven older bull for the rest of the breeding season. Calving was mainly in April and May

and 2 year olds were calved separately, closely supervised and remained separated until breeding commenced. Calves remained with their dams until weaning in early October each year. Heifers and cows failing to wean a calf each year were culled. Heifers and cows were also culled for unsoundness and defects such as bad udders, leg and feet problems, *etc.* The frequencies of the various reasons for disposal for the herds have been reported by Arthur *et al* (1992). The lifetime productivity of these cows has also been reported by Arthur *et al* (1993).

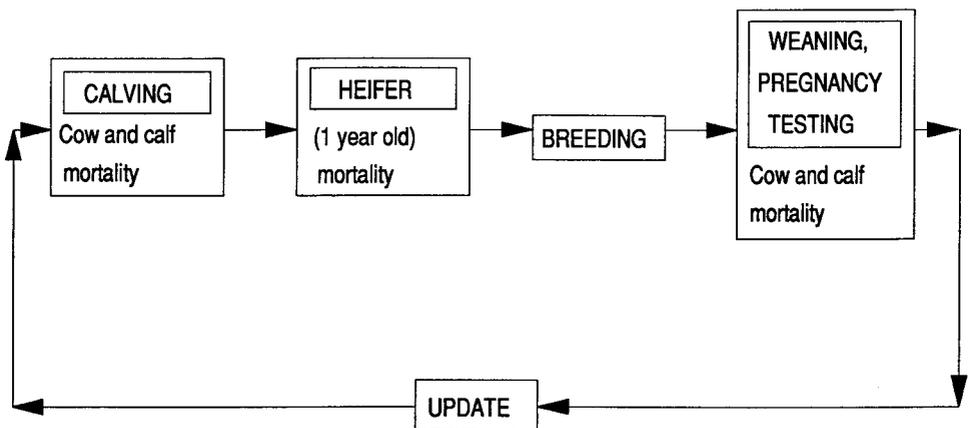
**Table I.** Average breed composition of the multibreed SY1 females born during the study period.

Breed	1966	1968	1970	1972	1974
Angus	41.6	42.9	37.6	33.0	36.0
Charolais	29.8	27.8	35.1	36.3	34.4
Galloway	26.4	22.5	20.3	23.2	21.4
Other <sup>a</sup>	2.2	6.8	7.0	7.5	8.2

<sup>a</sup> Includes Hereford, Holstein, Jersey and Brown Swiss.

### Demographic analyses

Life table statistics were computed for the 2 herds in this study. The cohort method of life table construction was used. This method follows an actual cohort (birth year group) from birth to the end of the last member's life (Caughley, 1966, 1967; Mertz, 1970). Data on 10 full cohorts (1966 through 1975; all animals had left the herd) were used in the construction of the life tables for each herd. The model utilized females only and involved seasonal breeding and overlapping generations. The time reference was immediately postpartum, with birth considered age 0 and time interval being 1 year. Leaving the herd for any reason was equated with mortality. The biological flow chart of the model is illustrated in figure 1.



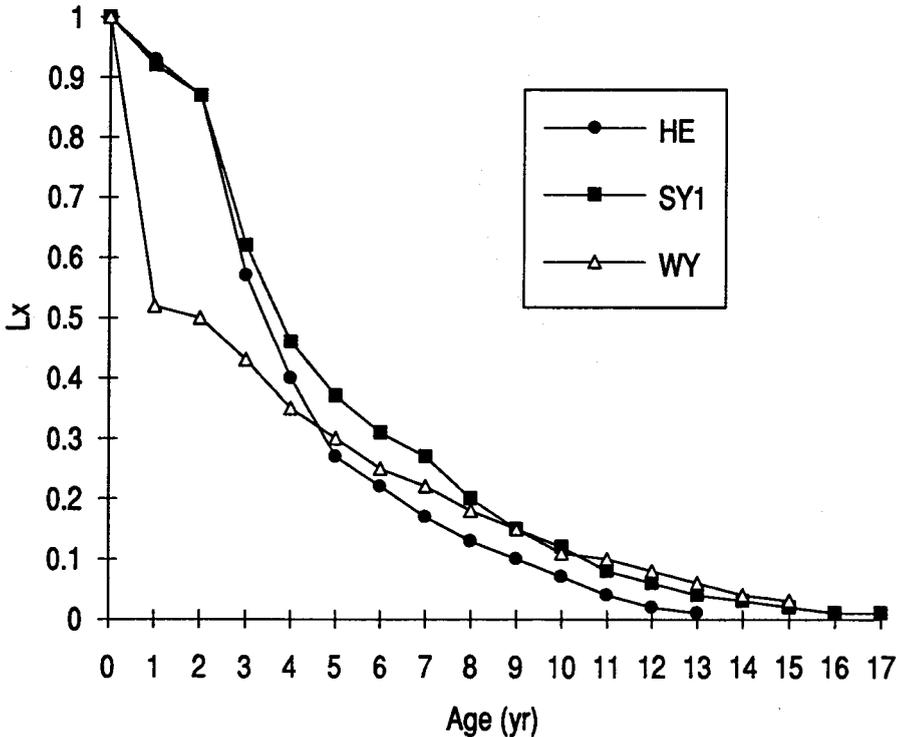
**Fig 1.** Biological flow chart of the model.

Six age-specific life table statistics and 3 overall life table statistics were computed (Caughley, 1966, 1967; Mertz, 1970; Pianka and Parker, 1975). The age-specific life table statistics computed were as follows: survivorship (probability at birth of an animal surviving to a particular age,  $Lx$ ); survival rate (probability at a particular age of surviving to the next age,  $Px$ ); mortality rate (probability at a particular age of dying before the next age,  $Qx = 1 - Px$ ); expected herd life (additional number of years an animal of a particular age is expected to remain in the herd,  $Ex$ ); birth rate (probability of a cow of a particular age producing a live female calf,  $Mx$ ); and reproductive value (relative contribution of an animal of a particular age to future generations,  $Vx$ ). The overall life table statistics computed were net reproductive rate (expected number of daughters produced by each animal,  $Ro$ ), instantaneous rate of population increase (a measure of herd number increase or decrease,  $r$ ) and generation interval in years. The computational formulae for these life table statistics have been summarised by Schons *et al* (1985). In many studies populations are characterized by constructing a life table pooled across cohorts (Krehbiel *et al*, 1962; Greer *et al*, 1980; Melton, 1983). Another method to cancel out any differences between cohort and distortions due to small numbers of animals at older ages is to average each life table statistic over all cohorts and at each age, if age-specific (Schons *et al*, 1985). The age-specific survivorship ( $Lx$ ) forms the basis of all the life table statistics. Preliminary analysis of  $Lx$  curves indicated that using the pooled or the average life table method described the herds in a similar manner, hence only the average life table method was used for the computation of all the life table statistics. The Lee-Desu  $D$  statistic (Lee and Desu, 1972) was computed, using the Survival procedure in SPSS (1990), to compare the age-specific survivorship of the two herds. The  $D$  statistic is based on a score that compares the  $Lx$  values or another statistic between herds and tests the null hypothesis that the herds are samples from the same survival distribution. Differences between the 2 herds in the overall life table statistics ( $Ro$ ,  $T$  and  $r$ ) were tested using a  $t$ -test. Within each herd, simple linear regression analysis was done for each of the overall life table statistics to examine the nature of the slope (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

Comparison of the survivorship ( $Lx$ ) values of the 2 herds using the Lee-Desu  $D$  statistic showed significant difference between the herds ( $D = 3.98$ ;  $p < 0.05$ ) leading to the rejection of the null hypothesis that the survival distributions of the 2 herds are the same. The survival patterns ( $Lx$ ) for HE and SY1 were similar up to age 2 years, after which there was a faster rate of the decline in HE compared to SY1 (fig 2). A detailed discussion on the  $Lx$  curves and the reasons for disposal of the females of the 2 herds have been reported previously (Arthur *et al*, 1992, 1993). The probabilities at a particular age of surviving to the next age ( $Px$ ) are presented in table II. There was a high probability for survival from birth to age 1 year and from age 1 to age 2 years (greater than 0.9). This was due to the facts that firstly there were very few deaths prior to age 2 years and, secondly, all available females entered the breeding herd as replacements. From age 2 years, causes other than death, *viz* culling for reproductive failure, calving problems, calf survival and udder problems, become additional sources of mortality, resulting in relatively lower  $Px$

values after age 1 year. In general, SY1 had higher survival probabilities than HE after age 1 year. The age-specific mortality rate ( $Qx$ ) is a mirror image ( $1 - Px$ ) of the age-specific survival rate ( $Px$ ) and the results are opposite those of the  $Px$  statistic discussed.



**Fig 2.** Relationship between age and survivorship (probability at birth of an animal surviving to a particular age,  $Lx$ ) for the 2 Kinsella herds (HE( $\bullet$ ) and SY1( $\blacksquare$ )) and a commercial herd (WY( $\triangle$ )) from another study (Schons *et al*, 1985).

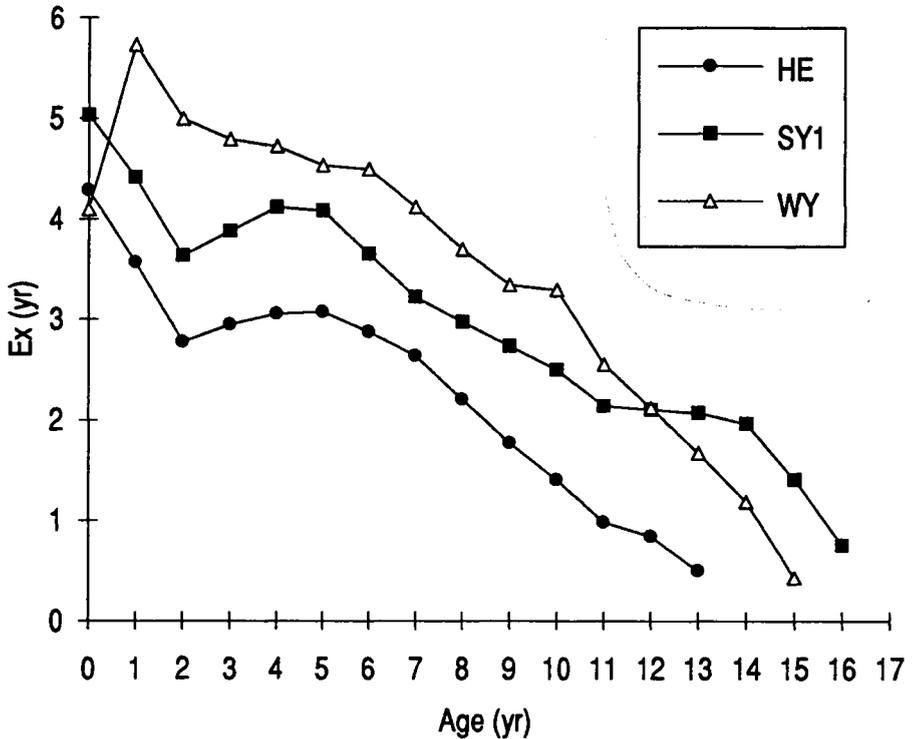
SY1 had higher values for expected herd life ( $Ex$ ) at all ages compared to HE (fig 3), indicating that at any particular age SY1 females were expected to live longer than HE females. The age-specific birth rate (probability of a cow of a particular age producing a live female calf,  $Mx$ ) is a very important statistic in beef cattle production, because it influences the number of replacement heifers available, population growth and generation interval.  $Mx$  is dependent on the sex ratio of progeny. At older ages there were fewer cows present in the herd, hence the likelihood that the sex ratio of progeny of cows at these ages was not 1:1 was high. This deviation from the expected 1:1 sex ratio contributed to the relatively high or low  $Mx$  values obtained at older ages (table II). Mean  $Mx$  across all ages was 0.46 and 0.48 for HE and SY1, respectively. Reproductive value ( $Vx$ ) is also

Table II. Means and standard errors for age-specific life table statistics<sup>a</sup>,  $P_x$ ,  $M_x$  and  $V_x$ , for the purebred HE and SY1 herds.

Age (years)	$P_x$		$M_x$		$V_x$	
	HE	SY1	HE	SY1	HE	SY1
0	0.93 ± 0.02	0.92 ± 0.02			1.00	1.00
1	0.94 ± 0.02	0.95 ± 0.02			1.03 ± 0.03	1.10 ± 0.02
2	0.66 ± 0.05	0.72 ± 0.04	0.42 ± 0.02	0.43 ± 0.02	1.07 ± 0.06	1.21 ± 0.03
3	0.69 ± 0.05	0.73 ± 0.05	0.38 ± 0.03	0.40 ± 0.04	0.74 ± 0.06	0.91 ± 0.03
4	0.68 ± 0.07	0.80 ± 0.03	0.39 ± 0.05	0.46 ± 0.04	0.56 ± 0.08	0.73 ± 0.04
5	0.76 ± 0.05	0.87 ± 0.03	0.39 ± 0.05	0.42 ± 0.03	0.43 ± 0.08	0.58 ± 0.03
6	0.75 ± 0.08	0.85 ± 0.04	0.64 ± 0.06	0.51 ± 0.06	0.34 ± 0.08	0.47 ± 0.03
7	0.78 ± 0.07	0.78 ± 0.05	0.54 ± 0.06	0.43 ± 0.05	0.21 ± 0.05	0.35 ± 0.03
8	0.79 ± 0.07	0.75 ± 0.04	0.48 ± 0.11	0.49 ± 0.03	0.14 ± 0.03	0.26 ± 0.03
9	0.70 ± 0.09	0.76 ± 0.06	0.42 ± 0.12	0.39 ± 0.04	0.10 ± 0.03	0.18 ± 0.03
10	0.58 ± 0.10	0.71 ± 0.08	0.38 ± 0.12	0.41 ± 0.06	0.05 ± 0.01	0.13 ± 0.02
11	0.38 ± 0.16	0.66 ± 0.07	0.56 ± 0.15	0.43 ± 0.09	0.03 ± 0.01	0.09 ± 0.02
12	0.34 ± 0.24	0.57 ± 0.13	0.42 ± 0.25	0.30 ± 0.11	0.02 ± 0.01	0.07 ± 0.02
13	0.00	0.59 ± 0.16		0.56 ± 0.15	0.00	0.07 ± 0.02
14		0.75 ± 0.16		0.71 ± 0.16		0.06 ± 0.02
15		0.70 ± 0.20		0.77 ± 0.15		0.05 ± 0.02
16		0.25 ± 0.25		0.42 ± 0.25		0.02 ± 0.01
17		0.00				0.02 ± 0.00

<sup>a</sup>  $P_x$  = survival rate (probability at a particular age of surviving to the next age);  $M_x$  = birth rate (probability of a cow of a particular age producing a live female calf);  $V_x$  = reproductive value (relative contribution of an animal of a particular age to future generations).

defined as the ratio of the expected size of a herd (at some future time) founded by a cow or group of cows of a particular age to the expected size of a herd founded simultaneously by a heifer calf or group of heifer calves aged 0 (MacArthur and Wilson, 1967). The  $Vx$  values for both herds peaked at age 2 years and gradually dropped off with SY1 having higher values than HE at all ages (table II). The rise in the  $Vx$  values up to age 2 years was due to the lack of reproduction until 2 years of age ( $Mx$  values are zero for ages 0 and 1 year).



**Fig 3.** Relationship between age and expected herd life (additional number of years an animal of a particular age is expected to remain in the herd,  $Ex$ ) for the 2 Kinsella herds (HE(●) and SY1(■)) and a commercial herd (WY(△)) from another study (Schons *et al*, 1985).

The overall life table statistics for the 2 herds are presented in table III. The means for net reproductive rate ( $R_0$ ) were greater than unity and those for instantaneous rate of population increase ( $r$ ) were greater than zero for both herds. These results, which represent the average for the entire study period, indicate that cows in both herds were more than replacing themselves and that herd numbers were increasing. The means for these statistics were higher in SY1 than in HE. For natural populations  $r$  can be used as a measure of a population's capacity for sustained change in numbers; the higher the  $r$  the more fit the population.

Alternatively, the environment in which a population has its highest  $r$  is the optimal environment for that population (Mertz, 1970). Because of human influence on livestock management for production efficiency, the application of  $r$  as a measure of a population's capacity for sustained change in numbers is limited. Herd differences in generation interval ( $T$ ) also followed a pattern similar to  $R_o$  and  $r$  with SY1 having higher means than HE.

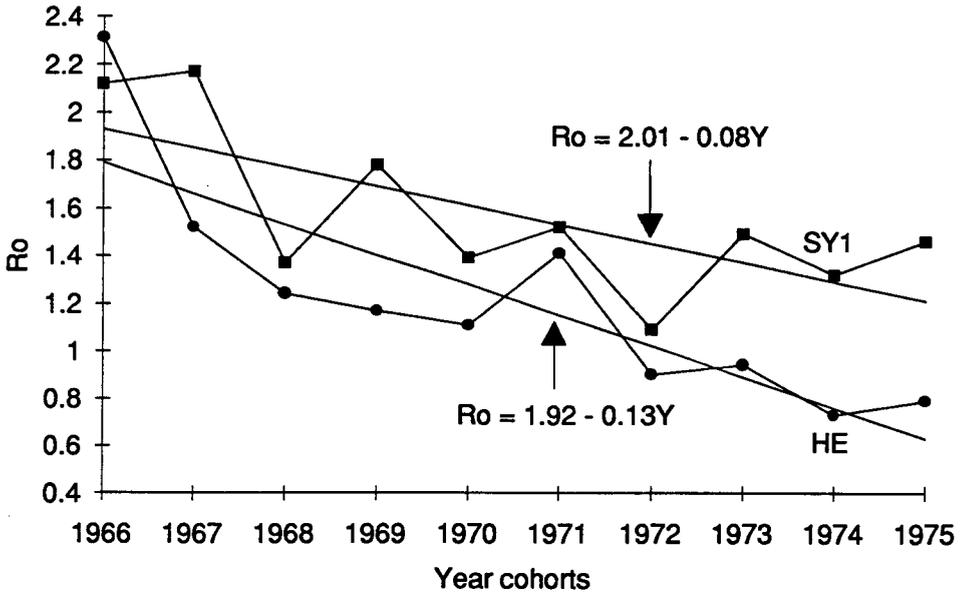
**Table III.** Means, standard errors and ranges of overall life table statistics<sup>a</sup> for the purebred HE and SY1 herds.

Statistic	$R_o$		$r$		$T$	
	HE	SY1	HE	SY1	HE	SY1
Mean $\pm$ SE	1.21 $\pm$ 0.15	1.57 $\pm$ 0.11	0.03 $\pm$ 0.02	0.09 $\pm$ 0.01	4.25 $\pm$ 0.19	5.09 $\pm$ 0.15
Range	0.72-2.31	1.09-2.17	-0.02-0.17	0.02-0.17	3.41-5.19	4.44-6.05
Prob <sup>b</sup>	0.066		0.041		0.003	

<sup>a</sup>  $R_o$  = reproductive rate (expected number of daughters produced by each animal);  $r$  = instantaneous rate of population increase (a measure of herd number increase or decrease);  $T$  = generation interval in years. <sup>b</sup> Level of significance.

Examination of the trend in the overall life table statistics indicated that the means of these statistics had been decreasing with time. For  $R_o$  both herds had a negative regression coefficient although the coefficient for SY1 was smaller than that for HE (fig 4). For HE the predicted  $R_o$  values were less than unity for the 1972 and later cohorts, indicating that those cohorts were not replacing themselves. The pattern for  $r$  was similar to  $R_o$  and hence the results are not presented. For  $T$ , the regressions for SY1 ( $T = 5.73 - 0.11Y$ ) and for HE ( $T = 4.84 - 0.108Y$ ) were significant and both herds had negative regression coefficients.  $Y$  in the equations represents year cohorts, with the 1966 cohorts having a value of 1. The declining trend in the overall life table statistics was probably the result of the stringent culling policy. The contribution of inbreeding to this decline, if any, would be minimal since efforts were made to prevent inbreeding in both herds, through the selection of breeding bulls, as well as through the occasional use of Hereford bulls from outside the HE herd. The breed composition of the multibreed SY1 herd stabilized around 1970 (table I). The trends in the overall life table statistics were also evaluated using only the 1970 to 1975 cohorts for both herds, to reflect the period of stable breed composition of SY1. For these cohorts the regressions for SY1 were not significant ( $R_o = 1.36 - 0.004Y$  and  $T = 5.22 - 0.103Y$ ) while those for HE were significant ( $R_o = 1.34 - 0.103Y$  and  $T = 5.16 - 0.286Y$ ). These results indicate that after the breed composition of the SY1 herd had stabilized in 1970 its  $R_o$  and  $T$  statistics also stabilized, while those for the HE herd continued to decrease. If this declining trend needs to be arrested, strategies which aim at increasing the survival rates of 2 and 3 year old cows should be considered, since survival rates ( $P_x$ ) dropped at ages 2 and 3 years relative to ages 1-2 and 4-5 years. In this study, 2 and 3 year old cows are first and second calvers; 53 and 65% of mortalities in first and second calvers, respectively, were due to reproductive failure (culling for failure

to produce a calf, Arthur *et al*, 1992). The stringency of culling for reproductive failure can be relaxed for these 2 ages, or cows at these ages could be provided with a higher level of husbandry, such as improved nutrition, to increase their reproductive rates.



**Fig 4.** Relationship between time (year cohorts) and net reproductive rate (expected number of daughters produced by each animal,  $R_o$ ) for the 2 Kinsella herds. In the regression equation,  $Y$  has a value of 1 for the 1966 cohorts to 10 for the 1975 cohorts.

There were no significant differences between the herds in the percentages of cows disposed (referred to as mortality in this study) for any of the major reasons for disposal reported by Arthur *et al* (1992), except for calf survival problems (perinatal and preweaning). The value of 17.1% of all cows disposed from the HE herd was due to the fact that they gave birth to stillborn calves or that their calves did not survive to weaning. This compares to 9.1% for the SY1 herd. In the execution of the culling policy no cow or herd was given preferential treatment, hence any cow or heifer which produced a stillborn calf or failed to wean its calf was culled. The HE and SY1 herds were raised at the same location and under similar management and culling policy hence herd differences were likely due to the genetic make-up of the females. The positive effect of heterosis on calf survival has been reported in beef cattle (Cundiff *et al*, 1974; Spelbring *et al*, 1977). It is thus likely that the calf survival in the SY1 herd, being a multibreed composite, was positively influenced by heterosis while the HE herd, being purebred, was not. The difference in the life table statistics for the 2 herds can be attributable, at least in part, to the relative difference in calf survival between the herds.

Population analysis of a commercial herd of Angus cattle in Wyoming was reported by Schons *et al* (1985) using similar biological model and computational formulae. The  $Lx$  curves of herds in this study (Kinsella herds) and that of the Wyoming herd (Schons *et al*, 1985) are presented in figure 2. The most noticeable difference between the  $Lx$  curves of the Kinsella herds and that of the Wyoming herd occurred at ages 1 and 2 years, where the  $Lx$  values for the Kinsella herd were almost double those of the Wyoming herd. This is attributable to differences in replacement heifer policy at the 2 locations. In the Kinsella herds all sound heifers were included in the breeding herd and exposed to bulls as yearlings, hence an  $Lx$  of over 0.9 at 1 year of age. In the Wyoming herd, not all heifers entered the breeding herds. Replacement heifers were selected based on weaning weight, yearling weight, dams record, and in some years on information on their sires. Hence just over 50% of the heifers ( $Lx$  of 0.52) were used as replacements. Another difference between the Kinsella and Wyoming herds is in the slope of the  $Lx$  curves after age 2 years, although the curves were all smooth with no major disruptions. The slopes of the Kinsella herds are sharper than that of the Wyoming herd. This is likely due to differences in the culling policies at the 2 locations. Culling was very stringent in the Kinsella herds; any cow failing to wean a calf each year was culled. Cows were also culled for caesarian sections, bad udders, and leg and feet problems (Arthur *et al*, 1992). In the Wyoming herd cows were culled for some of the reasons as in the Kinsella herds, but culling was not as stringent. The  $Lx$  curve reported by Krehbiel *et al* (1962), using data (1939–1961) from the Virginia Beef Cattle Improvement Association (VBCIA), was similar to that of the Wyoming herd except for its slightly steeper slope.  $Px$  values for the Kinsella herds were higher than that of the Wyoming herd at age 1 year, similar at age 2 years generally lower at subsequent ages, due to the same reasons discussed for differences in  $Lx$  values between the 2 locations.

$Ex$  curves from the Wyoming (Schons *et al*, 1985) and VBCIA (Krehbiel *et al*, 1962) herds peaked at age 1 year, whereas those of the Kinsella herds were highest at age 0 but peaked again at ages 4 and 5 years (fig 3). Although the  $Ex$  values reported by Greer *et al* (1980) for a herd of mostly Hereford cattle in Montana did not include ages 0 and 1 years, the values for ages 2 to 10 years provided did not show any peak beyond the highest value at age 2 years. The difference in the direction of the  $Ex$  curves between ages 0 and 1 years for the Kinsella herds (decreasing) compared with those of the other studies (increasing) is probably due to differences in replacement heifer policy. All heifers were used as replacements in the Kinsella herds *versus* the selection of a proportion of heifers which was used as replacement in the other studies. In the Kinsella herds females were expected to wean a calf each year. Culling for reproductive failure and calf survival problems accounted for 63% of all mortalities (Arthur *et al*, 1992). There was therefore an indirect reproduction related automatic selection with age. This automatic selection could be responsible for the rise in the  $Ex$  curves after first calving (age 2 years) and reaching a peak at ages 4 and 5 years, which is unique to the Kinsella herds.  $Mx$  values for the Kinsella herds (overall average of 0.46 for HE and 0.48 for SY1) were generally higher than those of the Wyoming herd (overall average of 0.42).  $Mx$  is a function of sex ratio, fecundity and foetal mortality. In the Kinsella herds any females which failed to calve in any year was culled, hence there is an indirect automatic selection

for females with high reproductive efficiency. This could account for the higher  $Mx$  value in the Kinsella herds compared to the Wyoming herd, where culling for reproductive failure was not as stringent.  $Vx$  values in the Wyoming herd are higher than those of the Kinsella herds, probably due to differences in culling policy and replacement heifer management as discussed for  $Lx$ . Means of overall  $Ro$  and  $r$  values for the SY1 herd were higher than, whereas those of the HE herd were similar to, those of the Wyoming herd. Generation intervals ( $T$ ) for the Kinsella herds were lower than that of the Wyoming herd. The value of  $T$  for most beef cattle herds is between 4.5 and 6 years (Neumann and Snapp, 1969) hence the Kinsella herds are at the lower end of the range, due to the stringent culling policy.

In addition to the reproduction-related automatic selection with age, the stringent culling policy had the effect of reducing  $T$ . In situations where genetic progress is being made for any trait, this reduction in  $T$  may be beneficial, as a lower  $T$  increases the rate of genetic gain. In these herds, direct selection of bulls for pre- and postweaning gain was occurring, which resulted in positive genetic gain (Sharma *et al*, 1985). The rate of this genetic progress was thus enhanced by the reduction in  $T$  for the females. It is however recommended that in using such a stringent culling policy careful monitoring should be exercised to ensure that cows are able to replace themselves ( $Ro \geq 1$ ) so that herd numbers do not decrease ( $r \geq 0$ ).

## CONCLUSION

The results of this study and those of other studies in beef cattle indicate that life table statistics can differ among herds where management and culling policies differ. However, this study also shows that the same management and culling policy may result in different life table statistics. This is probably due to the influence of heterosis for calf survival in the multibreed composite SY1 herd. The stringent culling policy had the effect of reducing the net reproductive rate, instantaneous rate of population increase and generation interval in both herds over time. However, in the SY1 herd the trend stabilized in 1970 and the ability to maintain herd numbers was retained, while in the HE herd the trend continued to the point where herd size could not be maintained ( $Ro < 1$  for 1972 and later cohorts, fig 4). If the decline in these overall life table statistics needs to be stopped, it is suggested that strategies that aim at reducing mortality rates in 2 and 3 years olds should be considered.

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