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PROBLEM OF ESTIMATION OF MORTALITIES IN CATTLE AND BUFFALOES

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INTRODUCTION

The problem of estimation of death rates in various species of livestock is important since the dead animals find multifarious use avenues. Hides and skins obtained from dead cattle, buffaloes, sheep and goats form one of the major raw materials for leather and leather goods industries. The performance of these industries depends on the number of hides and skins available to these industries which, besides many other factors, is a function of the mortality rates prevalent in each category of livestock and implicitly on the size of the population and the birth rates. Similarly, many other industries are dependent on various other products of dead livestock, *e.g.*, flesh, bones, hairs, horns, etc. Further for planning all the livestock development programmes, a proper insight into the birth and the death rates will be essential. The estimation of the contribution to the national income from the animal husbandry sector can also be very much improved if the mortality rates can be estimated satisfactorily. Besides all this, a proper knowledge of prevailing birth and death rates may provide yet another evidence into the fact that the livestock numbers are staggeringly large and the animals are almost in famished state with the result that their yields are extremely low.[1]

Unfortunately, the procedure of estimation of mortality rates has not been put on any sound footing so far. There has been no survey worth the name of deaths and slaughter of any type of animal. Most of the existing studies depend very much on guesswork and personal observations rather than on any comprehensive and systematic thinking. The present paper first confines itself to a brief survey of the existing methods and their inadequacies and then goes on to discuss the possibilities of devicing a method to estimate these mortalities. The limitations of the assumptions made in the method suggested in the paper have also been discussed at length. Consequently, a judgment on the extent of validity of results can easily be made.

EARLIER ATTEMPTS[2]

The Indian Munition Board had evolved a method for estimating the annual production of raw hides on the basis of the export performance. According to their formula worked on the basis of the data for the early 1920's, twice the quantity of hides exported in raw form was assumed to be the internal production. Im-

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1. This is one view expressed by several writers and since many decades.

2. An excellent review of the earlier attempts has been brought out in the paper by K. Seshagiri Rao and P.N. Chaudhry, "A Study on Supply Position of Raw Hides in India," Central Leather Institute. This section depends heavily on the aforesaid paper.

possibility of using this procedure in further years is self-evident. In 1929, the Imperial Institute of Veterinary Research estimated the annual production of raw hides on the assumption that the life span of cattle would vary between 4 and 6 years depending on whether the year in question is a year of draught and famine or a normal year. The production figure for hides could then be obtained by dividing the cattle population by the average life span. The Hides Cess Enquiry Committee[3] endorsed the above view regarding the average life span for cattle and also the procedure of estimating the production of hides. The main drawback of this method was that it failed to take into account the variations in the average life span of cattle in different States. It might be remarked that no organized and systematic field survey for estimating the average life span directly (or indirectly by measuring the mortalities) existed then. No such investigations have been carried out even later. Moreover, with the improvement of various veterinary services, the life span is likely to increase and therefore the assumption even if valid in 1929 will not be valid for later years.

A major attempt in this direction was made by the Directorate of Marketing and Inspection in the year 1948 when they estimated the production of hides and skins taking into account the variations in the mortality and slaughter rates. Their procedure was a considerable improvement over all the previous methods—at least inasmuch as that it had a very much greater coverage. Nevertheless, it seems that the methodology lacked statistical rigour and was different for different regions. For example, the data pertaining to fallen hides in Western Indian States were collected from those who had the right of annual contracts for the collection of raw hides and such other agencies. In Madhya Pradesh, the data were got from records maintained on cattle mortality. In Mysore there was a cattle mortality report from where the data were taken. Similar approaches were adopted for other States. These different methods used rendered inter-State comparisons of the results rather difficult.

For estimating the production of slaughtered hides, the Directorate of Marketing and Inspection depended on the records maintained at the municipal slaughter houses for urban areas. The regional hide merchants were the source of information in respect of arrivals of slaughtered hides to the markets in rural areas.

These rates provided some basis for estimating the deaths and slaughter of animals of various kinds. Moreover it was for the first time that such a break-down was available for the whole country and regionwise. Nevertheless, not only these estimates cannot be considered valid (except for some opinions that slaughter rates were better than the mortality rates), but also they cannot be used for estimating the availability of hides, etc., for much later years. The slaughter rates are functions of the changing government policies and public sentiments and are likely to change considerably in a relatively short period and as such it becomes meaningless to use them for other years. The mortality rates also will change—though perhaps less violently—with various improvements in veterinary services.

The Directorate of Marketing and Inspection on a special request by the National Income Unit undertook a fresh survey in the year 1958-59 whereby the

3. Hide Cess Enquiry Committee Report, Vol. I, Central Publications Branch, Government of India, 1930.

data have been collected on the numbers slaughtered and on the mortality rates. While the number of slaughtered animals were obtained as before, the annual mortality rates were arrived at by using the average life span of the animals. The exact basis on which these average life spans were calculated is not known except that they were arrived at in consultation with the animal husbandry and veterinary departments of various States. The 1958-59 estimates in all probability would be more reliable than the earlier ones. At least uniform methodology used does make inter-State comparisons more meaningful than before. An important point worth noting here is that the national income estimates of the availability of hides and skins are just equivalent to their estimates of deaths and slaughter of cattle, buffaloes, sheep, etc. Therefore, in that framework the possibilities that the number of deaths are likely to be more than the number of hides and skins used are ruled out. Such leakages in the system must be existing and are very important.

Reference should also be made to yet another set of estimates contained in the Report on the Poona Schedules of the National Sample Survey.[4] This report gives, for cattle and buffaloes, mortalities per thousand in one year age-intervals up to 9 years of age and finally for the age-group 9+. From this table all-India young and adult stock averages roughly seem to work out at 12 and 9 per cent respectively for cattle and 24 and 12 per cent respectively for buffaloes. However, these results not only refer to the year 1950-51 but also are based on a total sample[5] of only 644 villages. Further, no information on Statewise mortalities is contained in this report.

The above mentioned studies are broadly based on surveys. No attempt was ever made to check upon the validity of the results obtained. Moreover in the absence of any fertility studies, even a crude cross-checking of the estimates was rendered rather difficult.

SUGGESTED METHODOLOGY

The methodology suggested herein is basically derived from the internal evidence obtained from the Livestock Census data. In other words, the age distribution of the total population is utilized to indicate as to how the mortalities could be estimated. While the main focus in the paper is on measuring the death rates, procedures for the estimation of birth rates have also been appended in a Note (Appendix I). For making a judgment on the validity of the size of the deaths arrived at in the paper, a cursory discussion on the size of the births is very much desirable—though not inevitable. Birth and death estimates can thus be cross-checked to determine whether they are consistent with each other. If they are not, the reasons for their not being so can be looked into. The computations have been carried out by States and for all-India; and only for cattle and buffaloes. The agewise classification of the total population on which depends the procedure of estimation of deaths for cattle and buffaloes, is different for sheep and goats. Hence the death rates have not been estimated for sheep and goats. Also the

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4. V. M. Dandekar: Second Report on the Poona Schedules of the National Sample Survey, Gokhale Institute of Politics and Economics Publication No. 29, 1954, Chapter 6, Table No. 45, p. 76.

5. Of 644 villages allotted to be surveyed, 609 were actually surveyed and only 585 admitted to final tabulations.

computations are for the 15 States, *i.e.*, all the States leaving out Assam for which the data in the required form are not available. The all-India results are based on data from these 15 States only. Further, 1961 Livestock Census counts for which the reference date was 15th April, 1961 are being utilized for this study. It should be emphasized that this is a study on methodology and 1961 data serve well to illustrate the procedures. Moreover, data from the 1966 Livestock Census have not yet been published in full details and from all the States.

Mortality Rates in Young Stock[6]

The Census reports the population figures in the case of cattle and buffaloes in three age-groups, *viz.*, 0-1, 1-3 and 3 and above. The former two taken together comprise the young stock and the latter the adult stock. The crux of the argument in the present method is that if there were no mortality in the young stock and if the number of births every year were the same, the population in the 1-3 group would be exactly twice the number in the 0-1 group at the all-India level. Further, if there were no movements, this relationship will hold good even for smaller regions. A very detailed examination of the data shows that this does not happen at the district, State, or even at the all-India level. Generally, the population in the 1-3 group is much less than twice in the 0-1 group, very often it is only marginally more than the 0-1 population and in some cases the former is even less than the latter. This happens on account of the prevailing mortalities, movements, and owing to the fact that the flow of births are not uniform. To estimate the mortality rate in the young stock at the State and at the all-India levels, the following three assumptions are made to start with.

(1) There is a uniform flow of births in consecutive years, *i.e.*, the numbers in the 0-1 group in the consecutive years are the same. In other words, if the census were taken in the year 1960 or in 1959 the 0-1 population would have been reported equal to that of 1961. Implicit in this is the assumption that until the date of census counting these births are subjected to uniform mortality rate. This mortality has been termed as infant mortality in further development.

(2) The annual survival rate is the same for the young stock, *i.e.*, over the first three years of life. In other words, the populations in the 1-2 and 2-3 age-groups are the same (constant) proportion of the population in the previous age-group.

(3) It is assumed that there are no inter-regional movements.

These assumptions then mean that if x is the number reported in the 0-1 group, and 'r' is the proportion that survives after a year, xr will be the number in the 1-2 age-group and xr^2 will be the number in the 2-3 age-group. That is, the number reported in the 1-3 age-group should be equal to $xr+xr^2$. The equation $xr+xr^2 = y$ where y is the population in the 1-3 age-group is solved. The solution

6. The original exposition of this approach was given by V. M. Dandekar in his article "An Economic Approach to Cattle Development in India," published in Nalin Mehta: Fiscal Policies and Economic Growth, Sarva Seva Sangh, New Delhi, 1965.

$$r = -\tfrac{1}{2} + \tfrac{1}{2}\sqrt{1 + \frac{4y}{x}}$$

gives the annual proportion of survival; 1—r will then be the annual mortality rate of the young stock. To illustrate the point, let us see Andhra's cattle population. The numbers in the 0-1 and 1-3 age-groups according to the 1961 Census were 14.78 and 15.13 lakhs respectively. The annual survival and mortality ratios worked on the above lines turned out to be .6286 and .3714 respectively. This suggests that the numbers in the 1-2 and 2-3 age-groups would have been 9.29 and 5.84 lakhs respectively. In other words, 37.14 per cent cattle die in Andhra between the ages 0-1 and 1-2 and another 37.14 per cent between the ages 1-2 and 2-3. Taking the average age in the three age-groups, *viz.*, 0-1, 1-2, and 2-3 as 0.5, 1.5 and 2.5 respectively, it means that there are 37.14 per cent deaths between the ages 0.5 to 1.5 and the same again from 1.5 to 2.5.

It should be observed that the number of births in consecutive years may not be even more or less equal. Therefore 'x' the size of the 0-1 population which occurs in the equation determining 'r' will be different for different years. Let x_1 and x_2 denote the actual 0-1 population on the 15th April of 1960 and 1959 respectively and let 'R' be the average annual survival rate in this new situation. Then this R will be determined by equation $x_1 R + x_2 R^2 = y$ where y is the 1-3 population as before. Of course, the equation can be solved only if x_1 and x_2 are known. In principle, these will depend on the number of births during the years 1959-60 and 1958-59 and also on the mortality to which these births are subjected to during the respective years. The problem of estimation of the number of births leads to another set of questions related to the fertility of the breeding cows and allied matters which are not simple to be handled on the basis of the age and sex distribution of the population. Also there does not seem to be any way of easily judging the prevailing mortality to which these births are exposed to during the year. These issues can be circumvented by interpolating for x_1 and x_2 on the assumption of a uniform compound growth rate of 100 g per cent in the 0-1 population between the years 1956 and 1961 for which the data are available. In other words, the 0-1 population is assumed to grow in a geometric progression. Explicitly, this amounts to relaxing the first assumption in favour of another more meaningful assumption. Thus if the first assumption is replaced by this alternative one, a little calculation will show that the new survival rate R equals $r(1 + g)$ where r is the earlier survival rate and g the growth rate of 0-1 population between 1956 and 1961.

For the computations which have been carried out in this paper, the assumption of inter-regional movements not being there is really trivial. This is because at the all-India level the assumption is not operative at all and at the State levels the movements will largely cancel out or at best be very small. The cattle movements are generally to short distances. The State being a fairly large geographical unit the aggregation over the State can safely be assumed to be almost devoid of movements. However, if the movements are there a judgment on the mortality rates obtained for any smaller area other than the whole country—which in our case is a State—can be made provided prior information on the movements to and from the region together with the age-distribution of the moving population is known. The annual survival rate will have a downward bias and the annual mortality rate an upward bias if the 0-1 population moves in and/or the 1-3 population moves out. In the converse situation, the survival rate has an upward bias and the mortality rate a downward bias. These interpretations follow straight from the form of solution for R.

Mortality Rates in Adult Stock

After having outlined the method of building up survival rates in young stock, an attempt is made to build up corresponding estimates for adult stock. It should be observed that a part of the adult stock at any point of time would have been in the age-group 2+a year before. The balance are the survivors out of the previous years stock of adults. That is, the 2-3 age-group population moves to join the group of adults after a lapse of one year. The procedure here is a direct extension of the method of estimation of annual survival rates in young stock and uses once again the same three assumptions, *viz.*, (1) 2-3 population is the same in consecutive years, (2) the annual survival rate is the same in the adult stock, and (3) there are no inter-regional movements. Suppose that r_1 is the annual survival rate in the adult stock. The population in the 2-3 age-group after a year gets into the 3-4 age-group and is r_1 times the former population. The population in the 2-3 group has already been estimated to be xr^2. Therefore, the population in the 3-4 group will be xr^2r_1. Similarly the population in the subsequent one year age-groups will be $xr^2r_1^2$, $xr^2r_1^3$ etc. If all these are added up, the sum will be equivalent to the size of the adult stock. Therefore, $xr^2 (r_1 + r_1^2 + \ldots.) = Z$ where Z is the reported population in the 3+ age-group is the relevant equation to be solved now,

$$i.e., \quad xr^2 \frac{r_1}{1-r_1} = Z$$

$$\text{or} \quad r_1 = \frac{Z}{xr^2 + Z}$$

If the assumption of the uniform flow of population in the 2-3 age-group is relaxed, it will be seen as before that the annual survival rate in the adult stock will change from r_1 to $R_1 = r_1 (1+g)$ where g is the growth rate in the 0-1 population as before. Hence R_1 is the average proportion of survival of animals in ages 2-3 onwards, *i.e.*, from 2.5 years of age. $1-R_1$ is the corresponding mortality rate in the animals aged $2\frac{1}{2}$ years and over. Further, the effect that inter-State movements might have on these rates can be interpreted exactly on lines parallel to the ones before. The mortality rate for young stock and adult stock obtained above are applied to the young and adult population to calculate the number of deaths that should have occurred during 1961-62 in these two populations respectively. Strictly speaking the young stock mortalities are valid for the animals between the ages 0.5 to 2.5 and the adult stock ones for the animals aged 2.5 years and above. In actual calculations of deaths, however, the young stock mortalities are applied to the 0-3 population and adult stock mortalities to the 3+ population. It is hoped that this will not affect the results on the total number of deaths.

Infant Mortality

The total number of deaths during one year after the date of census enumeration will have two components. There will be deaths out of the population reported by the census. This is what has been estimated using young and adult stock mortality rates. Besides, there will also be deaths out of births during the year. This is being termed as infant mortality. In a sense it is the mortality between the ages 0.0 to 0.5. For estimating the infant mortality, *i.e.*, deaths out of the births during the year, the first step is to calculate or estimate the number of births. The appended "Note on Estimation of Births" suggests a method of adjusting the 0-1 population to estimate the number of births. The number of deaths in the infant age is then obtained as the difference between the estimated births and the 0-1 population. The total deaths is the sum of the deaths out of births thus obtained and the deaths out of the existing population earlier obtained.

The total number of deaths during 1961-62 along with its distribution in the three age-groups, *viz.*, infant, young, and adult is presented for cattle in Appendix II and for buffaloes in Appendix III. It is seen that the total number of deaths in cattle works out at 259 lakhs, *i. e.*, 15.4 per cent of the total cattle population. The corresponding figures for buffaloes are 132.6 lakhs and 26.3 per cent. These estimates indicate that mortality rates in both the species are very high. The States with appreciably higher death rates than the average in the case of cattle are Jammu & Kashmir 19.4 per cent, Kerala 24.0 per cent, and Punjab 22.6 per cent. For buffaloes the corresponding rates are Mysore 30.4 per cent and Punjab 31.5 per cent. In the case of buffaloes there are States with appreciable low death rates as well, *viz.*, Himachal Pradesh 17.8 per cent, Kerala 15.7 per cent, Madhya Pradesh 19.6 per cent, Orissa 12.9 per cent and West Bengal 14.0 per cent. The infant mortality in cattle is 16.9 per cent while that in young stock and adult stock is 30.4 per cent and 6.1 per cent respectively. The corresponding figures for buffaloes are 25.5 per cent, 43.0 per cent and 6.1 per cent.

The mortality rates in buffaloes in the total population and also in the individual age-groups are very much higher than those in cattle. While this is in consonance with the general thinking, one surprising feature of the Appendices II and III is that the mortality rates in young stock both for cattle and buffaloes are glaringly high. It is argued in several quarters that the bovine population in the country is too large to be supported by the existing resources and consequently a large number of animals not directly useful are doomed to deliberate neglect and starvation. The high death rates obtained here amply speak of the poor feeding conditions and thus support the above thesis. The abnormally high death rates in the young stock, differential mortality patterns between cattle and buffaloes as also between the States can then be interpreted to be a consequence of the differential usefulness of the two species and of animals in various age-groups.

Validity of the Estimates

So far, the methodology used for estimating the total number of deaths together with a brief analysis of the results has been presented. The total number of deaths and death rates arrived at in the paper using the suggested methodology are much larger than those from any other known source and also than what is generally believed or expected. Besides ascertaining the rationality of the adopted method, it is equally important—and much more so in this case—to check the results by some other approach, *e.g.*, by building up alternative and/or complimentary estimates. The complimentary estimates in our case would be the birth estimates. The estimated births, deaths and growth of population could then be tallied with each other for consistency. One way of obtaining the births would be through breeding cows. This approach as has been pointed out earlier is not easy to be handled. The accompanying Note suggests an alternative approach to estimating the number of births. It has been indicated in that Note that the estimates of deaths obtained here tally well with those of births obtained there, a fact which goes to support the validity of the methodology used and the results obtained both for deaths as well as for births.

One can also go about making heuristic judgments on the validity of the estimates by looking at the populations reported in the Census on variables related to the number of births and hence to the number of deaths. These related variables are (1) cows in milk and (2) dry cows. The data for cattle and buffaloes on these populations have been presented in Appendix IV. At the all-India level, the cows in milk on 15th April, 1961 numbered 193.6 lakhs for cattle and 123.2 lakhs for buffaloes. Thus, so many births must have occurred during the year. Besides, there would have been some cows which were in milk during the year (*i.e.*, they had given births) but has become dry on the day of enumeration. If the lactation period is taken to be 8 months, the number of such cows would work at 96.8 lakhs for cattle and 61.6 lakhs for buffaloes. These figures add up to 290.4 lakhs for cattle and 184.8 lakhs for buffaloes which although very rough indicate the number of births that should have occurred in the two species during 1960-61. However, since the lactation period for buffaloes is known to be substantially higher than that for cattle and if it is taken to be 12 months instead of 8, none of the she-buffaloes having given birth during the previous 12 months would have become dry on the day of enumeration. The number of births in buffaloes would therefore appear to be only 123.2 lakhs and not 184.8 lakhs. These figures are minimum because while obtaining them some factors have been ignored. For instance, the mortality of cows in milk and also of dry cows has not been taken into account. Further, Appendix IV shows that the dry cows numbered 242.6 lakhs for cattle and 93.3 lakhs for buffaloes. Thus the difference between these figures and those for cows which presumably gave birth and had become dry appears to be very large. In other words, the number of breeding cows which remained dry during the whole year in question is rather too large. There are two possible explanations for this. Firstly, the lactation period may be less than 8 months for cattle and 12 months for buffaloes. Secondly, some of the useless cows may have been classified as breeding cows. On these numbers of births if we impose the fact that the bovine population is growing roughly at 2 per cent, the number of net growth in the two species would be 33.7 and 11 lakhs respectively. It will then be implied that the number of deaths was of the order of 256.7 lakhs in cattle and 113.2 lakhs in buffaloes. The closeness of these figures to the ones obtained in the paper (*viz.*, in Appendices II and III) presents a very strong case for considering the suggested methodology as valid. It may be pointed out that no Statewise comparisons are attempted here or anywhere else because of the fear that inter-State movements might have affected the results.

To sum up, this paper briefly reviews the earlier attempts to evaluate the mortality rates in cattle and buffaloes Then it goes on to suggest a method of building up estimates of these rates from the age and sex distribution of the population reported by the Census. A method of constructing birth rates on the same basis is also discussed. Finally arguments to prove the validity of the estimates are given by reconciling the estimated numbers of births and deaths with each other on the one hand and with the number of cows which might have given births on the other. It is hoped that if this approach can be put on sound footing, point estimates of the birth and deaths can be made without indulging in expensive field surveys just from the age and sex distribution of the population reported by the Census every five years.

APPENDIX I

A NOTE ON ESTIMATION OF BIRTHS AND BIRTH RATES

Since the question of estimating birth rates is relevant to so many issues, let us examine if a satisfactory method of obtaining the births and birth rates can be formulated. Conceivably, there can be two approaches to tackling this problem. One of them, also mentioned in the main text, is to go through the number of breeding cows, their lactation periods, etc. An alternative approach could be to adjust the 0-1 population for the mortality to which it was exposed to and arrive at the size of the births. It appears that a greater number of hurdles is to be crossed in having the first approach to the problem. We therefore resort to the alternative approach and explore the possibilities of relating the 0-1 population to the number of births. The number of births and the mortality pattern during the year are such that the survivors of those born during the period in question form the observed 0-1 population on the 15th April, 1961. The ages of the numbers of this population will vary from one day to just a little less than a year. We can assume that the average age of the above population is half a year. Similarly, the number of births on each day of the year is exposed to the risk of dying from one day to just a little less than a year. We can assume again that the births are exposed to mortality on an average for six months. Therefore, if r is the annual survival rate, $r^{1/2}$ is the half-yearly survival rate. This means that out of the number of births during the year (denoted by B henceforth) a proportion $r^{1/2}$ will be counted on the day of enumeration. In other words, $Br^{1/2}=x$ is the equation which will determine B.

Assuming six months as the average age for the numbers in the 0-1 group is not quite satisfactory since it is not in consonance with the assumption of uniform mortality over the period and hence under-estimates the number of births. As an improvement over this we can assume that there is a uniform flow of births and mortality even in smaller periods say every month. Hence if r is the annual survival rate, $r^{1/12}$ is the monthly survival rate. In this scheme, if b denotes the number of births every month, each b will be exposed to mortality for different periods which will be 12 months, 11 months.... 1 month. Those animals which are exposed to mortality for 12 months, the proper multiplier to work out the number surviving after 12 months will be r. Similarly the multiplier for those exposed to mortality for 11 months will be $r^{11/12}$ and so on. But since the births take place throughout the length of the month, the geometric mean will be a better multiplier and the corresponding proportions will be $r^{11\cdot5/12}$, $r^{10\cdot5/12}$, ... $r^{0\cdot5/12}$. The final equation estimating the number of births will be:

$$br^{11\cdot5/12} + br^{10\cdot5/12} + \ldots + br^{0\cdot5/12} = x$$

or $$br^{0\cdot5/12}\,(1+r^{1/12} + r^{2/12} + \ldots + r^{11/12}) = x$$

or $$\frac{B}{12}r^{0\cdot5/12}\;\frac{1-r}{1-r^{1/12}} = x$$

where 12 b = B.

The above logic can be extended and it can be assumed that there is a uniform flow of births everyday (say c) and the daily mortality is $r^{1/365}$. We will then arrive at the following corresponding equations.

$$cr + cr^{364/364} + \ldots + cr^{1/365} = x$$

$$\text{or} \quad \frac{B}{365} r^{1/365} \frac{1-r}{1-r^{1/365}} = x \quad \ldots\ldots\ldots \quad \text{(I)}$$

where $B = 365c$.

Finally, the number of divisions of a year can be made infinitely large and equation (I) can be converted to give a continuous formula in the following way. Equation (I) above will be

$$\frac{B}{n} r^{\frac{1}{n}} \frac{(1-r)}{1-r^{\frac{1}{n}}} = x \quad \text{if the year has n sub-divisions.}$$

$$\text{Hence} \quad B = \frac{nx\,(1-r^{\frac{1}{n}})}{(1-r)\,r^{\frac{1}{n}}} \quad \ldots\ldots\ldots \quad \text{(II)}$$

If the births are taking place continuously, the estimate of B will be given by the limit of the expression on the right hand side of equation (II) as n goes off to infinity. That is B will be equal to

$$\frac{x}{1-r} \lim_{n\to\infty} \frac{n(1-r^{\frac{1}{n}})}{r^{\frac{1}{n}}} = \frac{-x \log r}{1-r} \quad \ldots\ldots\ldots\text{(III)}$$

An alternative and much neater way of arriving at the above result is as follows. If the total births during the year is B, the births in any interval of time between t and $t + \triangle t$ will be $B\triangle t$. These births will be exposed to the risk of dying for a period $1-t$ if $\triangle t$ is sufficiently small. Hence $B\triangle t\, r^{1-t}$ when $\triangle t \to 0$ gives the number surviving at the time of enumeration of the births $B\triangle t$, and the integral of this from 0 to 1 will be the observed 0-1 population x.

$$\text{therefore} \quad \int_0^1 B\, r^{1-t}\, dt = x$$

$$\text{or} \quad B\left[\frac{-(1-r)}{\log r}\right] = x$$

$$\text{or} \quad B = \frac{-x \log r}{1-r}$$

This equation can be used to estimate the number of births that possibly would have taken place during the year 1960-61. However, this equation will work only if the survival rate prevailing in the first year of life is known. In the absence of any knowledge on the survival rate prevailing in the first year of life, the annual survival rate worked out for the young stock has been used as an approximation to arrive at the estimates. These estimates are presented in Appendix IV. In general, the mortality in the first year of life will be more than the average mortality over the first three years, *i.e.*, in young stock and therefore the survival rate in the former period will be less than that in the latter. Thus the survival rate which has been used in estimating the number of births is higher than what should have been used and inasmuch as this is right, the estimates of B are under-estimates. Further the survival rates used for computing the births are those obtained in the first round on the assumption of the uniform flow of births and not the ones obtained when this assumption was relaxed. This has been done purely on grounds of convenience of carrying out the computations. Since the former in most cases is smaller than the latter, an element causing a further downward bias in the birth estimates has been introduced. The foregoing statements are intended to indicate that the birth estimates obtained here are under-estimates.

It is seen from Appendix IV that during the year 1960-61 in 15 States in question there would have been 262 lakh births in cattle and 133 lakh births in buffaloes. For a proper perspective of the magnitudes of these figures, a better indicator would be the birth rates defined as the proportion of the total births during 1960-61 to the initial (total) population. The total population was assumed to grow at a constant rate between 1956 and 1961 and April, 1960 population interpolated. This population was related to the estimated births and the birth rates were obtained for States and for all-India. These are presented in Appendix V for cattle and in Appendix VI for buffaloes. In the case of cattle, the all-India birth rate works at 15.89 per cent which means that for every 100 cattle there are approximately 16 births during a span of one year. The Statewise variations are from a minimum of 12.94 per cent for Madras to a maximum of 25.10 per cent for Kerala. It appears that inter-State variations are not really large. Most of the States have birth rates around 15 to 16 per cent. The three States where the birth rates are definitely high are Jammu & Kashmir 20.63 per cent, Kerala 25.10 per cent and Punjab 21.33 per cent. Madras is the only State with a relatively low birth rate. The all-India birth rate for buffaloes stands at 27.11 per cent. That is on an average the buffalo population reproduces much more than one-fourth of its size during one year. The Statewise variations are from a minimum of 8.68 per cent for Kerala to a maximum of 33.35 per cent for Punjab. Thus not only is the all-India birth rate for buffaloes much higher than that for cattle but also the Statewise variations in the former case are much larger than those in the latter. The States having high birth rates in buffaloes are Mysore 29.44 per cent, Punjab 33.35 per cent, and Uttar Pradesh 30.74 per cent; the ones with the low birth rates are Kerala 8.68 per cent, Himachal Pradesh 14.41 per cent, Orissa 14.03 per cent and West Bengal 14.81 per cent. In general, the high birth rates may be indicative of relatively better feeding conditions and the converse may be true of areas with low birth rates. However, whether such a relationship exists has not been investigated. Also if any such causation is there, it will be more apparent when the births are related to the breeding cows rather than to the total population. It should be borne in mind that the State level computations may be affected by the inter-State movements and hence are to be always interpreted cautiously.

Death Rates through Birth Rates

Although it has been argued that the birth estimates of the earlier section are under-estimates, these are used nevertheless—as an exercise—to build up alternative estimates of the number of deaths in the year 1961-62. In the first step, the growth rates are subtracted from the birth rates to obtain the death rates. The death rates thus obtained are applied to the 1961 population. This gives the number of deaths during 1961-62 under the assumption that the growth rate during this period continues to be the same as that during 1956-61. The number of deaths for 1961-62 is presented in col. 4. of Appendix V for cattle and of Appendix VI for buffaloes. These estimates of the number of deaths during the year 1961-62 (and also of the death rate) are under-estimates to the extent the birth rates are under-estimates. Further, since the average pressure of the cattle and the buffalo population in India is very high, it is probable that the cattle and the buffalo population may not have risen during 1961-66 at as high rates as during 1956-61 specially in regions where the growth rates and the densities per unit of land are particularly high. If this is conceded, the figure of deaths would become even greater under-estimates. In view of the foregoing comments, it can be concluded that the estimates presented in col. 4 should be regarded at the all-India level as the minimum number of deaths which must have occurred during 1961-62.

Appendices V and VI show that there were at least 234 lakh deaths for cattle and 128 lakh deaths in buffaloes. Even these figures are much higher than the ones estimated by the Directorate of Marketing and Inspection and used for national income estimation. For all-India the death rates in these appendices are 13.9 per cent for cattle and 24.5 per cent for buffaloes. The corresponding figures obtained earlier were 15.4 per cent for cattle and 26.3 per cent for buffaloes. The two sets of mortality rates will be much closer to each other if the downward bias in the birth estimates can be eliminated by using the right mortality rates for infant stock. This goes to indicate on the one hand that the methodology used to estimate birth rates is reasonable and on the other hand that the earlier methodology used to estimate death rates also gives reasonable results. Finally a comparison of the number of births with the cows in milk and dry cows given in Appendix IV (done earlier) goes to corroborate once again the validity of the procedure and also of the results.

APPENDIX II

ESTIMATED NUMBER OF DEATHS FOR CATTLE DURING 1961-62

(in lakhs)

State	Cattle							
	Infant stock		Young stock		Adult stock		Total stock	
	Percentage to total births	Number	Percentage	Number	Percentage	Number	Percentage	Number
1. Andhra Pradesh ..	20.08	3.71	37.09	11.09	5.80	5.43	16.39	20.23
2. Bihar	14.75	3.58	27.05	12.59	7.92	9.07	15.67	25.24
3. Gujarat	15.73	1.41	28.83	4.82	6.66	3.25	14.47	9.48
4. Himachal Pradesh ..	9.80	0.17	19.73	0.76	12.04	0.99	15.83	1.92
5. Jammu & Kashmir	17.99	0.68	31.05	2.02	7.31	0.87	19.39	3.57
6. Kerala	22.84	1.55	38.02	3.90	6.70	1.16	24.01	6.61
7. Madhya Pradesh ..	7.78	2.73	13.69	11.43	11.61	19.07	13.41	33.23
8. Madras	21.35	2.93	40.55	8.51	4.25	3.71	13.99	15.15
9. Maharashtra ..	16.18	3.71	29.91	12.54	7.12	7.93	15.78	24.18
10. Mysore	20.41	3.10	38.33	9.32	6.97	5.05	18.06	17.47
11. Orissa	19.31	2.83	29.28	7.11	6.19	4.57	14.79	14.51
12. Punjab	23.25	2.99	42.00	7.92	6.72	2.80	22.63	13.71
13. Rajasthan	13.47	2.85	25.07	10.62	10.68	9.50	17.49	22.97
14. Uttar Pradesh ..	22.33	9.49	37.69	24.20	0.60	1.19	13.27	34.88
15. West Bengal ..	21.81	4.32	37.79	11.49	2.80	2.36	15.83	18.17
16. All-India	16.87	43.82	30.41	141.31	6.07	73.87	15.40	259.00

N. B. : Percentage figures are in relation to the population in the respective age-groups.

APPENDIX III

ESTIMATED NUMBER OF DEATHS IN BUFFALOES DURING 1961-62

(in lakhs)

State	Buffaloes							
	Infant stock		Young stock		Adult stock		Total stock	
	Percentage to total births	Number	Percentage	Number	Percentage	Number	Percentage	Number
1. Andhra Pradesh ..	28.39	5.43	49.16	11.75	4.81	2.19	27.87	19.37
2. Bihar	23.22	2.12	40.13	5.48	9.00	2.10	26.23	9.70
3. Gujarat	22.63	1.70	37.14	4.36	11.33	1.98	27.58	9.70
4. Himachal Pradesh ..	16.37	0.05	30.03	0.17	10.66	0.15	17.77	0.37
5. Jammu & Kashmir	24.60	0.25	40.04	0.58	4.46	0.11	23.41	0.94
6. Kerala	22.00	0.09	43.42	0.28	9.24	0.39	15.72	0.76
7. Madhya Pradesh ..	15.60	1.76	25.20	5.34	11.16	3.86	19.65	10.96
8. Madras	29.39	2.05	51.09	4.30	3.79	0.66	27.06	7.01
9. Maharashtra ..	24.64	1.90	41.94	4.59	6.30	1.25	25.08	7.74
10. Mysore	30.75	2.67	53.06	5.38	5.65	1.14	30.36	9.19
11. Orissa	20.98	0.30	30.47	0.68	4.76	0.40	12.86	1.38
12. Punjab	29.01	4.16	45.11	8.27	5.80	1.50	31.47	13.93
13. Rajasthan	21.71	2.37	33.59	5.92	11.06	2.50	26.83	10.79
14. Uttar Pradesh ..	29.57	9.75	49.05	19.73	4.46	3.10	29.69	32.58
15. West Bengal ..	25.44	0.36	38.15	0.73	3.67	0.30	13.99	1.39
16. All-India	25.49	33.56	42.98	78.63	6.35	20.40	26.30	132.59

N.B. : Percentage figures are in relation to the population in the respective age-groups.

APPENDIX IV

ESTIMATED NUMBER OF BIRTHS AND RELATED POPULATION

(*in lakhs*)

State	Cattle			Buffaloes		
	Estimated births 'B'	Cows in milk	Dry cows	Estimated births 'B'	Cows in milk	Dry cows
1. Andhra Pradesh	18.49	11.18	19.18	19.13	15.11	11.55
2. Bihar	24.29	16.33	22.01	9.13	7.83	7.21
3. Gujarat	8.99	8.04	8.72	7.51	8.98	6.54
4. Himachal Pradesh	1.73	1.54	2.03	0.30	0.61	6.54
5. Jammu & Kashmir	3.76	3.09	2.89	1.01	1.14	0.82
6. Kerala	6.78	4.28	5.03	0.42	0.60	0.49
7. Madhya Pradesh	35.06	26.54	41.97	11.16	10.58	11.33
8. Madras	13.71	11.57	11.41	6.99	6.13	3.86
9. Maharashtra	22.94	16.31	23.52	7.70	8.27	5.73
10. Mysore	15.20	11.25	14.60	8.69	7.69	6.76
11. Orissa	14.67	9.79	12.96	1.41	0.95	1.05
12. Punjab	12.88	9.89	6.18	14.32	12.76	8.36
13. Rajasthan	21.13	16.67	25.52	10.92	9.73	8.29
14. Uttar Pradesh	45.52	27.29	32.71	32.97	31.23	20.37
15. West Bengal	19.83	19.82	13.84	1.40	1.60	0.22
16. All-India	261.99	193.59	242.57	133.05	123.21	93.25

Source :

(1) Estimated births are calculated on the lines suggested in the text.

(2) Other data are reproduced from Livestock Census of India 1961, published by the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India, New Delhi.

APPENDIX V

ESTIMATE OF DEATH RATES THROUGH BIRTH RATES FOR CATTLE

State	Birth rate 'r'	Growth rate 'g'	Death rate m=r—g	Estimated number of deaths (in lakhs) (1961-62)
1. Andhra Pradesh	0.1525	0.0182	0.1343	16.58
2. Bihar	0.1543	0.0226	0.1317	21.21
3. Gujarat	0.1393	0.0159	0.1234	8.09
4. Himachal Pradesh	0.1441	0.0070	0.1371	1.66
5. Jammu & Kashmir	0.2063	0.0092	0.1971	3.61
6. Kerala	0.2510	0.0186	0.2324	6.40
7. Madhya Pradesh	0.1441	0.0181	0.1260	31.22
8. Madras	0.1294	0.0219	0.1075	11.64
9. Maharashtra	0.1520	0.0159	0.1361	.20.86
10. Mysore	0.1595	0.0153	0.1442	13.95
11. Orissa	0.1581	0.0565	0.1112	10.91
12. Punjab	0.2133	0.0037	0.2096	12.70
13. Rajasthan	0.1636	0.0170	0.1466	19.26
14. Uttar Pradesh	0.1661	0.0268	0.1393	36.61
15. West Bengal	0.1739	0.0065	0.1674	19.21
16. All-India	0.1589	0.0196	0.1393	234.27

APPENDIX VI

ESTIMATES OF DEATH RATES THROUGH BIRTH RATES FOR BUFFALOES

State	Birth rate 'r'	Growth rate 'g'	Death rate m=r—g	Estimated number of deaths (in lakhs) (1961-62)
1. Andhra Pradesh	0.2838	0.0309	0.2529	17.57
2. Bihar	0.2507	0.0153	0.2354	8.71
3. Gujarat	0.2628	0.0200	0.2428	7.08
4. Himachal Pradesh	0.1441	0.0024	0.1417	0.30
5. Jammu & Kashmir	0.2542	0.0140	0.2402	0.96
6. Kerala	0.0868	—0.0010	0.0878	0.43
7. Madhya Pradesh	0.2044	0.0217	0.1827	10.19
8. Madras	0.2826	0.0491	0.2335	6.06
9. Maharashtra	0.2562	0.0273	0.2289	7.07
10. Mysore	0.2944	0.0254	0.2690	8.14
11. Orissa	0.1403	0.0672	0.0731	0.79
12. Punjab	0.3335	0.0304	0.3031	13.41
13. Rajasthan	0.2814	0.0356	0.2458	9.88
14. Uttar Pradesh	0.3074	0.0229	0.2845	31.22
15. West Bengal	0.1481	0.0467	0.1014	1.00
16. All-India	0.2711	0.0260	0.2451	128.58