Demographic Parameters of a Domestic Cattle Herd in a Contagious-Bovine-Pleuropneumonia Infected Area of Ethiopian Highlands

M. Lesnoff[1‡*] M. Diedhiou[2] G. Laval[1]
P. Bonnet[1‡] A. Workalemahu[2] D. Kifle[2]

Key words

Cattle – Contagious bovine pleuropneumonia – Demography – Population structure – Ethiopia.

Summary

Demographic parameters of a cattle (Horro breed) herd in a rural highland district of Ethiopia (Boji, West Wellega) are described. Data were collected in the course of a herd-monitoring project on the spread of contagious bovine pleuropneumonia (CBPP). The mean age at first calving and calving rate (for females older than 4 years) in the monitored herds were estimated at 5.8 years and 0.37 year^{-1}, respectively. The annual natural mortalities were 17, 9 and 3% for calves (0 to 9 months old), subadults (> 9 months to 4 years) and adults (> 4 years), respectively. No effect of the herd status (CBPP-free or CBPP-infected) was observed on the mean mortality of weaned animals. A main feature of cattle management in the area was the common practice of animal lending between farmers (more than 35% of the adults in the monitored herds were loaned during the year), mainly for agricultural activities and manure. This practice may have had a major impact on the observed age structure of the cattle population.

■ INTRODUCTION

Ethiopia has the highest livestock population in Africa with 30 million head of cattle and 40 million small ruminants (18). The agricultural sector employs 80 to 85% of the estimated 65 million inhabitants and contributes to more than 40% of the country's gross national product (5). The rural population is primarily composed of smallholders engaged in agriculture and livestock production and lives in the highlands (> 1500 m above sea level) – In 1979, the highlands accounted for 70% of the human and animal population of Ethiopia (16). One of the major constraints on productivity in the agricultural sector (including livestock) in the highlands is the decline in soil fertility and erosion over many centuries due to the high density of farmers and livestock (16). Animal diseases and particularly contagious bovine pleuropneumonia (CBPP) are also severe constraints on livestock productivity (27, 32). Nevertheless, few field data were reported on livestock productivity and disease epidemiology in the Ethiopian highlands, and particularly in the western highlands. In this context, a CBPP herd-monitoring research project was initiated in 2000 in the highlands of Boji District, West Wellega zone, to evaluate the CBPP epidemiological situation, the disease cost to farmers and the efficiency of CBPP control programs. The livestock production system in Boji District was recently described (24). The objective of this paper was to present the main demographic parameters (calving, natural mortality, offtakes and intakes) estimated from herd monitoring in the CBPP project area.

1. Centre de coopération internationale en recherche agronomique pour le développement, Campus international de Baillarguet, 34398 Montpellier Cedex 5, France

2. International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia

‡ Present address: ILRI, PO Box 5689, Addis Ababa, Ethiopia

* Corresponding author

Tel.: +251 (0)1 46 32 15; Fax: +251 (0)1 46 12 52; E-mail: m.lesnoff@cgiar.org

■ MATERIALS AND METHODS

Study area and livestock production system

The first step of the project was to find a recently CBPP-infected area. The western part of Ethiopia was indicated as such by the national veterinary services. A field survey was conducted in West Wellega Province, in cooperation with local veterinary services and peasants' associations. Two districts were identified: Nole Kaba and Boji. Farmers' interviews and farm visits were then carried out to detect clinical cases of CBPP. After this preliminary investigation, Nole Kaba was discarded and Boji was retained (Figure 1).

The major portion of the district lies between 1500 and 2100 m above sea level – Woina Dega zone of the highlands (unpublished report from ILCA, Addis Ababa, Ethiopia, 1978). A smaller portion in the northeast is below the altitude of 1500 m. The rainfall pattern is unimodal with a rainy season from May to October and a dry season during the rest of the year. Annual rainfall for West Wellega region varies between 1300 and 2000 mm depending on the districts and on the years (West Wellega Zonal Agricultural Office, 2002, pers. commun.).

Boji population density was recently estimated at 104 inhabitants/km^2 (5). The dominant agricultural system is a sedentary, highly integrated crop-livestock farming system (24). The farmers belong to the Oromo ethnic group; most of them are smallholders – 83% of the farms in West Wellega zone cover less than two hectares (14). About 50% of them keep cattle (unpublished report from ILRI, Addis Ababa, Ethiopia, 2003), mainly of the Horro breed of the Sanga-Zebu type (1). The animals are of medium size and have a uniformly reddish brown coat.

Cattle herds have a small size (mean = 8 animals; range = [1, 45]; unpublished report from ILRI, Addis Ababa, Ethiopia, 2003). Almost 20% of the herds are composed of one or two animals, which are kept within the farm. In larger herds (80% of the herds), the weaned animals (older than nine months) are kept at night in open temporary paddocks (called *della*) built around the farms. During the day, they graze on pastures or on crop residues during harvest time under the guidance of a herder. Suckling calves are kept away from the main herd and sleep inside the farm at night. They have no contact with mature animals except during milking.

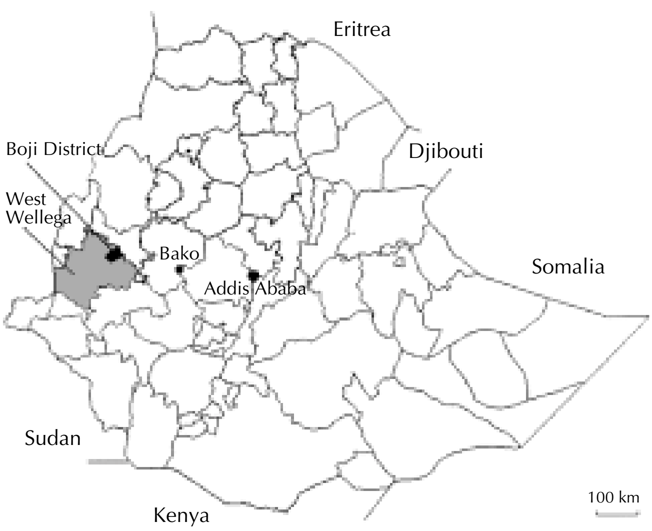

Figure 1: *Location of Boji District in West Wellega Province in Ethiopia.*

Animals are used for agricultural activities (draft, threshing and trampling), manure, milk and meat production. The loaning of animals between farmers is frequent and different types of contracts are encountered: fattening for manure (*dereba*, covering a period of a few months); ploughing for adult males (*goubo*, covering a few days to a few weeks); and herding (covering several years) (24).

The farmers divide the year into four cultural seasons: *bona* (December to February), *arfassa* (March to May), *gana* (June to August) and *birra* (September to November). Animals are used for agricultural activities throughout the year although the most intensive periods of usage are the *arfassa* and *gana* seasons (ploughing for maize, sorghum and teff) and the *bona* season (threshing of teff and ploughing for maize in the lower damp gullies) (24).

Herd selection

Information meetings were organized in Boji District with veterinary services and peasant associations to explain the goal of the survey. In particular, farmers were provided with veterinary information on CBPP and they were made aware that the study was targeted on within-herd CBPP spread. Incentive measures were proposed to farmers to participate in the survey: at the end of the herd monitoring period, any sick animal would be treated and vaccination against CBPP would be organized for monitored herds. No restriction was applied to farmers' management practices (cattle utilization and importation, disease prevention measures, cattle medical treatment, etc.). All the herds of the farmers who volunteered to be involved in the study were visited. Herds were finally selected according to two primary criteria: (i) they comprised at least five owned animals (excluding borrowed cattle) at the beginning of the monitoring period to ensure survey continuity at the herd level; (ii) those newly contaminated were searched using farmers' interviews (report of recent cattle death caused by respiratory disease) and slide agglutination tests on any cattle presenting respiratory symptoms (33). In addition, other herds (presumably CBPP-free) were selected. The overall herd-sample size was determined by the available financial, human and material means. All monitored herds were selected in a 20-km-diameter circle around Bila, Boji District main town.

Herd monitoring

Each selected herd was monitored for a period of 12 to 18 months, between June 2000 and December 2001. Herd monitoring was set up according to the Panurge method (9, 10). Each animal was ear-tagged for permanent identification. Three teams of two enumerators visited the herds every two weeks to record demographic events (birth, mortality, offtake and intake), clinical signs of sick animals, and type and cost of veterinary care. The birth date and parity of animals born outside of the herd or the monitoring period (animals in the herd at the start of the monitoring period and animals that entered the herd through purchase or loan) were estimated with farmers' interviews. In case of death, a postmortem diagnosis was established by the veterinary supervisors according to the clinical signs reported by farmers and enumerators, and, whenever possible, a necropsy examination was carried out. For this latter case, lungs and chest cavity were examined to reveal whether or not CBPP caused the death. Blood samples were collected every three months from all animals to determine their serological CBPP status. Any animal showing respiratory symptoms and any animal entering a herd (loan, purchase) was also sampled. All available information was entered and validated in relational database management systems with graphical user interfaces specifically designed for herd monitoring and serological data management (3, 19).

Data

Seventy-one herds were monitored (1700 head of cattle). Data were limited to the annual period between December 2000 and November 2001 (all herds were monitored for 12 months during this period, which ensured data homogeneity). The mean herd size (including calves kept at home) was 15.3 head of cattle and ranged from 4 to 31. The interquartile range was [10, 20].

According to serological results obtained by a competitive ELISA test (26), clinical symptoms, and necropsies, 15 out of the 71 herds were classified as infected with CBPP (unpublished results). The results reported here were recorded on the whole sample (71 herds), irrespective of their CBPP status.

Demographic parameters estimation

Demographic parameters for calving, natural mortality, offtakes and intakes were defined as hazard rates. Offtakes were divided between slaughterings, sales and loans of animals between farmers. Intakes were divided between purchases and loans. For loans, two exit and two entry reasons were considered:

- the loan of the animal to another farmer (coded DEC);
- the return of an animal to the herd of origin (coded FIC);
- the arrival of an animal on loan (coded ARC);
- the return of an animal that was previously on loan (coded REC).

These four reasons (DEC, FIC, ARC and REC) were considered separately.

For a homogeneous set of individuals, the rate μ (assumed constant within an age class) of a specific event (e.g. natural death) was estimated by the ratio y / T, where y was the number of observed cases of this event (e.g. the number of natural deaths) and T the total time at risk (25). A log-linear model was used to estimate the rates for the different demographic events according to a set of explanatory variables (17, 21):

$$\log(m_i / T_i) = x_i' \beta$$

where x_i is a vector describing the explanatory-variable pattern i (i.e. a unique combination of the modalities of the different explanatory variables), β the vector of the corresponding parameters, and m_i and T_i, the expected number of cases and the total time at risk (animal-year) for the explanatory-variable pattern i. The equation may be written as:

$$\log(m_i) = x_i' \beta + \log(T_i)$$

Considering $\log(T_i)$ as an “offset” (i.e. as a fixed and known parameter) and assuming that m_i was generated from a Poisson law, this model was adjusted with standard algorithms for log-linear models. Rates were estimated by: $\hat{\mu}_i = \hat{m}_i / T_i$

In the study, the explanatory variables were:

- the season (*bona*: December to February; *arfassa*: March to May; *gana*: June to August; or *birra*: September to November);
- the sex of the animals (female or male);
- the age class of the animals. Exact ages were used (e.g. two years old represented 730 days): suckling calves (age ≤ 9 months), subadults (9 months < age ≤ 4 years), adults (cows, bulls and oxen; age > 4 years);
- the CBPP herd status (infected or non-infected) for the natural mortality rate of weaned animals – the CBPP effect was not considered for suckling calves, which have low susceptibility and do not develop the severe pulmonary form (31).

For each type of demographic event, the best model was selected based on Akaike’s information criterion (AIC: “smaller is better”). AIC allows the selection of parsimonious models achieving a compromise between the variance and the bias of the parameter estimators (2). A set of models was defined for each rate, composed of a “complete” model (including all the explanatory variables and their first-order interactions) and of all the simpler, nested submodels. In each set, the model with the minimum AIC was retained. For the selected models, the significance of the variables was checked with likelihood ratio tests (LRT). Finally, their global adequacy was checked with a Chi-square test of goodness of fit (28).

Sensitivity of calving rates

During the monitoring period, many cows (loaned to non-monitored farmers) returned to their originating herd just after calving. This practice might lower the estimated value of the calving rate because calvings not observed within the monitored herds were not taken into account. Three adjusted values were calculated to assess the sensitivity of the calving rate: the number of calves along with their mothers in the monitored herds due to loaning reasons and aged between 0 and 30 days, 0 and 60 days and 0 and 180 days (7, 9 and 17% of the observed calvings, respectively) were added to the number of observed calvings.

■ RESULTS

Herd structure

Calves, subadults, cows and bulls-oxen represented 13, 26, 40 and 21% of the cattle under study, respectively. The total percentage of females was 61%. The age structure dropped after one year and remained at the same level until five years (Figure 2). Higher age-class sizes were then encountered until eight years for females, and sizes regularly dropped afterwards. Animals older than 12 years represented less than 2% of the studied sample. Seasonal variations were low in the sex and age structures (the between-season differences were less than 1%).

Reproduction

The farmers reported neither abortion nor stillbirths during monitoring. There were no multiple births either. Thirty-four

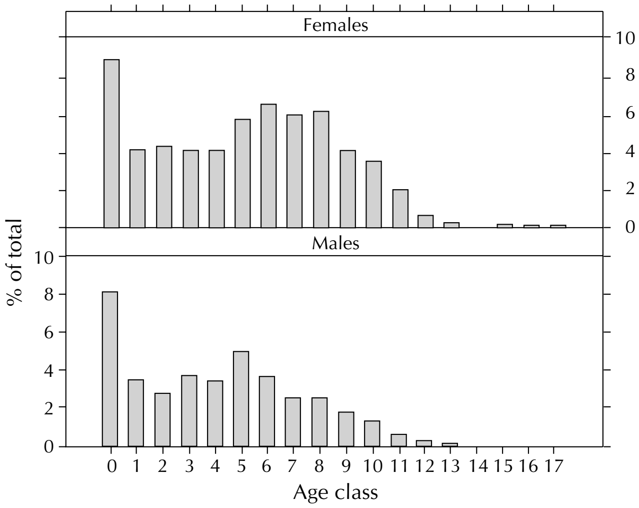

Figure 2: *Age-by-sex cattle structures in the monitored herds; The x-axis represents the annual age classes: 0 represents the class “age ≤ 1 year”, 1 represents the class “1 < age ≤ 2 years”, etc.*

observed calvings were declared as being the first ones. The estimated density of probability function of age at first calving (Figure 3) showed a peak between 5 and 6 years (47% of calvings) thus showing a strong synchronization of heifers in age of first calving. Only two of these calvings were observed before 4 years of age and three were observed after the age of 7 years (the maximum observed value was 9.7 years). The estimated mean age at first calving was 5.8 years (S.E. = 0.2; median = 5.6 years).

The season was retained in the AIC-best statistical model for calving rates (Table I). Calving distribution was unimodal throughout the year (Figure 4). The highest rates were observed between September and January (*birra* and *bona* seasons). The global calving rate (average over the year) was 0.37 $years^{-1}$ (S.E. = 0.03). The adjusted calving rates remained relatively poor: 0.40, 0.41 et 0.44 $years^{-1}$, respectively.

Natural mortality

The CBPP status at the herd level was not retained in the AIC-best statistical model including weaned animals (LRT of the status effect was not significant, P = 0.63). The AIC-best model including all age groups was additive between age and season (Table II).

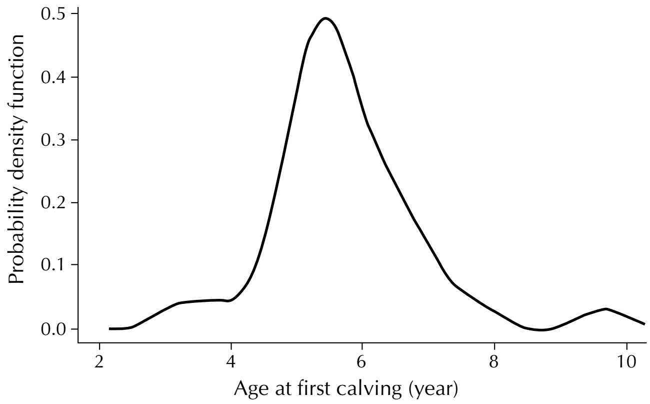

Figure 3: *Kernel estimate of the probability density function (pdf) of the age at first calving in the monitored herds; pdf was estimated with a smoother kernel (Venables and Ripley, 1999, Springer). The kernel bandwidth smoothing parameter was set to 0.4.*

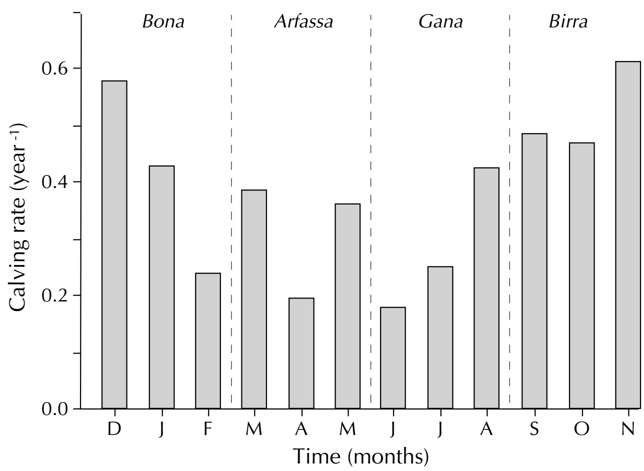

Figure 4: *Monthly variations of the calving rate ($year^{-1}$) for females older than four years in the monitored herds.*

Table I

Best statistical models selected by AIC[a] for calving, mortality, sale, purchase and loan rates in the monitored herds

Models	**Deviance**	χ^2	**df**	**P[b]**
Calving: season	0	0	0	-
Mortality: season + age	24.9	20.1	18	0.33
Offtake				
Slaughtering: no effect (grand mean model)	8.1	6.7	7	0.96
Sale: season + sex + age + sex*age + season*sex	6.2	5.4	12	0.45
Loan				
DEC: season + sex + age + season*age + season*sex	11.1	10.3	8	0.25
FIC: sex + age + sex*age	25.9	25.6	18	0.11
Intake				
Purchase: sex + age	17.9	24.1	20	0.24
Loan				
ARC: season + age + season*age	9.2	8.6	12	0.71
REC: sex + age + sex*age	24.9	24.9	18	0.13

[a] Akaike's information criterion
[b] P-values for the global χ^2 test of model goodness of fit
DEC: loan of the animal to another farmer; FIC: return of an animal to the herd of origin; ARC: arrival of an animal on loan; REC: return of an animal that was previously on loan

The estimated natural mortality rates by age group (average over the year) were 0.21 (S.E. = 0.04), 0.13 (S.E. = 0.02) and 0.04 $year^{-1}$ (S.E. = 0.01) for the calves, subadults and adults, respectively (Table III). The highest rates were observed during the *bona* and *arfassa* seasons (mid and end of the dry season). They were 1.8 and 2.6 higher than in the *birra* season, which showed the lowest rates.

Offtakes and intakes of animals in the herds

Slaughtering

Few slaughterings occurred during the survey period: only nine animals (seven females and two males, all older than four years). The AIC-best model did not include the season nor the sex. The estimated slaughtering rate for adults was 0.01 $year^{-1}$ (S.E. < 0.01).

Sales and purchases

The AIC-best model for purchases only included the sex and age. The model for sales was more complex (Table I). Sales and purchases of calves were rare (one calf for each category during the year). Globally, there were more sales than purchases; the ratios of sale rates to purchase rates varied from 1.4 to 1.8 for subadults and adults, respectively (Tables II and III). The highest sale rates were observed for bulls and oxen (0.16 $year^{-1}$, S.E. = 0.03) (Table III). The sales of males showed more seasonal variations than those of females, with a peak during the *arfassa* season. No seasonal effect was observed in purchases.

Loans between farmers

In general, the AIC-best models related to loans showed interactions between season, sex and age (Table I). Only the main patterns are presented here.

On average, the sampled farmers gave more animals for loaning than they acquired through loaning. For example, the rates associated with male exit due to loans (DEC) were higher than those associated with entry due to loans (ARC): the ratio of DEC rates to ARC rates were 1.3, 2.8 and 1.2 for calves, subadults and

Table II

Estimated rates ($year^{-1}$) of mortality and offtakes by sex and age group in the monitored herds

	Sex	Age groups (months)		
		Age ≤ 9	9 < age ≤ 48	48 < age
Mortality	T	0.21 (0.04)[a]	0.13 (0.02)	0.04 (0.01)
Slaughtering	T	–	–	0.01 (< 0.01)
Sales	F	0.01 (< 0.01)	0.08 (0.02)	0.06 (0.01)
	M	0.00 (0.00)	0.07 (0.02)	0.16 (0.03)
	T	< 0.01 (< 0.01)	0.07 (0.02)	0.09 (0.01)
Loans (DEC + FIC)	F	0.21 (0.05)	0.46 (0.05)	0.42 (0.03)
	M	0.14 (0.05)	0.62 (0.07)	0.57 (0.05)
	T	0.17 (0.04)	0.53 (0.04)	0.48 (0.03)

[a] Standard error

T = total; F = females; M = males

DEC: loan of the animal to another farmer; FIC: return of an animal to the herd of origin

Table III

Estimated rates ($year^{-1}$) of intakes by sex and age group in the monitored herds

	Sex	Age groups (months)		
		Age ≤ 9	9 < age ≤ 48	48 < age
Purchases	F	0.01 (< 0.01)[a]	0.03 (0.01)	0.02 (0.01)
	M	0.00 (0.00)	0.07 (0.02)	0.08 (0.02)
	T	< 0.01 (< 0.01)	0.05 (0.01)	0.05 (0.01)
Loans (ARC + REC)	F	0.21 (0.05)	0.34 (0.05)	0.32 (0.03)
	M	0.20 (0.05)	0.37 (0.05)	0.51 (0.05)
	T	0.20 (0.04)	0.35 (0.04)	0.39 (0.02)

[a] Standard error

T = total; F = females; M = males

ARC: arrival of an animal on loan; REC: return of an animal that was previously on loan adults, respectively. The same trend was also observed to a lesser extent for females (with a ratio of 1.7 for weaned females).

The highest rates associated with exit due to loans (DEC) were observed for subadults, while the highest rates associated with entry due to return from loans (REC) were observed for adults (Figure 5).

As for sales, the rates of exit (DEC plus FIC) and entry (ARC plus REC) for males were higher than those for females (except for calves). For subadults and adults, the male-female ratios for exit rates were 1.3 and 1.4, respectively (Table II), and for entry rates 1.1 and 1.6, respectively (Table III).

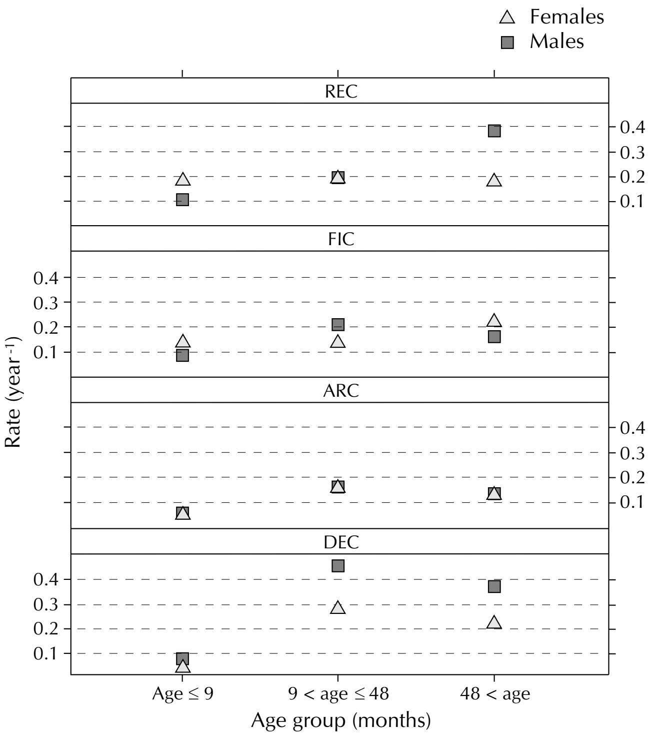

Figure 5: *Rates (year^{-1}) of exit due to loans (DEC), exit due to end of loans (FIC), entry due to loans (ARC) and entry due to return from loans (REC) by sex and age group in the monitored herds.*

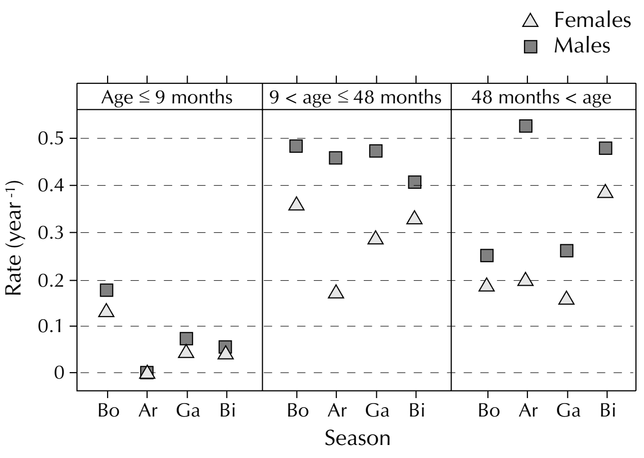

Figure 6: *Rates (year^{-1}) of exit due to loans (DEC) by sex, age group and season in the monitored herds. B =* bona *(December to February); Ar =* arfassa *(March to May); Ga =* gana *(June to August); Bi =* birra *(September to November).*

The highest seasonal variability in exit rates due to loans (DEC) was observed for adults (Figure 6). For cows, the highest rate was observed during the *birra* season. For bulls and oxen, they were observed during the *arfassa* and *birra* seasons.

Comparison of causes of exit of animals from herds

For all age groups, the loan of animals represented the most frequent cause of exit from the herd. For example, almost 36% of the animals older than nine months left the herds during the year for loan (the percentages were calculated from rates given in table II).

Among the calves and subadults, natural mortality was the second cause of exit from the herd (17 and 9% of the animals in the year, respectively), followed by sale. The reverse was observed for adults: 7% of adults were sold in the year against 3% due to mortality. Slaughtering was negligible (only 1% of the adults were slaughtered during the year).

■ DISCUSSION

Herd sampling design

A purposive sampling frame was used to select the herds included in the survey. They were selected according to their size, CBPP status and farmers' willingness to cooperate. The mean herd size monitored was twice higher than the average herd size in Boji District. CBPP herd prevalence (proportion of infected herds) in the monitored herds was about 20% (unpublished results) and probably higher than that in the district (although the district herd prevalence was unknown at the time the manuscript was written). The potential effects of the sampling design on the estimated age-by-sex structures and loans, natural mortality and reproduction rates are discussed thereafter.

Animal loans between farmers

The loaning of animals between farmers was the primary cause for exit and entry of animals within herds and is an important aspect of the agricultural system in the area (24). This was different from the results reported by Mukasa-Mugerwa (30) for the cattle livestock in the central zone of the highlands (Ada District), where natural mortality was reported as the primary cause of exit.

Seasonal variations of loan rates showed complex and various patterns between sex and age groups. These complex patterns were the result of the diversity of loan types in the area and farmers' behavior. Regarding males, the seasonal peak of loans was associated with the *goubo* contracts. Regarding sales, it was observed during the *arfassa* (March to May) and *birra* (September to November) seasons, just before the two intensive ploughing periods (April to July for maize, sorghum and teff, and December to January for maize in the lower damp gullies) (24). Regarding subadult females and males, most of exit for loans (*derebas*) were observed out of the *gana* season (rainy season), when pastures are less abundant.

In principle, if the herd sampling design was random and loans were only practiced between farmers of the study area, then exit due to loans (DEC) and entry due to loans (ARC) in the sample should have been roughly equal throughout the year. The same should have been observed for exit due to end of loans (FIC) and entry due to return from loans (REC). Globally, results presented in Tables II and III did not follow this pattern. Loan exit rates of animals were higher than loan entry rates: the monitored farmers were more loaners than receivers of animals. We believe that a significant part of loaned animals were sent to farms without or with few owned animals (for manure and ploughing or others contracts). This type of farms was not included in the sample in accordance with the epidemiological goal of the study. Another group of animals could have been sent out of the study area, especially in the lowland areas, north of Boji District, and have had more abundant pastures (24). At last, because a recently CBPP-infected area was purposively selected, such a pattern might also be related to a disease-escape strategy adopted by the farmers.

Age-by-sex cattle population structure

The percentage of female cattle in the sample (61%) was lower than in farming systems where agricultural activities are lesser or null (about 65%) (7). However, it was greater than those found in intensive livestock production systems using animal draft. De Leeuw and Wilson (8) reported a value of 53% in an agropastoral system in Mali. In some districts of the highlands which use cattle for agricultural activities, the percentage of females may be as low as 37% (30). Although the study area is characterized by a strong integration of crop and animal production, this intermediary percentage (in addition to the relatively high herd sizes compared to other smallholder systems in Ethiopia) expresses a strong tradition of Oromo farmers' livestock composition in Boji District.

The percentage of reproductive females (40% of females older than four years or 44% of females older than three years) matched the range reported by de Leeuw and Wilson (8) in pastoral and agropastoral African livestock production systems (40 to 45%).

A noticeable feature was the drop of the age structure of females and males aged between 1 and 5 years. It was stable throughout the year and could not be associated to a seasonal phenomenon. This type of drop is generally described as a non-equilibrated age structure, due for example to high mortalities having affected the first age groups or to a high drop of fecundity during the years preceding the monitoring study (23). It might also be due to biases in age estimation leading to the size of some age groups being overestimated or underestimated. However, the highest rate of exit due to loan (DEC) was observed between 1 and 2 years of age and the highest rate of entry due to loan (REC) was observed for cattle older than 4 years. The drop observed in the age structure might then be associated to loans to other farms of animals not yet productive (long-term herding contract) (24) and which returned to their herd of origin three or four years later. Thus, the observed pattern might correspond to an uncommon equilibrated age structure.

Reproduction

The estimated mean age at first calving for cattle in Boji District (5.8 years) was coherent with some values reported for similar Ethiopian farming systems. For example, in the neighboring highlands of Boji District, Dadi *et al.* (6) reported a mean age at first calving greater than five years. This was also coherent with values reported for zebu breeds of large size (7). Nevertheless, it was higher than the 4.4 years reported by Mukasa-Mugerwa *et al.* (30) for the Highland Shorthorn zebu cattle in the central part of the highlands. It was also higher than the values reported for the Horro breed on a research station in the same area: 2.8 years according to Galal *et al.* (13) and 4.6 years according to Kebede *et al.* (20) – the latter explained the wide difference with the former because of a change in management in the research station. The reliability of the estimation of the mean age at first calving depends on the correct identification of the calving rank of the monitored females and on the accurate estimation of their birth date. The authors' view is that errors on the identification of first calving were small in this study. Errors on birth dates were probably more frequent, especially for females older than five years. Nevertheless, the authors believe that these errors did not exceed six months on average during the monitoring.

In African semiarid zones, when reproduction is not controlled, the fecundation peak is primarily related to the feeding conditions of reproductive females (35). In Boji, the highest calving rates (November and December) corresponded to fecundations in February and March. This period was the end of the dry season and the most unfavorable period during the year (few pastures and crop residues) (24). Farmers explained this peak by the agricultural uses of bulls and their poor availability before February: from November to January, bulls are intensively used for ploughing activities and trampling (24). This effect was already noticed by Dadi *et al.* (6) in Bako region. A better management of reproduction, particularly of bulls' availability, may significantly enhance herd productivity in the studied system.

Neither abortion nor stillbirths were observed throughout the monitoring period. Abortions did not seem to be a major problem in Boji District, like in other areas of the highlands (unpublished report from ILCA, Addis Ababa, Ethiopia, 1981). However, abortions were difficult to detect and might have been underestimated. In a research station, Gebre-Yohannes and Kebede (14) reported 3% abortion for the Horro breed.

The calving rate (0.37 $year^{-1}$) estimated for cows in Boji District was low compared to other values observed in some African agropastoral systems, e.g. 0.48 $year^{-1}$ in Nigeria and 0.59 $year^{-1}$ in Mali (8). For the Horro breed, Galal *et al.* (13) estimated a calving rate of 0.42 $year^{-1}$ in the research station of Bako. For the Highland Shorthorn zebu in the central part of the highlands, Mukasa-Mugerwa *et al.* (30) reported a calving rate of 0.46 $year^{-1}$. Finally, for the highland zebus from central Ethiopia (breed not indicated), Gryseels and Anderson (16) reported a calving rate of 0.50 $year^{-1}$. The lower value observed in Boji District did not seem to be related to the estimation method because none of the calving rates adjusted to a possible loan effect reached the value of 0.50 $year^{-1}$.

In the literature, calving rate estimations are often reported globally for the group of "reproductive" or "mature" cows. Different definitions were given for this category, according to the livestock production system and the authors. For example, de Leeuw and Wilson (8) considered as mature the cows older than three years. Other authors did not define them (30). In this study, reproductive cows were defined as those older than four years because only two calvings were observed before this age. The choice of this threshold age is important because it may result in major differences in calving rates (and also in the percentage of reproductive females in the herds). In the present study, the estimated calving rate ranged from 0.34 $year^{-1}$ for cows older than 3 years to 0.37 and 0.40 $year^{-1}$ for cows older than 4 and 5 years, respectively. One alternative to global calving rate estimation would be to report results based on annual age groups (12).

Natural mortality

The CBPP herd status had no significant effect on the global mortality of weaned animals in the herds. This result was related to the relatively low incidence, morbidity and fatality-case rates observed in CBPP-infected herds (unpublished results). In these herds, 36% of weaned animals were infected at the end of the year and 39% of them showed clinical signs. According to a case-fatality rate of 13%, annual CBPP mortality in the herds should be approximately 1.8%, which was not detected in the analysis (lack of statistical power due to an insufficient sample size).

Revue Élev. Méd. vét. Pays trop., 2002, 55 (2) : 139-147

No sex effect was observed, as also reported by Kebede *et al.* (20) for Horro calves on a research station. The highest mortality rates were observed during the *arfassa* season (end of the dry season and period of welding). This might be related to a nutritional deficiency of animals, as in other livestock production systems (8).

Annual mortality of calves and adults (17 and 3%, respectively) was of the same magnitude as those reported in agropastoral systems in Nigeria and Mali by de Leeuw and Wilson (8) (15-17% for calves and 4-5% for cows). In smallholder dairy farms in Kenya, Gitau *et al.* (15) found a higher value for calf mortality (22%). The only reference found on natural mortality in on-farm studies in Ethiopian highlands was that of Mukasa-Mugerwa *et al.* (30). They reported annual mortalities of 7% for calves, 4% for growing heifers, 5% for growing bulls, 4% for cows and 2% for oxen. These values were lower than those observed in the monitored herds for calves and subadults (17 and 9%, respectively). The higher rates observed in Boji District might be due to the existence of large forests and the frequent attack of cattle by wild animals (hyena, panthers), which represented 41% of the mortality during the monitoring period.

Between-herd variability

The between-farm variability was not tackled. For this purpose, many factors might have been taken into account such as herd management practices, herd size, household features, socioeconomic activities of the farmer, distance from the farms to the market or to the grazing pastures and the epidemiological status of the herds. Different statistical methods are available to analyze between-farm variability, and for livestock applications in particular (11, 22, 29): multivariate analysis methods (e.g. principal component analysis or correspondence analysis) to cluster the farmers or regression mixed models to test factors of interest including herd effects. The between-farm variability in Boji District will be studied in a subsequent paper.

Acknowledgments

We thank the Ministry of Agriculture (MoA) of Ethiopia and the West Wellega Zonal Agricultural Office for their friendly cooperation on this herd-monitoring project. We are grateful to the field enumerators and the farmers of Boji District for their help in data collection. We thank the two anonymous referees whose comments allowed us to improve a first version of this paper.

REFERENCES

1. ALBERRO M., HAILE-MARIAM S., 1982. The indigenous cattle of Ethiopia. Part I. *FAO World Anim. Rev.*, **41**: 2-10.

2. BURNHAM K.P., ANDERSON D.R., 1998. Model selection and inference. A practical information-theoretic approach. New York, NY, USA, Springer.

3. CHAVERNAC D., JUANES X., THIAUCOURT F., 2002. CORA : Logiciel d'aide à la gestion des résultats d'analyses. Montpellier, France, Cirad-emvt.

4. CSA, 2000. Report on land utilisation. Agricultural sample survey 1999/2000, Volume IV. Stat. Bull. 227. Addis Ababa, Ethiopia, Central Statistical Authority.

5. CSA, 2001. Ethiopia statistical abstract 2000. Addis Ababa, Ethiopia, Central Statistical Authority.

6. DADI L., GEDENO G., KUMSA T., DEGU G., 1987. Bako mixed farming zone diagnostic survey report. Addis Ababa, Ethiopia, Department of Agricultural Economics and Farming Systems Research.

7. DE LEEUW P.N., MCDERMOTT J.J., LEBBIE S.H.B., 1995. Monitoring of livestock health and production in sub-Saharan Africa. *Prev. vet. Med.*, **25**: 195-212.

8. DE LEEUW P.N., WILSON R.T., 1987. Comparative productivity of indigenous cattle under traditional management in Subsaharan Africa. *Q. J. int. Agric.*, **26**: 377-390.

9. FAUGERE O., FAUGERE B., 1986. Suivi de troupeaux et contrôle des performances individuelles des petits ruminants en milieu traditionnel africain. Aspects méthodologiques. *Revue Elev. Méd. vét. Pays trop.*, **39** : 29-40.

10. FAUGERE O., MERLIN P., FAUGERE B., 1991. Méthodologie d'évaluation de la santé et de la productivité des petits ruminants en Afrique : l'exemple du Sénégal. *Revue sci. tech. Off. int. Epizoot.*, **10** : 103-130.

11. FAYE B., LESCOURRET F., DORR N., TILLARD E., MCDERMOTT B., MCDERMOTT J., 1997. Interrelationships between herd management practices and udder health status using canonical correspondence analysis. *Prev. vet. Med.*, **32**: 171-192.

12. FRENCH N.P., TYRER J., HIRST W.M., 2001. Smallholder dairy farming in the Chikwaka communal land, Zimbabwe: birth, death and demographic trends. *Prev. vet. Med.*, **48**: 101-112.

13. GALAL E.S.E., KEBEDE B., TEGEGN A., 1981. A study on the reproduction of local zebu and F1 crossbred (european x zebu) cows. II. Age at first calving and calf production. *Ethiop. J. agric. Sci.*, **3**: 81-95.

14. GEBRE-YOHANNES G.-E., KEBEDE M., 1996. Fertility of Horro and crossbred cows at Bako research center. In: Proc. 4th Conference ESAP, Addis Ababa, Ethiopia, p. 120-126.

15. GITAU G.K., MCDERMOTT J.J., WALTNER-TOEWS D., LISSEMORE K.D., OSUMO J.M., MURIUKI D., 1995. Factors influencing calf morbidity and mortality in smallholder dairy farms in Kiambu District of Kenya. *Prev. vet. Med.*, **21**: 167-177.

16. GRYSEELS G., ANDERSON F.M., 1983. Research on farm and livestock productivity in the central Ethiopian highlands: initial results, 1977-1980. ILCA Research Report 4. Addis Abeba, Ethiopia, International Livestock Center for Africa.

17. HOLFORD T.R., 1980. The analysis of rates and of survivorship using log-linear models. *Biometrics*, **36**: 299-305.

18. ILRI, 2000. Handbook of livestock statistics for developing countries. Socio-economics and policy research working paper 26. Nairobi, Kenya, International Livestock Research Institute.

19. JUANES X., LANCELOT R., 1999. LASER : Logiciel d'aide au suivi d'élevages de ruminants. Montpellier, France, Cirad-emvt.

20. KEBEDE M., KUMSA T., GEBRE-YOHANNES G.-E., 1993. Some productive and reproductive performances of Horro cattle at Bako research center. In: Proc. 4th National Livestock Improvement Conference, Addis Ababa, Ethiopia, 13-15 November 1991. Addis Ababa, Ethiopia, Institute of Agricultural Research, p. 78-82.

21. LAIRD N., OLIVIER D., 1981. Covariance analysis of censored survival data using log-linear analysis techniques. *J. Am. stat. Assoc.*, **76**: 231-240.

22. LANCELOT R., LESCOURRET F., FAYE B., 1995. Multilevel modelling of pre-weaning kid mortality during the cold, dry season 1991-1992 in the outskirts of N'Djamena, Chad. *Prev. vet. Med.*, **24**: 171-186.

23. LANDAIS E., SISSOKHO M.M., 1986. Bases méthodologiques du contrôle des performances animales pour l'analyse zootechnique et démographique : collecte des données et choix des variables. In : Landais E., Faye J. eds, Méthodes pour la recherche sur les systèmes d'élevage en Afrique intertropicale. Maisons-Alfort, France, Cirad-Iemvt, p. 433-485. (Etudes et synthèses de l'Iemvt n° 20)

24. LAVAL G., 2002. Analyse coût-bénéfice des méthodes de lutte contre la Ppcb (péripneumonie contagieuse bovine). Une application au niveau du troupeau dans le district de Boji, West Wellega (Ethiopie). Thèse Doct., Université de Lyon I, France.

25. LEE E.T., 1992. Statistical methods for survival data analysis, 2nd Ed. New York, NY, USA, Wiley.

26. LE GOFF C., THIAUCOURT, F., 1998, A competitive ELISA for the specific diagnosis of contagious bovine pleuropneumonia (CBPP). *Vet. Microbiol.*, **60**: 179-191.

27. MASIGA W.N., DOMENECH J., WINDSOR R.S., 1996. Manifestation and epidemiology of contagious bovine pleuropneumonia in Africa. *Revue sci. tech. Off. int. Epizoot.*, **15**: 1283-1308.

28. MCCULLAGH P., NELDER R.W.M., 1989. Generalized linear models, 2nd Ed. New York, NY, USA, Chapman and Hall.

29. MCDERMOTT J.J., SCHUKKEN Y.H., SHOUKRI M.M., 1994. Study design and analytic methods for data collected from clusters of animals. *Prev. vet. Med.*, **18**: 175-191.

30. MUKASA-MUGERWA E., BEKELE E., TESSEMA T., 1989. Type and productivity of indigenous cattle in Central Ethiopia. *Trop. Anim. Health Prod.*, **21**: 120.

31. PROVOST A., PERREAU P., BREARD A., LE GOFF C., MARTEL J.L., COTTEW G.S., 1987. Contagious bovine pleuropneumonia. *Revue sci. tech. Off. int. Epizoot.*, **6**: 625-679.

32. SILESHI Z., TSEGAHUN A., YAMI A., TEGENE A., 2001. Status of livestock research and development in the highlands of Ethiopia. In: Proc. Two stakeholder workshops "Wheat and weeds: food and feed". Mexico City, Mexico, CIMMYT, p. 227-250.

33. TURNER A.W., ETHERIDGE J.R., 1963. Slide agglutination tests in the diagnosis of contagious bovine pleuropneumonia. *Aust. vet. J.*, **39**: 445-451.

34. VENABLES W.N., RIPLEY B.D., 1999. Modern applied statistics with S-PLUS. New York, NY, USA, Springer.

35. WILSON R.T., 1989. Livestock production in Central Mali: economic characters and productivity indices for Sudanes Fulani cattle in the agro-pastoral system. *Trop. Agric.*, **66**: 49-53.

Reçu le 04.07.2002, accepté le 17.02.2003

Résumé

Lesnoff M., Diedhiou M., Laval G., Bonnet P., Workalemahu A., Kifle D. Paramètres démographiques d'un cheptel de bovins domestiques dans une zone des hauts plateaux éthiopiens infectée par la péripneumonie contagieuse bovine

Les paramètres démographiques d'un cheptel de bovins (race Horro) dans un district rural d'Ethiopie (Boji, West Wellega) sont décrits. Les données ont été récoltées dans le cadre d'un suivi de troupeaux dont l'objectif a été d'étudier la diffusion de la péripneumonie contagieuse bovine (Ppcb). L'âge moyen à la première mise bas et le taux de mises bas (pour les femelles âgées de plus de 4 ans) ont été estimés respectivement à 5,8 ans et 0,37 année^{-1} dans les troupeaux suivis. Les mortalités naturelles annuelles ont été respectivement de 17, 9 et 3 p. 100 pour les veaux (âgés de 0 à 9 mois), les subadultes (plus de 9 mois à 4 ans) et les adultes (plus de 4 ans). Le statut des troupeaux pour la Ppcb (sain ou infecté) n'a pas montré d'effet sur la mortalité moyenne des animaux sevrés. La fréquence élevée des prêts d'animaux entre éleveurs (plus de 35 p. 100 des adultes des troupeaux suivis ont été prêtés dans l'année), principalement pour des activités agricoles et la fumure, a été une caractéristique importante du système d'élevage dans la zone. Cette pratique a pu avoir un effet important sur la structure d'âges observée dans les troupeaux suivis.

Mots-clés : Bovin – Péripneumonie contagieuse bovine – Démographie – Structure de la population – Ethiopie.

Resumen

Lesnoff M., Diedhiou M., Laval G., Bonnet P., Workalemahu A., Kifle D. Parámetros demográficos de un hato de bovinos domésticos en una zona de las altas mesetas etíopes, infectado con perineumonía contagiosa bovina

El presente artículo describe los parámetros demográficos de un hato de bovinos (raza Horro) en un distrito rural de Etiopía (Boii West Wellega). Los datos fueron recolectados dentro de un marco de seguimiento de hatos, con el objetivo de estudiar la difusión de la perineumonía contagiosa bovina (PPCB). La edad promedio al primer parto y la tasa de partos (para las hembras con edad superior a los 4 años) se estimaron respectivamente en 5,8 años y 0,37 año^{-1} en los hatos observados. Las mortalidades naturales anuales fueron respectivamente 17, 9 y 3% para los terneros (0 a 9 meses), los subadultos (> 9 meses a 4 años) y los adultos (> 4 años). El estado de los hatos para la PPCB (sano o infectado) no mostró efecto sobre la mortalidad promedio de los animales destetados. La elevada frecuencia de préstamos de animales entre los criadores (más de 35% de los adultos de los hatos seguidos fueron prestados durante el año), principalmente para actividades agrícolas y el abono con estiércol, fue una característica importante del sistema de cría en la zona. Esta práctica puede haber tenido un efecto importante sobre la estructura de las clases de edad observadas en los hatos.

Palabras clave: Ganado bovino – Pleuroneumonía contagiosa bovina – Estructura de la población – Demografía – Etiopía.