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Sustainable management of globally significant endemic ruminant livestock in West Africa (PROGEBE):

Estimate of livestock demographic parameters in the Gambia

Sustainable management of globally significant endemic ruminant livestock in West Africa (PROGEBE): Estimate of livestock demographic parameters in the Gambia

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Acronyms

ERL	Endemic Ruminant Livestock
NARS	National Agricultural Research Systems
PPR	Peste des petits ruminants
PRA	Participatory Rural Appraisal
PROGEBE	Projet Regional de Gestion Durable du Betail Ruminant Endemique (Sustainable Management of Globally Significant Endemic Ruminant Livestock in West Africa)
WAD	West African Dwarf

Executive summary

Introduction

This report describes the results of a 12-month retrospective survey for estimating livestock demographic parameters of endemic ruminant livestock (ERL) kept by smallholders in the Gambia. The demographic parameters estimated included natural rates, such as parturition, prolificacy and mortality rates, as well as management rates, such as offtake and intake rates.

The survey was carried out as one of several baseline surveys under the PROGEBE-Gambia project. At the onset of the survey, it was expected that the output (demographic parameter estimates) would serve the following functions:

a.   as an information source (to be combined with other information sources) for prioritizing project interventions

b.   for quantitative comparison of the demographic parameters between ERL and non-ERL, and

c.   to provide indications of the baseline status of livestock demographic parameters, which in combination with other baseline data and consideration for year effect can be used for evaluating the impact of project interventions.

However, as there were very few non-ERL within the surveyed sites, quantitative comparison of demographic parameters between ERL and non-ERL has not been possible.

Methodology

The methodology used was a 12-month retrospective survey, as described in full in Lesnoff et al. (2010a). The survey was carried out between the 13th and 20th of November 2009, and thus encompasses the 12 months period mid-November 2008 to mid-November 2009.

Suitable herds/flocks for enumeration were first identified within the project sites. For all species, these were considered those of size 5 to 30 animals (including juveniles) for a single household owned herd/flock, and 15 to 50 animals (including juveniles) for a multiple household owned herd/flock (though on occasion smaller or larger herds/flocks were surveyed). A trained enumerator then interviewed the farmer in relation to their herd/flock, in the presence of the animals. These animals were enumerated exhaustively for a number of basic data (such as breed, sex, age, parity etc.). The interviewee was also asked to recall all demographic events (such as births, deaths, slaughters, sales, purchases) that have occurred in the last 12 months.

From the data collected, three types of demographic parameters were estimated (Lesnoff et al. 2010a):

a.   variables describing the state of the herd/flock at the time of survey (such as herd size, sex by age structure);

b.   annual demographic rates (including natural rates, such as parturition, prolificacy and mortality rates, as well as management rates, such as offtake and intake rates); and

c.   overall demographic indicators summarizing the dynamics and productions of the herd/flock over the 12 months (such as annual growth rates and production rates).

The demographic parameters referred to as a rate (for example mortality rate, parturition rate) were instantaneous hazard rates. These were estimated as the number of events (e.g. number of mortalities) that have occurred in the last 12 months, divided by the total 'time at risk' (time spent by animals in the category over the last 12 months).

It should be noted that the demographic parameters were calculated for pure-breed ERL only (due to the low number of non-ERL in the data). Further, the estimated parameters should be considered approximate and interpreted with caution, due to several reasons (such as being based on recall) as discussed further in the main report.

Sample characteristics

Twenty-nine cattle herds were surveyed in total; 9 from Kiang West, 9 from Niamina East, and 11 from Nianija. The total number of animals within these herds at the time of survey was 1174, of which 1163 (99%) were pure-bred N'Dama. All 29 interviewees were male, with 19 interviewees being household heads, 5 'other household members', 4 herders and 1 interviewee from the category 'other'.

Eighty-three sheep flocks were surveyed in total, 24 from Kiang West, 27 from Niamina East, and 32 from Nianija. The total number of animals within these flocks at the time of survey was 887, of which 846 (95%) were pure-bred Djallonké. Nineteen per cent (16 of the 83) interviewees were female, with 67 interviewees being a household head, 15 'other household members' and 1 interviewee from the category 'other'.

Ninety-two goat herds were surveyed in total, 30 from Kiang West, 30 from Niamina East, and 32 from Nianija. The total number of animals within these herds at the time of survey was 963, of which 961 (99.8%) were pure-bred West African Dwarf (WAD). Twenty per cent (19 of the 92) interviewees were female, with 74 interviewees being household heads, 16 'other household members' and 2 interviewees from the category 'other'.

Interviewee's perception of the 12 months study period

For cattle, 55% of interviewees in Kiang West and Niamina East found the year to have been worse than average, while 33% of interviewees found the year to have been better than average and only 11% found the year to have been average. In Nianija, however, 64% of interviewees found the year to have been better than average, while 11% found it to have been worse than average and 11% found it to have been average. For sheep and goat, 59–66% of interviewees in Niamina East and Nianija found the year to have been worse than average, while 16–22% found the year to have been better than average. In Kiang West 40–54% found the year to have been better than average, while 27–33% found the year to have been worse than average. The main reason given by interviewees for scoring a year as worse or better than average was disease incidence.

Key results
Herd size and structure

The animals surveyed were mainly ERL for all species, i.e. 99.1% N'Dama cattle, 95.4% Djallonké sheep and 99.8% West African Dwarf goat.

The average herd structure for cattle was 21% calves, 33% sub-adults and 40% adult females and 6% adult males, with an average herd size of 40 cattle per household. For sheep the flock structure was 38% lamb, 55% adult females and 7% adult males, with an average flock size of 6. Finally, for goats 46% were kids, 49% adult females and 5% adult males, with an average herd size of 8.

The number of animals born in the herd/flock ranged from 82 to 87% for cattle (both sexes), adult female sheep and adult female goats. For male sheep and goats, the number of animals born in the flock/herd was higher, at 92% and 98% respectively.

Reproduction

There was wide variation in the age at first calving for cattle (generally 4 to 6 years), as well as the age at first lambing/kidding for small ruminants (1 to 3 years).

The parturition rate for cattle ≥4 years of age was 0.47, while the interval between parturition was 783 days. For sheep ≥3 years of age the parturition rate was 0.89 with an interval between parturition of 412 days, while for goats ≥2 years of age the parturition rate was 0.94 with an interval between parturition of 390 days.

The annual abortion rate and stillbirth rate were reasonable for cattle (0.03 and 0.04, respectively), while the abortion rate for sheep and goat was high (0.07 and 0.11, respectively). The stillbirth rate was reasonable for sheep (0.01) but high for goats (0.06).

Natural mortality

The mortality rates were found to be very high for cattle ≤1 year of age (0.20–0.23) and for sheep and goats across age groups (ranging from 0.27–0.54 and 0.25–0.53, respectively). Estimated losses for a typical herd/flock of 40 cattle, 6 sheep or 8 goats (assuming constant herd/flock size over the year) were 3.2, 1.9 and 2.7 animals per annum respectively.

Offtake and intake

The overall annual offtake rate was 0.08 for cattle, 0.15 for sheep and 0.21 for goats. Thus for a typical herd/flock of 40 cattle, 6 sheep or 8 goats (assuming constant herd/flock size over the year) 3.2, 0.9 and 1.7 animals are expected to exit via offtake (rather than death) annually. The highest single event offtake rate was sale, followed by slaughter. The main reason for slaughter was 'emergency disease' for cattle and goats and 'ordinary' followed by 'emergency disease' for sheep. The offtake rate was by far the highest for males >1 year of age for all species.

The annual intake rate was 0.07 for cattle and sheep and 0.06 for goats. Thus for a typical herd/flock of 40 cattle, 6 sheep or 8 goats (assuming constant herd/flock size over the year) 2.8, 0.4 and 0.5 animals are expected to enter the herd/flock (by means other than birth) annually. The highest type of intake was purchase/barter for all species. Mainly animals >1 year of age were purchased.

For cattle there was a net intake of females and a net offtake of males, while for sheep and goats there was a net offtake for both sexes. The overall net offtake rates per annum were 0.02 for cattle, 0.08 for sheep and 0.15 for goat.

Overall demographic indicators of production

The annual herd growth rate for cattle was 16%, while for sheep and goats the annual flock growth rate was 6% and 10%, respectively.

Conclusion and key recommendations

The findings of this survey clearly indicate that N'Dama cattle, Djallonké sheep, and WAD goats are the prominent breeds in the PROGEBE-Gambia project areas and suggest that some level of controlled breeding seems to be applied in most herds/flocks, primarily through

sire selection (although these may or may not be implemented with a specific breeding objective in mind). There seem to be a considerable scope for improvement of demographic parameters through improved herd/flock management in the short term, and breeding strategies in the long term. The single most striking result is the natural mortality rate, which was found to be very high for cattle less than one year of age and for sheep and goats across all age groups. As discussed in this report, the results from this survey are based on 12-month retrospective data and especially the mortality rate is likely vary considerably from year to year (Lesnoff 1999). However, although the mortality rate may be found to be lower in other years these results still indicate that years with high mortality rates do occur.

Specifically, it can be recommended that PROGEBE consider/prioritize the following issues for future project activities or interventions:

- Interventions towards lowering the natural mortality, including vulnerability to external shocks such as drought and disease. In the short to medium term (next few to 20 years) this should mainly be through changes to management practices. The results of the interviewees' perception of the 12 months study period, as well as the PROGEBE PRA survey (ILRI 2010), suggest that the main areas of intervention should be in relation to feed/water resources and diseases. However, any scheme of interventions should be based on local conditions and further investigations are required in this regard. In the much longer term (20 to 50 years) it may be possible to reduce mortality by genetically improving disease resistance of the animals through a breeding program.
- Interventions to improve other demographic parameters could as well be worth prioritizing, namely, age at first parturition, parturition interval, prolificacy rates and abortion rates. Again, this should mainly be through changes in management practices in the short-term, while in the longer term these parameters could potentially be improved through genetic improvement. Required interventions are likely to be in the areas of disease control and access to feed and water resources, and should be location specific.
- A modelling study using the demographic parameters estimated here, combined with other data from the household survey, livestock census and literature to determine the expected impact of potential PROGEBE interventions (such as improved health-care, feeding and/or animal genetic improvement) over different time horizons.
- Capacity building programs to improve awareness of traditional and alternate husbandry and breeding management practices and the effect these have on livestock production and productivity.

1   Introduction

Livestock play a central role in rural development in West Africa (Agyemang 2005). However, traditional livestock systems are in general characterized by high mortality rates, low reproductive rates and low offtake rates (Otte and Chilonda 2002). Furthermore, the presence of trypanosome-infected tsetse flies in the subhumid and humid areas seriously affects the potential for livestock production (Murray and Trail 1984; Snow et al. 1996; Osaer et al. 1999). Endemic ruminant livestock (ERL) such as N'Dama cattle, Djallonké sheep and West African Dwarf (WAD) goats are, however, highly adapted to the local environmental conditions and are able to survive and remain productive in tsetse infested areas with minimal inputs where other breeds succumb (Murray and Trail 1984; Snow et al. 1996; Osaer et al. 1999; Wilson 2007). Conservation and improvement of these breeds therefore have the potential to unlock the role of livestock in improving the livelihoods of livestock keepers in West Africa.

The 'Sustainable Management of Globally Significant Endemic Ruminant Livestock in West Africa' (PROGEBE) project aims at developing and implementing models for community based conservation and management of critical habitats for three endemic ruminant livestock (ERL) species (namely, N'Dama cattle, Djallonké sheep and WAD goats), and to demonstrate strategies for preserving the unique genetic trait/habitat complexes that are of global importance. Specifically, the objectives of the project are:

1.   to ensure sustainable populations of targeted ERL breeds in four West African countries; and

2.   to contribute to food security improvement and poverty reduction.

These objectives will be accomplished through reaching the following outcomes, namely:

1.   conserving ERL genetic traits and improving their productivity;

2.   facilitating improved market development and incentives for ERL and their products;

3.   promoting sustainable management of natural resources for ERL;

4.   facilitating the implementation of policies, legal and institutional frameworks favourable to ERL development; and

5.   improving cooperation, knowledge management and information sharing (UNDP Project Document).

To characterize the exiting ERL production and management system, as well as other key indicators relevant to the five strategic intervention areas, a number of baseline surveys were carried out in the three project sites in the Gambia. These included a Participatory Rural Appraisal (PRA) survey, a household questionnaire survey, a market actor survey and a retrospective survey of livestock demographic parameters.

This report describes the results of the retrospective survey for estimating livestock demographic parameters kept by smallholders in three sites in the Gambia. The demographic parameters estimated included natural rates, such as parturition, prolificacy and mortality rates, as well as management rates, such as offtake and intake rates.

These parameters have to some extent been reported in the literature for cattle (Otte and Chilonda 2002; Agyemang et al. 2005; Ba et al. 2011); sheep (Wilson 1991; Lesnoff 1999; Otte and Chilonda 2002); and goats (Wilson 1991; Ba et al. 1996; Otte and Chilonda 2002). However, the data are typically 10–40 years old and has limitations in terms of livestock species and breeds, farming system or country/region. Hence, this survey was carried out to collect up-to-date, site and breed specific data on livestock demographic parameters in the PROGEBE-Gambia project sites.

Three main survey approaches are used in practice for collecting data on livestock demographic parameters in smallholder systems in the developing world. These are individual animal follow-up, herd follow up and cross sectional retrospective surveys (Lesnoff et al. 2009). The retrospective survey is based on farmer interviews and their recall of past herd demographics. Compared to the other two methods it has the advantage of quick results and being relatively low cost. The main drawback is that the method relies on farmers' recall of past event and therefore will not be as accurate at the two other approaches. The 12 months retrospective survey is a methodology designed to provide a standardized methodology for estimating livestock demographic parameters, which is affordable and easily implementable in the field in order to be easily transferable to local structures (NARS, NGOs etc.) (Lesnoff et al. 2009). It is based on the farmers' recall of the last 12 months prior to the survey and is therefore sensitive to between year variation, which can be considerable (Lesnoff 1999). This survey methodology was, however, still found to be the most suitable for the purpose, due to the reasons given above and since no up-to-date site and species/breed specific data were available. The results of the survey should be interpreted with consideration of the year effect of the 12 months study period and cannot be considered as averages over years. They can, however, provide a useful and site/breed specific estimation of the productivity of livestock herds in the year prior to the survey. The advantages and disadvantages of the 12 months survey methodology were further discussed in the following section.

The specific objectives of the survey were to:

1.   serve as an information source that, combined with other information sources, can be used for prioritizing project interventions,

2.   enable quantitative comparison of the demographic parameters between ERL and non-ERL, and

3.   provide indication of the status of livestock demographic parameters in the project sites that, in combination with other baseline data and with consideration of year effect, can be used for evaluating the impact of project interventions.

However, as there were very few non-ERL within the surveyed sites, the second objective could not be fulfilled.

The report first describes the methodology used for the survey, as well as the sample surveyed for each of the three species (cattle, sheep and goat) (Section 2). Hereafter the results of the survey were presented by species (Sections 3, 4 and 5), followed by an overall discussion (Section 6). Finally, a conclusion and summary of recommendations for future PROGEBE interventions are given in Section 7.

2   Methodology

2.1   Overview of survey methodology and demographic parameters estimated

The methodology used was a 12-month retrospective survey, as described in brief below (detailed description is given in Lesnoff et al. 2010a). The survey was carried out between the 13th and 20th of November 2009, and thus encompasses the 12 months period mid-November 2008 to mid-November 2009.

In brief, the survey was carried out as follows. Suitable herd/flocks for enumeration were randomly identified within the project sites. These were considered those of size 5 to 30 animals (including juveniles) for a single household owned herd/flock, and 15 to 50 animals (including juveniles) for a multiple household owned herd/flock (though on occasion smaller or larger herds/flocks were surveyed). These herd/flock sizes were chosen as a compromise between fully representative of all herd/flock sizes, and practical issues related to survey time (the overhead associated with surveying smaller herd/flocks was considered too great, and it was too time-consuming to survey larger herd/flocks). The results of the PROGEBE Gambia household survey showed that 35, 50 and 55% of households owning cattle, sheep and goats, respectively, owned 5–30 animals, while 55, 45 and 44%, respectively, owned 1–4 animals. Differences in demographic parameters may exist between these two major groups of households, which should also be considered when interpreting the results. Ba et al. (2011) did not find a significant difference in mortality and offtake rates between different herd sizes for cattle in mixed crop–livestock systems in southern Mali. The main differences found were that herds of 1–5 cows had significantly a higher parturition rate compared to herds of 6–19 and ≥20 cows, as well as significantly higher intake of sub-adult and adult animals. A trained enumerator then interviewed the farmer in relation to their herd/flock, in the presence of the animals. These animals were enumerated exhaustively for a number of basic data (such as breed, sex, age, parity etc). The interviewee was also asked to recall all demographic events (such as births, deaths, slaughters, sales, purchases) that have occurred in the last 12 months. A full list of the data recorded is given in Table 1.

From this data three types of demographic parameters were estimated (Lesnoff et al. 2010a):

1.   variables describing the state of the herd/flock at the time of survey (such as herd size, sex by age structure);

2.   annual demographic rates (including natural rates, such as parturition, prolificacy and mortality rates, as well as management rates, such as offtake and intake rates); and

3. overall demographic indicators summarizing the dynamics and productions of the herd/ flock over the 12 months (such as annual growth rates and production rates).

Table 1. *Data recorded for the 12 month retrospective survey*

Level	Data
For each survey	Generic: survey date, survey location (site, village and GPS co-ordinates)
	Interviewee: name, gender, type (household head, other household member, herder, or other), livestock owner (yes, no)
	Seasonal effect over the last 12 months compared to the previous 5 years (choices of 'much worse than average', 'somewhat worse than average', 'average', 'somewhat better than average', 'much better than average', with respective scores of 1, 2, 3, 4 and 5
	Total number of households with animals within the herd/flock
For each animal present in the herd/ flock at the time of survey	Breed or crossbreed: based on phenotype, and as jointly agreed by the interviewee and enumerator
	Sex
	Born in herd
	Born from AI
	Age: as age class, where age class 0 corresponds to animals 0 to ≤ 1 year of age, age class 1 corresponds to animals >1 and ≤2 years of age etc.
For each female present in the herd/ flock at the time of survey	Number of lifetime parturitions (where a parturition is defined as the process of giving birth)
	Number of parturitions over the last 12 months
	For each parturition over the last 12 months the number of offspring born alive
	For each parturition over the last 12 months the number of offspring stillborn
	Number of lifetime abortions
	Number of abortions over the last 12 months
For each animal that has entered the herd over the last 12 months	Breed or crossbreed (as above)
	Sex
	Age (as above)
	Type of entry: purchase or barter; arrival in loan or contract; returned from loan or contract; gift, inheritance or dowry
For each animal that has exited the herd over the last 12 months	Breed or crossbreed (as above)
	Sex
	Age (as above)
	Type of exit: natural death; slaughter; sale or barter; departure in loan or contract; sending back from loan or contract; gift or dowry; withdrawal or theft
	Type of slaughter or sale: ordinary; emergency due to disease; emergency due to lack of feed; emergency due to traumatism

A full list of demographic parameters is given in Table 2.

Table 2. *Demographic parameters estimated for the 12 months retrospective survey[1]*

Natural rates	
Abortion rate	Annual instantaneous hazard rate of abortion (expected number of abortions per female when spending all the year in the herd; an abortion is a gestation that has not reached its term). Also calculated over the complete reproductive female histories, as the slope of the regression line fitted between ages and parities of the females present in the herd
Parturition rate	Annual instantaneous hazard rate of parturition (expected number of parturitions per female when spending all the year in the herd). Also calculated over the complete reproductive female histories, as the slope of the regression line fitted between ages and parities of the females present in the herd
Prolificacy rate	Average number of offspring (stillborn or born alive) per parturition
Stillbirth rate	Probability that an offspring is a stillborn (stillbirth is not included in the mortality rate, which only concerns animals born alive)
Mortality rate	Annual instantaneous hazard rate of natural death (natural death refers to all types of death except slaughtering)
Management rates	
Offtake rate	Annual instantaneous hazard rate of offtake (slaughtering, sales, loans, gifts etc.)
Intake rate	Annual instantaneous hazard rate of intake (purchases, loans, gifts etc.)
Additional demographic rates derived from the basic annual demographic rates	
Net prolificacy rate	Average number of offspring born alive per parturition, calculated directly or by: Prolificacy rate * (1-stillbirth rate)
Fecundity rate	Average number of offspring (born alive or stillborn) per reproductive female and year, calculated directly or by: Parturition rate * prolificacy rate
Net fecundity rate	Average number of offspring born alive per reproductive female and year, calculated directly or by: Parturition rate * net prolificacy rate
Overall demographic indicators	
Multiplication rate	Annual multiplication rate, calculated as: Herd size at date of survey/ herd size 12 months before. A value of >1 indicates a positive growth rate in the year
Growth rate	Annual population growth rate, calculated as: 100 * (annual multiplication rate – 1)
Production rate	Annual production rate, in the form of P/N, where P is (herd size at date of survey – herd size 12 months ago) + (number of offtake over the year – number of intake over the year), and N is the mean herd size over the year. Note that the numerator (P) represents the balance between births and deaths

1. Taken from Lesnoff et al. (2010a).

A number of demographic parameters (i.e. abortion, parturition, mortality, offtake and intake) are given as an instantaneous hazard rate (h). The instantaneous hazard rate can be estimated for a particular category of animals (e.g. all animals; males over one year of age etc.) as:

$$H = m/T$$

where m is the number of events (e.g. number of mortalities, number of animals entering the herd etc.) that have occurred in the last 12 months, and T is the total 'time at risk' (time spent by animals in the category over the last 12 months).

T is approximated by averaging the estimated number of animals in that category 12 months ago (n_{t-1}), and the current number of animals in that category (n_t). n_{t-1} for a particular age class (i) is calculated as:

$$n_{t-1,i} = n_{t,i+1} - ((m_{ent,i} - m_{exi,i})/2) - ((m_{ent,i+1} - m_{exi,i+1})/2)$$

where m_{ent} and m_{exi} are entries and exists into age class i in the last 12 months, respectively. $n_{t,i}$ is known from the data.

Note that calculation of T via this method assumes a uniform distribution of events (mortalities, number of animals entering the herd etc.) over the 12 months. If this assumption does not hold and there is a non-uniform event rate T will be biased: if an intensive event rate occurs close to the beginning of the year T will be over-estimated, and if an intensive event rate occurs close to the end of the year T will be under-estimated. One cannot expect events such as mortality and offtake to be uniformly distributed; however, it has been shown that this method of estimating T is less sensitive to herd size variations over the year than other methods (Lesnoff 2008). See Lesnoff et al. (2010a) for further details on the calculation of instantaneous hazard rates, and Appendix 1 for an illustrative example.

Further note that the data produced using this methodology should only be considered approximate and should be interpreted with caution for several reasons. Firstly, the data is based on a memory of events for the 12 month period preceding the time of survey, and thus is likely to contain a certain level of error, which could bias the results. Secondly, an underlying assumption for the annual hazard rates is that there is a uniform distribution of demographic events over time, with violation of this assumption again biasing the results. In particular, this may apply to adult male small ruminants as these are often slaughtered or sold during a short time period (e.g. Tabaski) but also to whole herds/flocks during the occurrence of seasonal disease outbreaks, such as PPR for sheep and goats. Thirdly, herds and flocks were selected based on a specific size range, meaning that results are less applicable to herds/flock smaller or larger than that targeted here. Finally, the results relate to the specific environmental conditions of the 12-month period surveyed, rather than being

an average over many years. The best option for validation of the demographic parameters presented here, if required, is a long-term longitudinal survey. All analysis, bar year effect, was performed combining data over sites.

2.2 Cattle survey sample

Twenty-nine herds were surveyed in total; 9 from Kiang West, 9 from Niamina East, and 11 from Nianija. The total number of animals within these herds at the time of survey was 1174, of which 1163 (99%) were pure-bred N'Dama. The final data-set used for the analysis comprised 1157 of the 1174 animals (with 11 animals excluded for not being pure-bred N'Dama, and a further 6 animals excluded for missing age). In addition, there were a total of 70 entries and 172 exits recorded of pure-bred N'Dama.

All 29 interviewees were male, with 19 interviewees being household heads, 5 'other household members', 4 herders and 1 interviewee from the category 'other'. Seventy-nine per cent (23 of the 29 interviewees) were livestock owners.

Interviewee perception of the 12-month study period

The interviewees' perception of the 12-month period covered by the survey is shown in Figure 1 for each site.

Fifty-five per cent of the interviewees in Kiang West and Niamina East (5 out of 9 at each site) found the year to be worse than average. Still, 33% (3 out of 9 at each site) found it to be better than average and only 11% (1 out of 9 at each site) had a perception of an average year. In Nianija, however, 64% (7 out of 11) found the year to have been better than average, while 18% (2 out of 11) found the year to be worse than average, and another 18% (2 out of 11) perceived the year as average.

Disease was the most frequently mentioned reason for the year to be scored as worse than average (10 out of 12 of interviewees who scored the year as worse than average), followed by access to feed (6 out of 12) and water (4 out of 12) (note that some interviewees mentioned several reasons). The most frequent reason mentioned for a better than average year in Kiang West and Niamina East was low disease incidence (5 out of 6) followed by access to feed (2 out of 6). In Nianija the main reasons were access to feed (6 out of 7) and low disease incidence (5 out of 7).

2.3 Sheep survey sample

Eighty-three flocks were surveyed in total, 24 from Kiang West, 27 from Niamina East, and 32 from Nianija. The total number of animals within these flocks at the time of survey was

887, of which 846 (95%) were pure-bred Djallonké. The final data-set used for the analysis comprised 833 of the 887 animals (with 41 animals excluded for not being pure-bred Djallonké, and a further 13 excluded for missing age). In addition, there were a total of 54 entries and 498 exits recorded of pure-bred Djallonké.
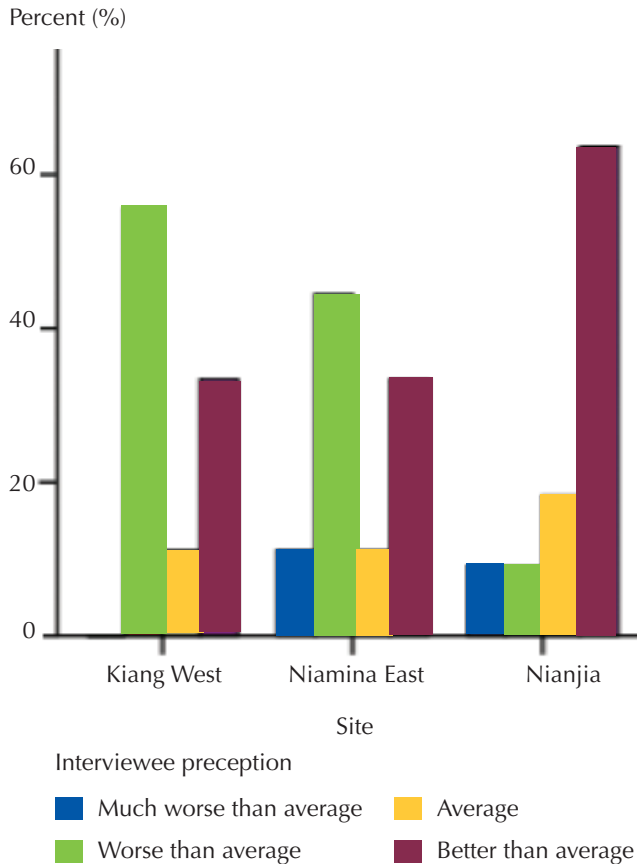
Percent (%)

Figure 1. *Interviewee perception of 12-month study period for cattle herds in the three sites.*

Nineteen per cent (16 of the 83) interviewees were female, with 67 interviewees being a household head, 15 'other household members' and 1 interviewee from the category 'other'. Ninety-nine per cent (82 of the 83 interviewees) were livestock owners.

Interviewee perception of 12-month study period

The interviewees' perception of the 12-month period covered by the survey is shown in Figure 2 for each site.

Percent (%)

Interviewee preception

■ Much worse than average   ■ Better than average
■ Worse than average   ■ Much better than average
■ Average
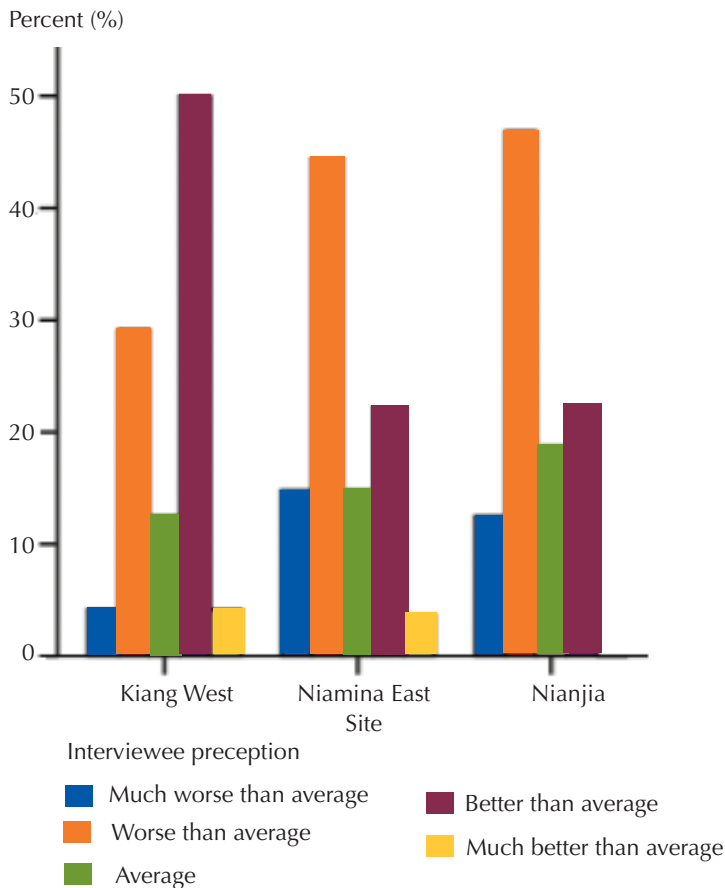
Figure 2. *Interviewee perception of 12-month study period for sheep flocks in the three sites.*

Fifty-nine per cent of interviewees in Niamina East and Nianija (16 out of 27, and 19 out of 32, respectively) found the year to have been worse than average, while 25 and 22%, respectively, found the year to have been better than average. In Kiang West 54% (13 out of 24) found the year to have been better than average. Still, 33% of the interviewees (8 out of 24) at Kiang West found the year to have been worse than average, while only 13% (3 out of 24) found the year to have been average.

Almost all interviewees mentioned disease as a reason for the year to be scored as worse than average (39 of 41 interviewees who scored the year as worse than average), while about a tenth mentioned access to feeds as a reason (4 out of 41) (note that some interviewees mentioned several reasons). Comparably, the most frequent reason mentioned for a better than average year was low incidence of disease (21 out of 27), followed by access to feed (9 out of 27), and improved housing (7 out of 41). Peste des petits ruminants (PPR) was by far the most frequent disease mentioned by interviewees naming disease as a reason for the poor year, with pasteurellosis, parasites and foot rot also mentioned.

2.4   Goat survey sample

Ninety-two flocks were surveyed in total, 30 from Kiang West, 30 from Niamina East, and 32 from Nianija. The total number of animals within these flocks at the time of survey was 963, of which 961 (99.8%) were pure-bred West African Dwarf (WAD). The final data-set used for the analysis comprised 945 of the 963 animals (with 2 animals excluded for not being pure-bred WAD, and a further 15 excluded for missing age). In addition, there were a total of 54 entries and 400 exits recorded of pure-bred WAD.

Twenty per cent (19 of the 92) of interviewees were female, with 74 interviewees being a household head, 16 'other household members' and 2 interviewees from the category 'other'. Ninety-six per cent (88 of the 92) of interviewees were livestock owners.

Interviewee perception of the 12-month study period

The interviewees' perception of the 12-month period covered by the survey is shown in Figure 3 for each site.
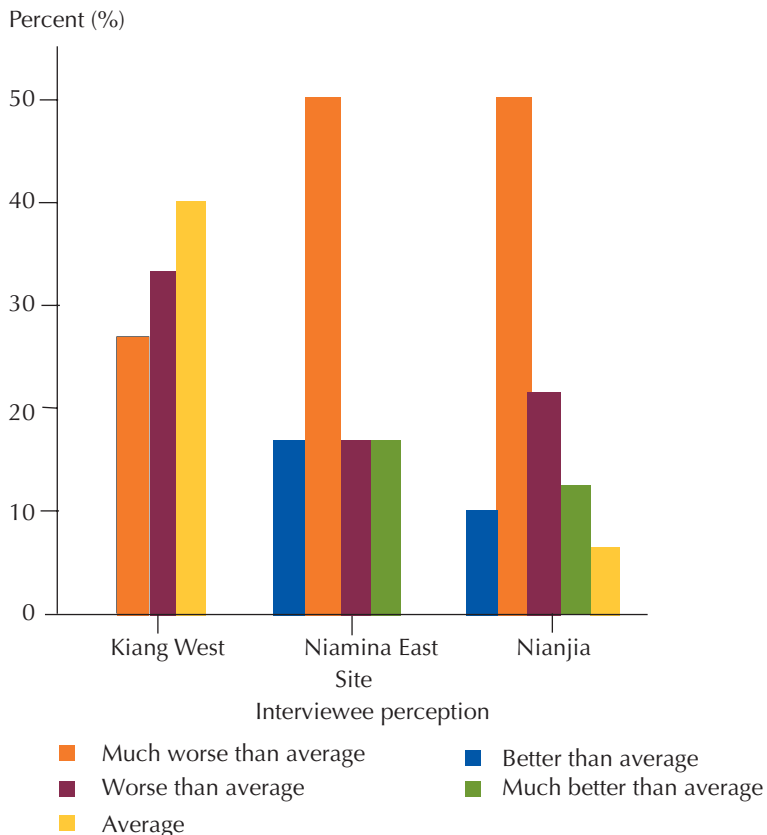
Figure 3. *Interviewee perception of the 12-month study period for goat herds in the three sites.*

Similar to that of sheep, 66% of interviewees in Niamina East and 59% of interviewees in Nianija (20 out of 30, and 19 out of 32, respectively) found the year to have been worse than average, while 16 and 19%, respectively, found the year to have been better than average. In Kiang West, 27% scored the year as worse than average (8 out of 30), 33% as average (10 out of 30), and 40% as better than average (12 out of 30).

Almost all interviewees mentioned disease as a reason for the year to be scored as worse than average (45 out of 46 interviewees who scored the year as worse than average), while some mentioned access to feeds as a reason (3 out of 46) (note that some interviewees mentioned several reasons). Comparably, the most frequent reason mentioned for a better than average year was low incidence of disease (17 out of 23), while about a third each mentioned access to feed and improved housing (8 out of 23 each). PPR was by far the most frequent disease mentioned by interviewees giving disease as a reason for being worse off, followed by pasteurellosis and parasites (although much less frequent).

3   Cattle results

3.1   Herd sizes and structure

Herd size

The surveyed cattle herd sizes ranged from 13 to 79 animals, with a mean of 40 animals (Figure 4). Fourteen of the 29 herds were owned by multiple households, with the number of households ranging from 2 to 9. Eighty-six per cent of female cattle and 87% of male cattle were born in the herd.

Number of herds
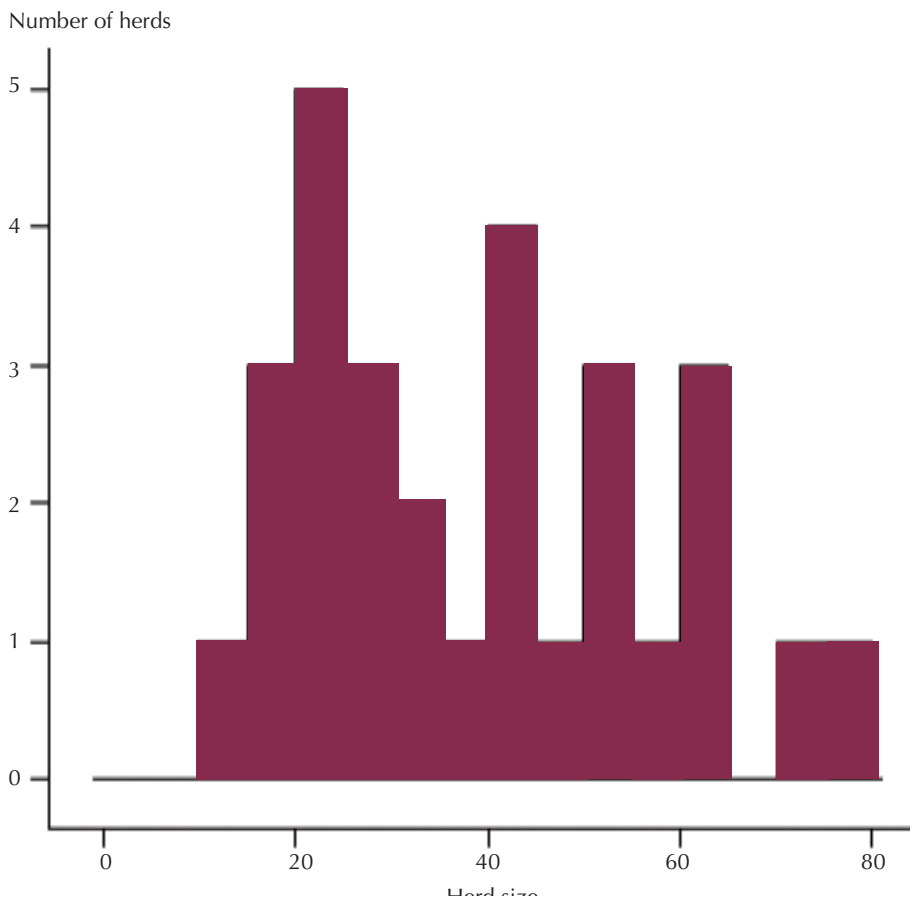
Figure 4. *Distribution of cattle herd sizes.*

Age-by-sex structure

The age-by-sex structure is shown in Figure 5. The combined herds comprised 21% calves (≤1 year of age), 33% sub-adults (>1 and ≤4 years of age), 40% adult females and 6% adult males. Overall, there were 71% females in an average herd. The majority of females (98%)

13

were ≤11 years of age, and the majority of males (95%) were ≤6 years of age. The reason for the drop in percentage of animals in age classes 1–2 is not clear. However, an investigation of entries and exits by age-class suggests that this drop may be related to a high level mortality at age class 0, combined with purchasing animals mainly of age classes 2–4 (see Tables 5 and 6).

Proportion of animals (%)
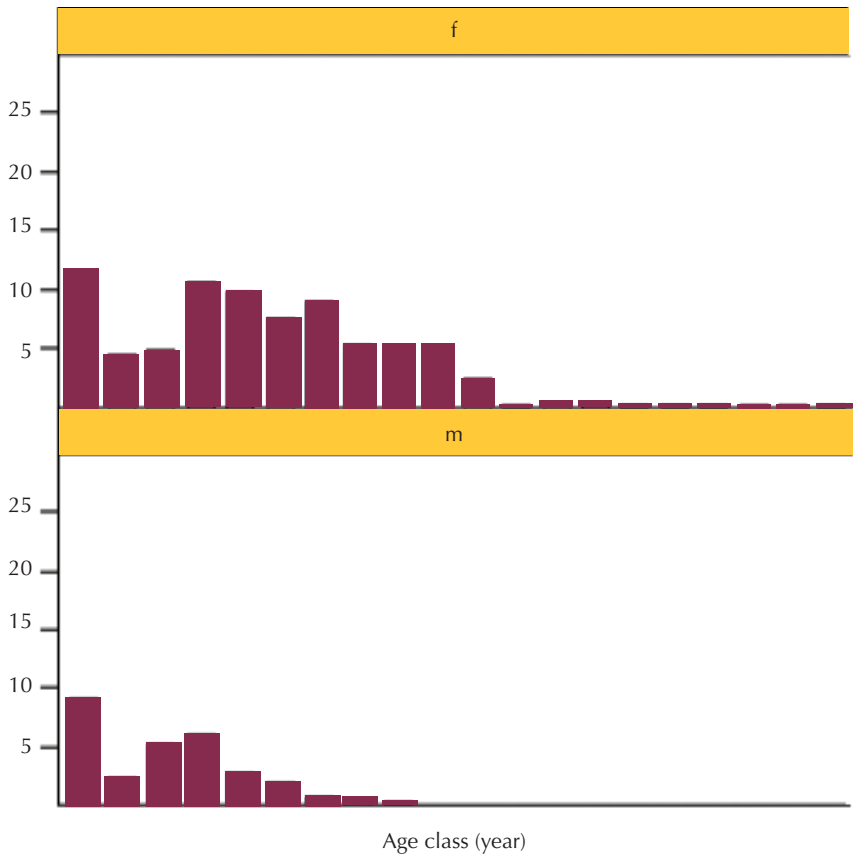
Age class (year)

Age class 0 refers to animals of ≤1 year of age, age class 1 refers to animals >1 year and ≤2 years of age etc.

Figure 5. *Age-by-sex structure in the surveyed cattle herds for females (f) and males (m).*

3.2   Reproduction

Parity in relation to age-class

Figure 6 shows age class vs. parity for the full reproductive history data. The average age at first parturition cannot be accurately determined from these results (as, for example, an animal of parity 1 and current age 6, may have given birth when it was 6, 5 or 4 years old),

but it appears the earliest age at first parturition is 4 to 6 years (and very infrequently 2 to 3 years). Other studies (Agyemang et al. 1997; Otte and Chilonda 2002) reported an average age of first parturition of 4.0–4.2 years. Animals of second parity are mostly 5 to 7 years of age, and animals of third parity mostly 7 to 8 years of age. Relatively few animals had a parity of three or greater.

Age class (year)
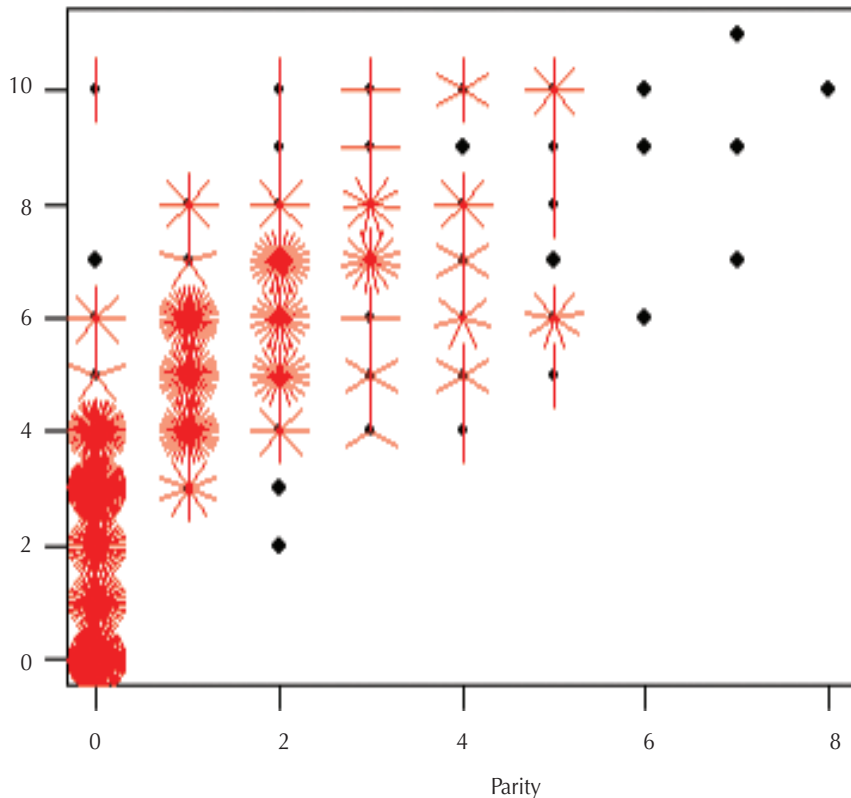
Age class 0 = animals of ≤ 1 year of age, age class 1 = animals >1 year and ≤2 years of age etc. Cattle of age class >11 were discarded due to the potential unreliability of this data.

Figure 6. *Parity in relation to age class (a sunflower plot where multiple points are shown as 'petals') for cattle.*

Parturition rates

Parturition rate by age class for the 12-month data is shown in Figure 7. It should be noted that from the age group >4 years the average parturition rate remains relatively constant.
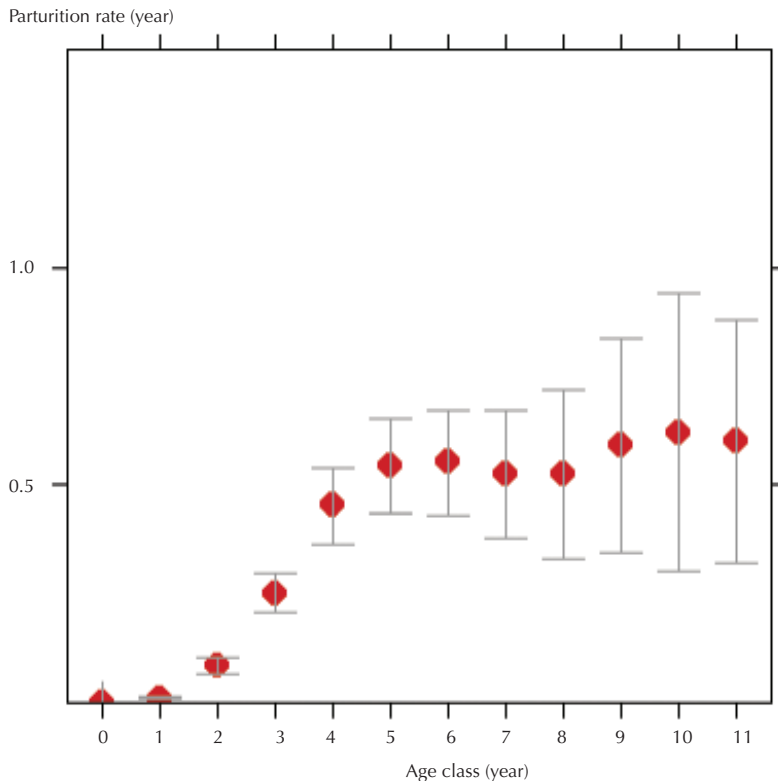
Age class 0 refers to animals of ≤1 year of age, age class 1 refers to animals >1 year and ≤2 years of age etc.
Cattle of age class >11 were combined into age class 11.

Figure 7. *Annual parturition rates of female cattle, with 95% confidence intervals indicated.*

Estimates of annual parturition rates, for both the 12-month data for females ≥3 and 4 years of age and the complete reproductive history of the females, are presented in Table 3. The difference between the 12 months retrospective data and the lifetime retrospective data may be due to differences in year effect (i.e. some years having greater abortion rates than others), or due to biases created from using a recall survey method. In comparison, Agyemang et al. (1997) found an average parturition rate at 0.54, while Ba et al. (2011) found the parturition rate to be 0.72 for herds with 1–5 cows and 0.51 for herds with 6–19 cows.

Table 3. *Various estimates of the annual parturition rates for female cattle*

Data	Annual parturition rate (standard error)	Interval between parturitions, in days (year)[3]
12 months, all females ≥3 years of age[1]	0.47 (0.02)	777 (2.1)
12 months, all females ≥4 years of age[1]	0.53 (0.03)	688 (1.9)
Lifetime reproductive history of females[2]	0.40 (0.01)	913 (2.5)

1. Average annual rate of parturition based on number of parturitions of all females ≥3 or 4 years during the last 12 months.

2. Average annual rate of parturition based on total number of parturitions of all females born in herd, and ≤11 years of age.

3. Calculated in days as 365/parturition rate.

Other reproductive parameters

Estimates of other reproductive parameters (i.e. abortion, stillbirth, prolificacy and fecundity rates) are given in Table 4. Of note is that the abortion and stillbirth rates were reasonably low (0.04 and 0.03, respectively), and that the prolificacy rate was 1.0 as all parturitions were single births.

Table 4. *Estimates of abortion, stillbirth, prolificacy and fecundity rates of cattle (standard errors)*

Parameter	Data source	Value
Annual abortion rate	12 months, all females ≥3 years of age[1]	0.03 (0.00)
	12 months, all females ≥4 years of age[1]	0.04 (0.00)
	Lifetime reproductive history of females[2]	0.02 (0.00)
Stillbirth rate	12 months	0.03 (0.01)
Prolificacy rate	12 months	1.00 (0.00)
Net prolificacy rate	12 months	0.97 (0.01)
Annual fecundity rate	12 months, all females ≥4 years of age	0.53 (0.03)
Annual net fecundity rate	12 months, all females ≥4 years of age	0.51 (0.03)

1. Average annual rate of abortion based on number of parturitions of all females ≥3 or 4 years during the last 12 months.

2. Average annual rate of abortion based on total number of parturitions of all females born in herd, and ≤11 years of age.

3.3   Natural mortality

The mortality rates are shown in Figure 8, and also given in Table 5 in subsection 3.4. The mortality rates were particularly high for animals ≤1 year of age (0.20 and 0.23 for males and females, respectively), though lower for animals >1 year of age (0.05 and 0.07 for males and females, respectively). The overall mortality rate was 0.08, meaning that for a herd with a constant size of 40 animals over the year, 3.2 natural deaths would be expected annually. It should be noted that the instantaneous hazard rates given here differs from the overall probability of a natural death (see Appendix 1), which is frequently used as an indication of mortality in literature. The difference between these rates are greater the higher the rate. Recalculated to probabilities,[1] the overall mortality rate found in this study was 0.08, while for males and females of ≤1 year of age it was 0.18 and 0.21, respectively. This is similar to other results of cattle mortality in the Gambia (Agyemang et al. 1997), southern Mali (Ba et al. 2011) and sub-Saharan Africa (Otte and Chilonda 2002) which ranged from an overall mortality of 6–8% and a calf (≤1 year of age) mortality of 13–22%.

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1. Effect of offtake rates not included.
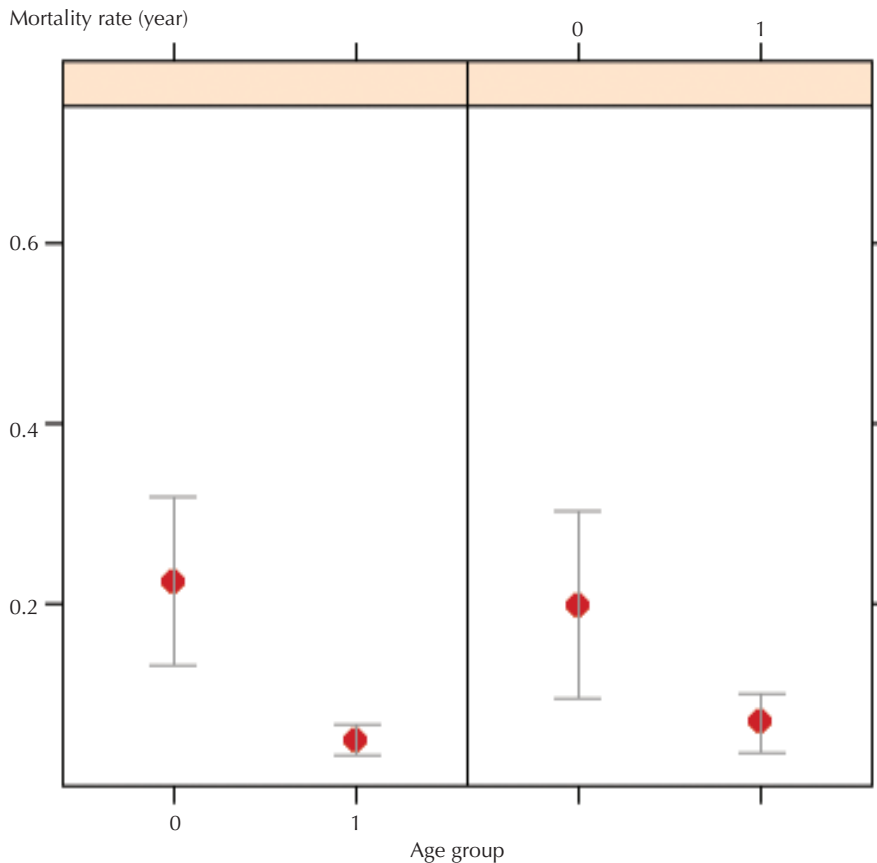
Age group 0 = animals ≤1 year of age, and age group 1 = animals >1 year.

Figure 8. *Annual mortality rates for natural death of cattle, for females (F) and males (M), with 95% confidence intervals indicated.*

3.4   Offtake and intake

Offtake rates

Overall offtake rates, as well as offtake rates by individual events (i.e. slaughtering, sales/barter, loans/contracts, gifts/dowry, withdrawal/theft) are given in Table 5. Rates of natural death (mortality) are included in this table for comparison purposes.

The overall rate of annual offtake was 0.08, meaning that for a herd with a constant size of 40 animals over the year, 3.2 exits would be expected annually. This is slightly lower than the offtake observed by Ba et al. (2011) in mixed crop–livestock systems in southern Mali, who found an overall offtake rate of 0.11. This was mainly due to the offtake rate of females >1 being higher than observed in this study.

Table 5. *Annual offtake rates (standard errors) for cattle, for different offtake events[1]*

| Sex | Age | Offtake events | | | | | | Natural death |
		Slaughter	Sales, barters	Loans, contracts	Gift, dowry	Withdrawal, theft	Overall	
Female	≤1 year	0	0	0	0	0	0	0.23 (0.05)
	>1 year	0.02 (0.01)	0.04 (0.01)	0	0.01 (0.00)	0.01 (0.00)	0.07 (0.02)	0.05 (0.01)
Male	≤1 year	0.01 (0.01)	0.01 (0.01)	0	0.03 (0.02)	0	0.06 (0.03)	0.20 (0.05)
	>1 year	0.02 (0.01)	0.12 (0.02)	0.02 (0.01)	0.01 (0.01)	0	0.17 (0.03)	0.07 (0.02)
Overall		0.01 (0.00)	0.05 (0.01)	0.00 (0.00)	0.01 (0.00)	0.01 (0.00)	0.08 (0.01)	0.08 (0.01)

1. Note the unreliability of some of these estimates (high standard errors), due to the low number of events recorded.

It is of note that the overall rate of offtake is equal to the overall mortality rate. The highest single event offtake rate was for sale/barter, followed by slaughter, followed by gift/dowry.

The main reasons for sale of animals were 'ordinary' (34 out of 61, 65% [i.e. 22 out of the 34] male), 'emergency disease' (10 out of 61, 20% male), and 'emergency lack of feed' (7 out of 61, 29% male). The main reasons for slaughter of animals was 'emergency disease' (9 out of 15, 22% male), followed by 'ordinary' (5 out of 15, 40% male), and 'emergency traumatism' (1 out of 15, male).

The highest offtake rate for a sex/age class category was for males >1 year (0.17) primarily due to sale/barter. For animals ≤1 year the only offtake recorded was for males, primarily for gift/dowry.

Intake rates

The overall rate of annual intake was 0.07, meaning that for a herd with a constant size of 40 animals over the year, 2.8 intakes would be expected annually. Ba et al. (2011) found the overall intake rate to be slightly higher at 0.10, which was mainly due to a higher intake of females and males >1 year of age.

Table 6 gives a breakdown by event (purchase/barters, loans/contracts, gifts/dowry/inheritance). As expected, the highest intake rate was for purchase/barter of animals >1 year of age.

Table 6. *Annual intake rates (standard errors) for cattle, for different intake events*

Sex	Age	Intake events			
		Purchases, barters	Loans, contracts	Gift, dowry, inheritance	Overall
Female	≤1 year	0.02 (0.02)	0	0	0.02 (0.02)
	>1 year	0.06 (0.01)	0.01 (0.00)	0	0.07 (0.01)
Male	≤1 year	0	0	0	0
	>1 year	0.07 (0.02)	0.02 (0.01)	0	0.09 (0.02)
Overall		0.05 (0.01)	0.01 (0.00)	0	0.07 (0.01)

Net offtake

Table 7 summarizes the annual net offtake. The overall rate was 0.02, meaning that for a herd with a constant size of 40 animals over the year, a net offtake of 0.8 animal is expected annually. For females there was a net intake of animals, while for males there was a net offtake.

Table 7. *Net offtake rates for cattle, as well as the underlying offtake and intake rates (standard errors)*

	Female		Male		Total
	≤1 year of age	>1 year of age	≤1 year of age	>1 year of age	
Offtake	0	0.065 (0.010)	0.057 (0.028)	0.165 (0.027)	0.080 (0.009)
Intake	0.021 (0.015)	0.070 (0.010)	0	0.087 (0.019)	0.065 (0.008)
Net offtake	–0.021 (0.015)	–0.005 (0.01)	0.057 (0.028)	0.078 (0.033)	0.015 (0.012)

3.5   Overall demographic indicators

The annual population multiplication rate, as the total herd size at the date of this survey (1157) divided by the total herd size 12 months ago (1002) was calculated to be 1.16. This indicates a positive growth rate of 16% for the year. Annual herd productivity, as the balance between total births and deaths (166) divided by the mean total herd size (1080), was 0.15.

4 Sheep results

4.1 Herd sizes and structure

Flock size

The surveyed sheep flock sizes ranged from 1 to 20 animals, with the exceptions of 2 larger flocks of size 26 and 39. The modes (most frequent flock sizes) were 5 and 6 (Figure 9). Almost all (98%) of animals ≤1 year of age were born in the flock, whereas 85% of females >1 year of age and 92% of males >1 year of age were born in the flock. All sheep flocks were single household owned.

Number of flocks
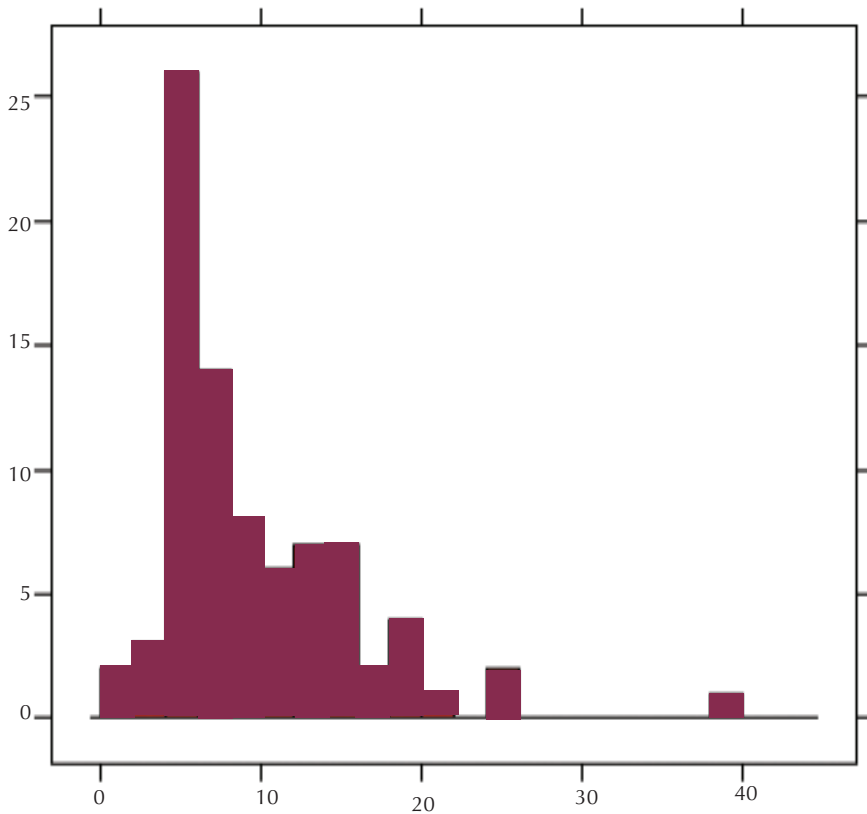
Figure 9. *Distribution of sheep flock size.*

Age-by-sex structure

The age-by-sex structure is shown in Figure 10. The combined flocks comprised 21% females ≤1 year of age, 17% males ≤1 year of age, 55% females >1 year of age, and 7% males >1 year of age. The majority of females (98%) were ≤9 years of age, and the majority of males

(96%) were ≤3 years of age. The reason for the drop in percentage of animals after age class is mainly related to a high number of exits through mortality, and to some extent exits through sales/slaughter, at age class 0 (see Table 10). The less steep drop for females is partly due to purchase of females at age group 1 and 2 (>1 to ≤3 years of age), whereas there were no purchases of males beyond age class 0 (see Table 11).

Proportion of animals (%)
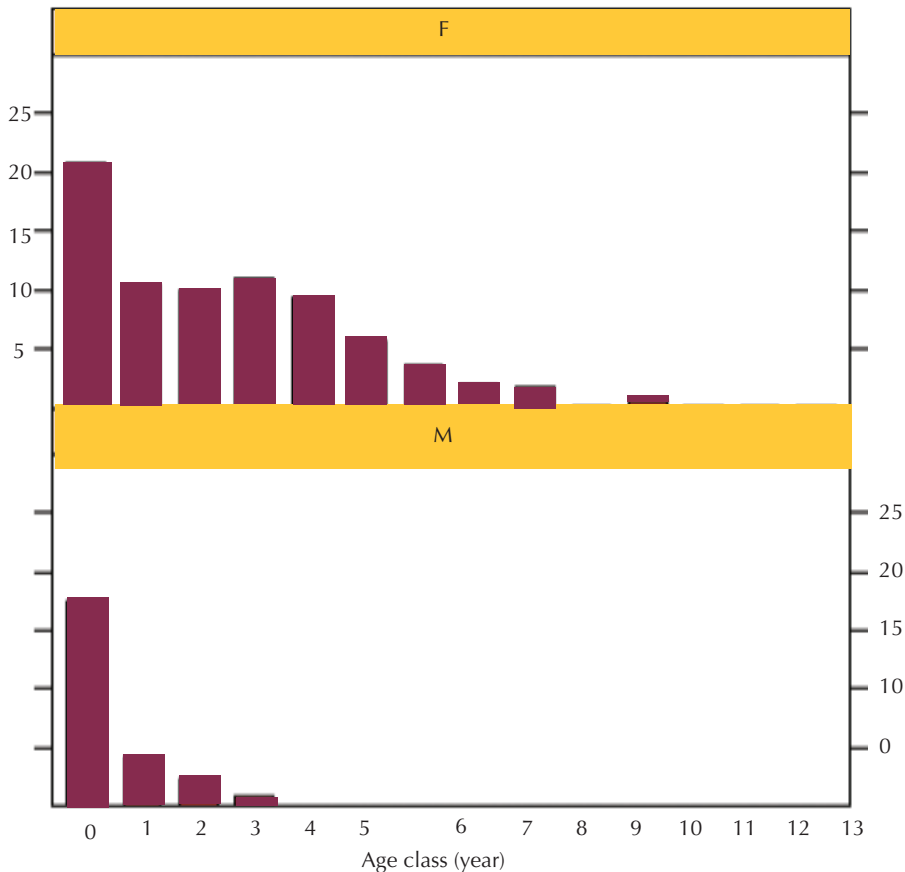
Age class 0 refers to animals of ≤1 year of age, age class 1 refers to animals >1 year and ≤2 years of age etc.

Figure 10. *Age-by-sex structure in the surveyed sheep flocks for females (F) and males (M).*

4.2   Reproduction

Parity in relation to age-class

Figure 11 shows age class vs. parity for the full reproductive history data. The average age of first parturition cannot be determined from this data, but the earliest age at first parturition appears to be 2 to 3 years. Other studies of sheep in Senegal (Wilson 1991) and sub-Saharan

Africa (Otte and Chilonda 2002) reported an average age of first parturition at 1.3–1.4 years. Animals of second parity are mostly 3 to 4 years of age and animals of third parity mostly 4 years of age (age classes 4).
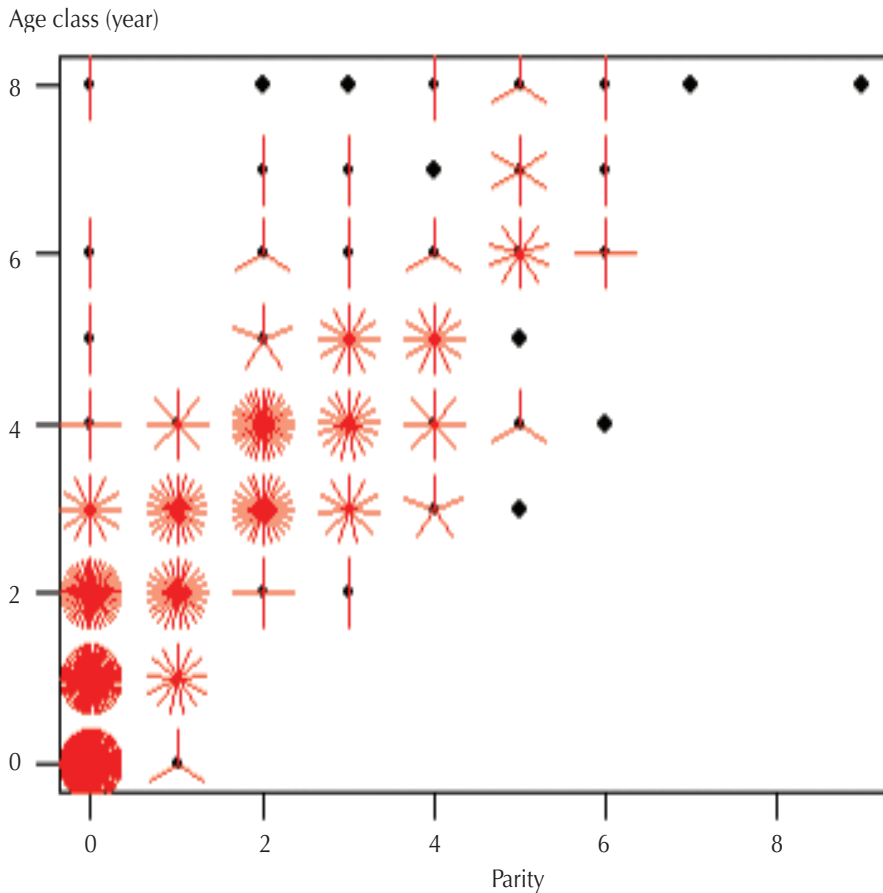
Age class (year)

Note: Age class 0 = animals of ≤1 year of age, age class 1 = animals >1 year and ≤2 years of age etc. Sheep of age class >8 were discarded due to the potential unreliability of this data.

Figure 11. *Parity in relation to age class (a sunflower plot where multiple points are shown as 'petals') for sheep.*

Parturition rates

Figure 12 shows parturition rate by age class for the 12 months data. The main increase in the annual parturition rate is seen from 0–3 years of age.

Estimates of annual parturition rates, for both the 12 months data for females ≥1, 2, and 3 years of age and the complete reproductive history of the females, are presented in Table 8. The estimates using the 12 months data were sensitive to the minimum age chosen for

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reproductive females (with rates of 0.70, 0.81 and 0.89 for females ≥1, 2, and 3 years of age respectively). The complete reproductive history gave a lower estimate of 0.63. This difference may be due to differences in year effect (i.e. some years having greater abortion rates than others), or due to biases created from using a recall survey method. In comparison, the parturition rate was found to be 1.36–1.50 in Senegal (Wilson 1991).
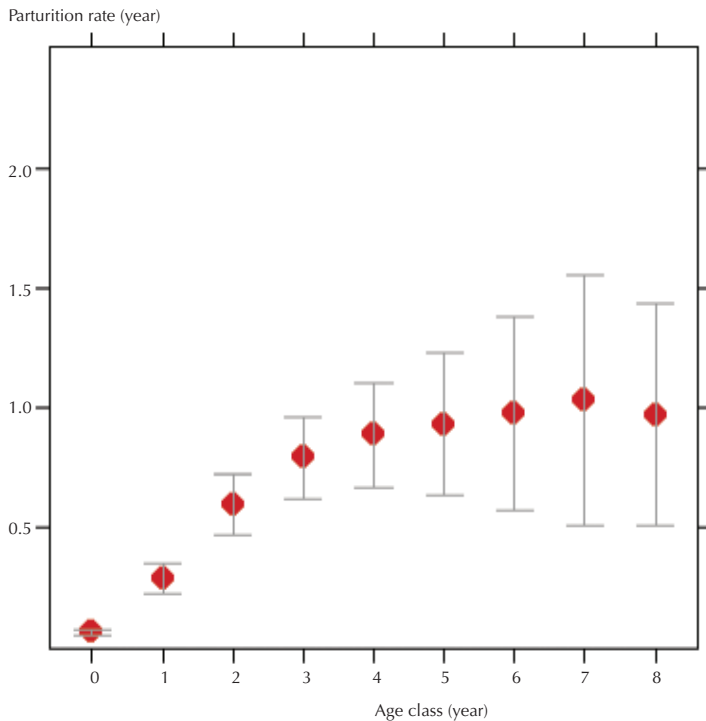
Note: Age class 0 = animals of ≤1 year of age, age class 1 = animals >1 year and ≤2 years of age etc. Sheep of age class >8 were combined into age class 8.

Figure 12. *Annual parturition rates of female sheep, with 95% confidence intervals indicated.*

Table 8. *Various estimates of the annual parturition rates for female sheep*

Data	Annual parturition rate (standard error)	Interval between parturitions, in days (year)[3]
12 months, all females ≥1 years of age[1]	0.70 (0.04)	521 (1.4)
12 months, all females ≥2 years of age[1]	0.81 (0.05)	450 (1.2)
12 months, all females ≥3 years of age[1]	0.89 (0.06)	410 (1.1)
Lifetime reproductive history of females[2]	0.63 (0.02)	579 (1.6)

1. Average annual rate of parturition based on number of parturitions of all females ≥1, 2 or 3 years during the last 12 months.

2. Average annual rate of parturition based on total number of parturitions of all females born in herd, and ≤9 years of age.

3. Calculated in days as 365/parturition rate.

Other reproductive parameters

Estimates of other reproductive parameters (abortion, stillbirth, prolificacy and fecundity rates) are given in Table 9. Of note is that the abortion rate was relatively high (0.07), and that the prolificacy rate was 1.09 as a result of some (8.8%) twin births. Other studies have found a prolificacy rate of 1.04–1.33 (Wilson 1991; Lesnoff 1999; Otte and Chilonda 2002).

Table 9. *Estimates of abortion, stillbirth, prolificacy and fecundity rates of sheep (standard errors)*

Parameter	Data source	Value
Annual abortion rate	12 months, all females ≥2 years of age[1,2]	0.07 (0.00)
	Lifetime reproductive history of females[3]	0.08 (0.01)
Stillbirth rate	12 months	0.01 (0.01)
Prolificacy rate	12 months	1.09 (0.02)
Net prolificacy rate	12 months	1.08 (0.02)
Annual fecundity rate	12 months, all females ≥2 years of age	0.88 (0.05)
Annual net fecundity rate	12 months, all females ≥2 years of age	0.87 (0.05)

1. Similar values were obtained for all females ≥ 3 years of age.
2. Based on number of abortion of all females ≥1 years during the last 12 months.
3. Based on total number of abortion of all females born in herd, and ≤7 years of age.

4.3   Natural mortality

Mortality rates are shown in Figure 13, and also given in Table 10 in subsection 4.4. Mortality rates were extremely high for all sex/age group combinations, ranging from 0.27 for female >1 year of age to 0.54 for males >1 year of age. The overall mortality rate was 0.32, meaning that for a flock with a constant size of 6 animals over the year, 1.9 deaths would be expected annually. This was somewhat similar to the average mortality rates observed by Lesnoff (1999) in north Senegal of 0.41 for females and 0.63 for males. Recalculated to probabilities[2] (see Appendix 1) the mortality rate of natural death was 0.28–0.32 for lambs and 0.24 for females >1 year of age. For lambs, this is similar to the 26% reported by Otte and Chilonda (2002) for sub-Saharan Africa, while it is considerably higher than their findings of an average ewe mortality of 8%.

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2. Effect of offtake rates not included.
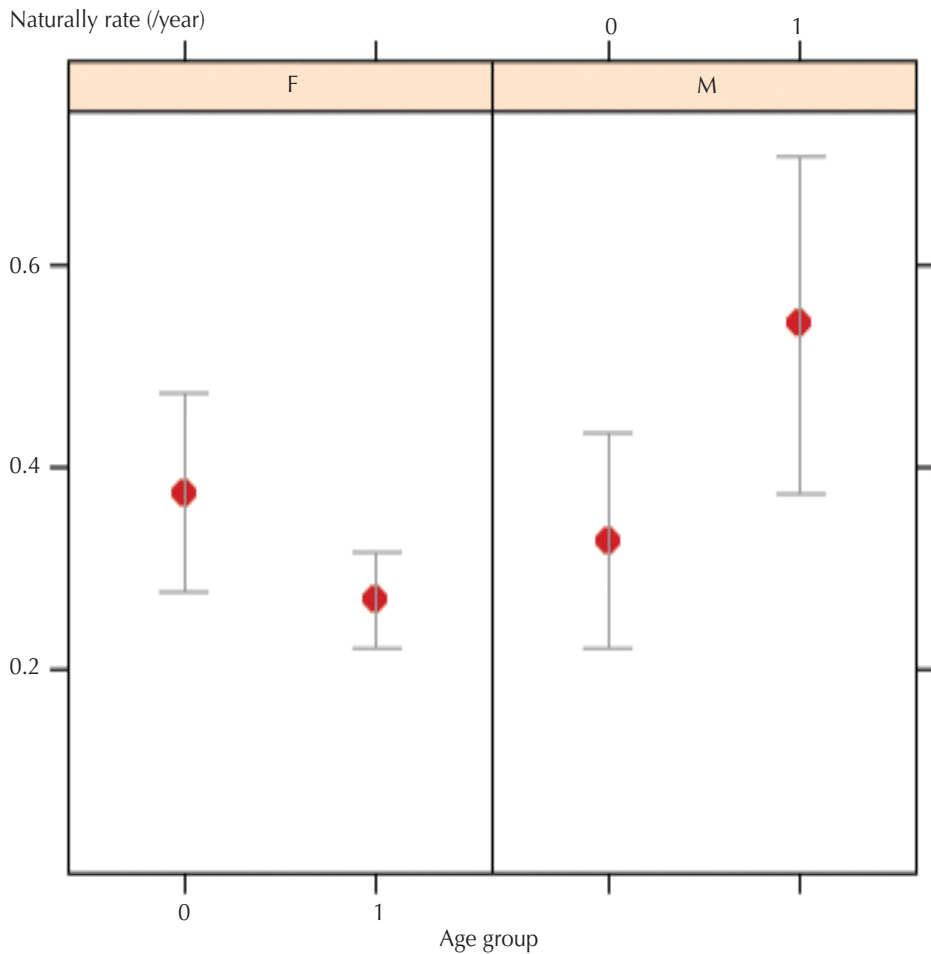
Age group 0 = animals ≤1 year of age, and age group 1 = animals >1 year.
Figure 13. *Annual mortality rates for natural death of sheep, for females (F) and males (M), with 95% confidence intervals.*

4.4   Offtake and intake

Offtake rates

The overall offtake rates, as well as the offtake rates by individual events (slaughtering, sales/barter, loans/contracts, gifts/dowry, withdrawal/theft) are given in Table 10. Rates of natural death (mortality) are included in this Table for comparison purposes. The overall rate of annual offtake was 0.15, meaning that for a flock with a constant size of 6 animals over the year, 0.9 exits would be expected annually. It is of note that the overall rate of offtake is much lower than the overall mortality rate. The highest offtake rate was for sale/barter of animals, followed by slaughter.

Table 10. *Annual offtake rates (standard errors) for sheep, for different offtake events*

Sex	Age	Offtake events						Natural death
		Slaughter	Sales, barters	Loans, contracts	Gift, dowry	Withdrawal, theft	Overall	
Female	≤1 year	0.01 (0.01)	0.01 (0.01)	0	0.01 (0.01)	0.02 (0.01)	0.05 (0.02)	0.38 (0.05)
	>1 year	0.03 (0.01)	0.05 (0.01)	0	0.01 (0.0)	0.03 (0.01)	0.10 (0.02)	0.27 (0.02)
Male	≤1 year	0.04 (0.02)	0.04 (0.02)	0	0.02 (0.01)	0.03 (0.02)	0.12 (0.03)	0.33 (0.05)
	>1 year	0.18 (0.05)	0.28 (0.06)	0	0.16 (0.05)	0.01 (0.01)	0.64 (0.09)	0.54 (0.09)
Overall		0.04 (0.01)	0.06 (0.01)	0	0.02 (0.01)	0.02 (0.01)	0.15 (0.01)	0.32 (0.02)

The main reasons for slaughter of animals was 'ordinary' (13 out of the 31 animals were recorded as being slaughtered, 92% [i.e. 12 out of the 13] male), followed by 'emergency disease' (8 out of 31, 25% male), and 'emergency lack of feed' (7 out of 31, 14% male). The main reasons for sale of animals were 'ordinary' (33 out of 48, 67% male), and 'emergency lack of feed' (9 out of 48, 44% male).

Intake rates

The overall rate of annual intake was 0.07, meaning that for a flock with a constant size of 6 animals over the year, 0.4 intake would be expected annually. Table 11 gives a breakdown of input rate by event (i.e. purchase/barters, loans/contracts, gifts/dowry/inheritance). As expected the highest intake rate was for purchase/barter.

Table 11. *Annual intake rates (standard errors) for sheep, for different intake events*

Sex	Age	Intake events			
		Purchases, barters	Loans, contracts	Gift, dowry, inheritance	Overall
Female	≤1 year	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.03 (0.01)
	>1 year	0.08 (0.01)	0.01 (0.01)	0	0.09 (0.01)
Male	≤1 year	0	0	0	0
	>1 year	0.08 (0.03)	0	0	0.08 (0.03)
Overall		0.06 (0.01)	0.01 (0.00)	0.00 (0.00)	0.07 (0.01)

Net offtake

Table 12 summarizes the overall annual offtake and intake rates by sex and age class. The highest rate of net offtake (at 0.55) was for males >1 year of age: from Table 10 it can be

observed that this is primarily through sales/barter and slaughter. The total net offtake rate was 0.08, meaning that for a flock with a constant size of 6 animals over the year, a net offtake of 0.5 animal is expected annually.

Table 12. *Net offtake rates for sheep, as well as the underlying offtake and intake rates (standard errors)*

	Female		Male		Total
	≤1 year of age	>1 year of age	≤1 year of age	>1 year of age	
Offtake	0.05 (0.02)	0.10 (0.02)	0.12 (0.03)	0.64 (0.09)	0.15 (0.01)
Intake	0.03 (0.01)	0.09 (0.01)	0	0.08 (0.03)	0.07 (0.01)
Net offtake	0.02 (0.02)	0.01 (0.02)	0.12 (0.03)	0.56 (0.10)	0.08 (0.02)

4.5   Overall demographic indicators

The annual population multiplication rate, as the total flock size at the date of this survey (833) divided by the total flock size 12 months ago (783) was calculated to be 1.06. This indicates a positive growth rate of 6% for the year. Annual herd productivity, as the balance between total births and deaths (95) divided by the mean total flock size (808) was 0.12.

5   Goat results

5.1   Herd sizes and structure

Herd size

The surveyed goat herd sizes ranged from 4 to 21 animals, with a mode (most frequent herd size) of 8 (Figure 14). Almost all animals ≤1 year of age, as well as males >1 year of age, were born in the herd (97% and 98%, respectively), whereas only 82% of females >1 year of age were born in the herd. All goat herds were single household owned.
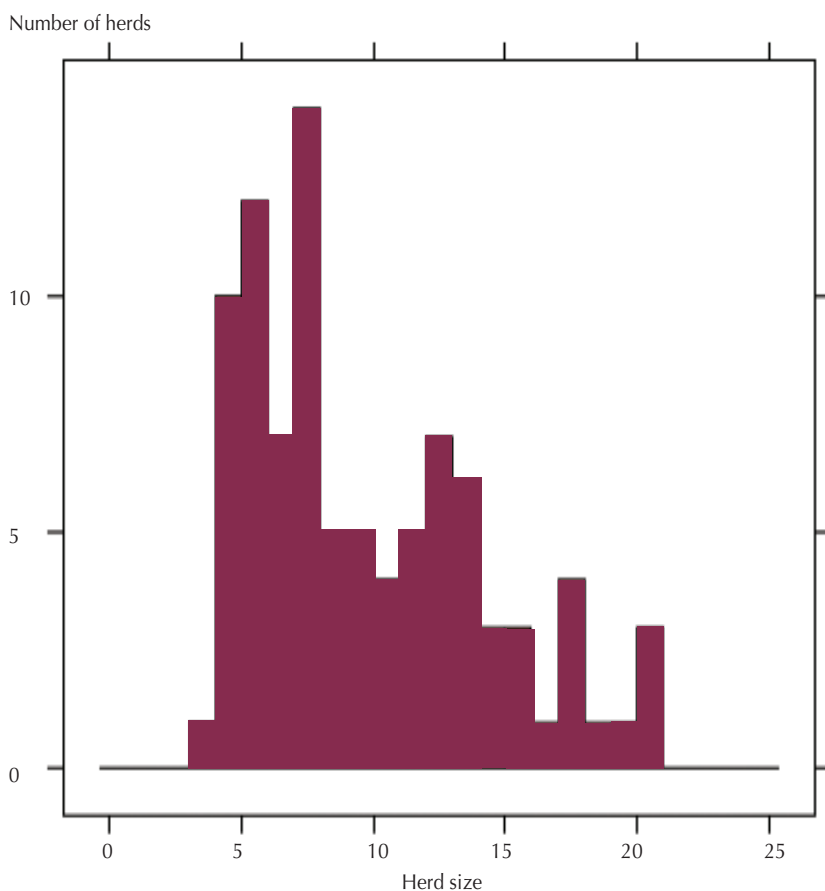
Figure 14. *Distribution of goat herd size.*

Age-by-sex structure

The age-by-sex structure is shown in Figure 15. The combined flocks comprised 26% females ≤1 year of age, 20% males ≤1 year of age, 49% females >1 year of age, and 5% males >1 year of age. The majority of females (98%) were ≤8 years of age, and the majority of males

(93%) were ≤2 years of age. The reason for the drop in percentage of animals in age class 1 is not clear, but an investigation of entries and exits by age-class suggests this drop may mainly be related to a high number of exits through mortality at age class 0, and to some extent exits through sales/slaughter/gift/loan/theft at age classes 0–2 (>0 to ≤3 years of age) (see Table 15), coupled with purchases of females at age classes 1 and 2 (>1 to ≤3 years of age) and no entries beyond age class 0 for males (see Table 16).

Proportion of animals (%)
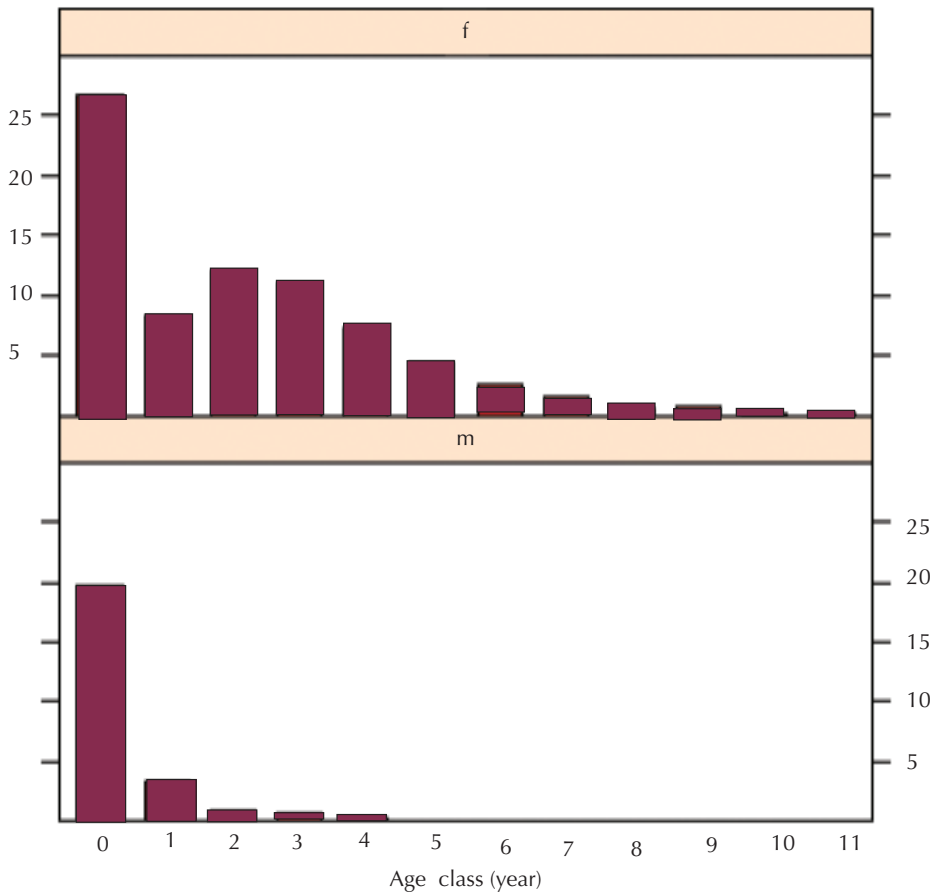
Age class 0 = animals of ≤1 year of age, age class 1 = animals >1 year and ≤2 years of age etc.
Figure 15. *Age-by-sex structure in the surveyed goat herds for females (F) and males (M).*

5.2   Reproduction

Parity in relation to age-class

Figure 16 shows age class vs. parity for the full reproductive history data. The average age at first parturition cannot be determined from this study, but the earliest age at first parturition

appears to be 1 to 3 years. Other studies gave an average age of first parturition of 1.0 year in Senegal (Wilson 1991) and 1.3 years in sub-Saharan Africa (Otte and Chilonda 2002). Animals of second parity are mostly 2 to 3 years of age and animals of third parity mostly 3 to 4 years of age. Relatively few animals had a parity of three or greater.

Proportion of animals (%)
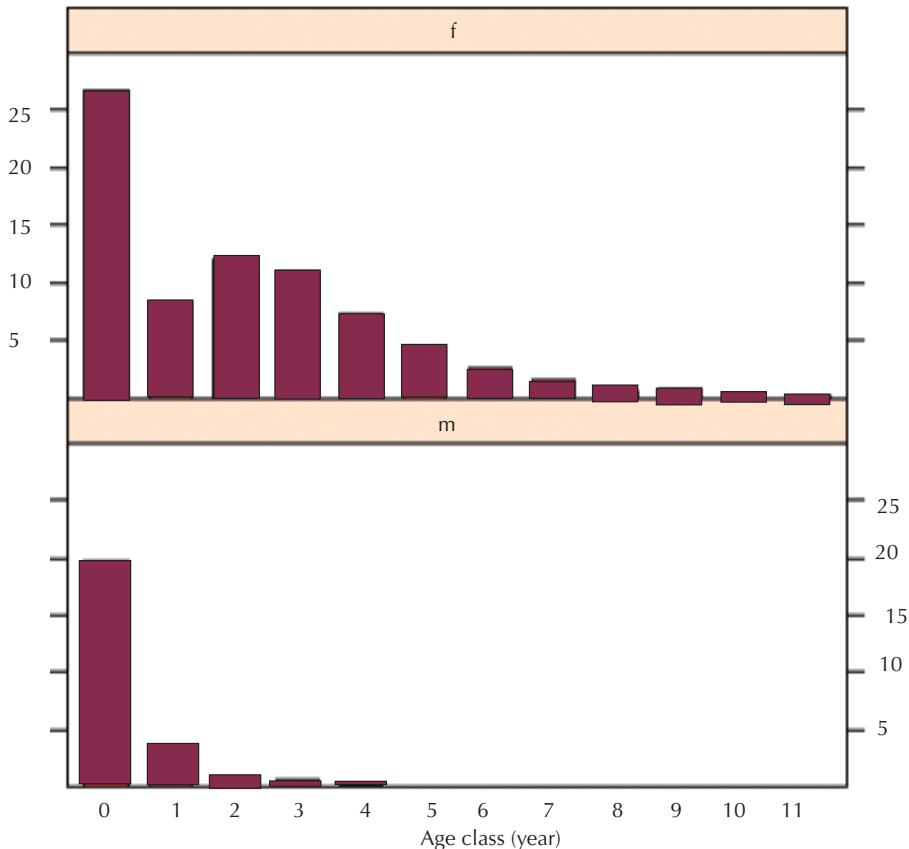
Age class 0 = animals of ≤1 year of age, age class 1 = animals >1 year and ≤2 years of age etc. Goats of age class >8 were discarded due to the potential unreliability of this data.

Figure 16. *Parity in relation to age class (a sunflower plot where multiple points are shown as 'petals') for goats.*

Parturition rates

Figure 17 shows parturition rate by age class for the 12 months data. Note the jump in annual parturition rate from ≤1 year of age to >1 year of age.

Estimates of annual parturition rates, for both the 12 months data for females ≥1, 2, and 3 years of age respectively and for the complete reproductive history of the females, were presented in Table 13. The estimates using the 12 months data were sensitive to the minimum age chosen for reproduction. The complete reproductive history gave a lower estimate of 0.7. This

difference may be due to differences in year effect (i.e. some years having greater abortion rates than others), or due to biases created from using a recall survey method. In comparison the parturition rate was observed to be 1.4–1.6 for WAD goats in Senegal (Wilson 1991).

Parturition rate (/year)
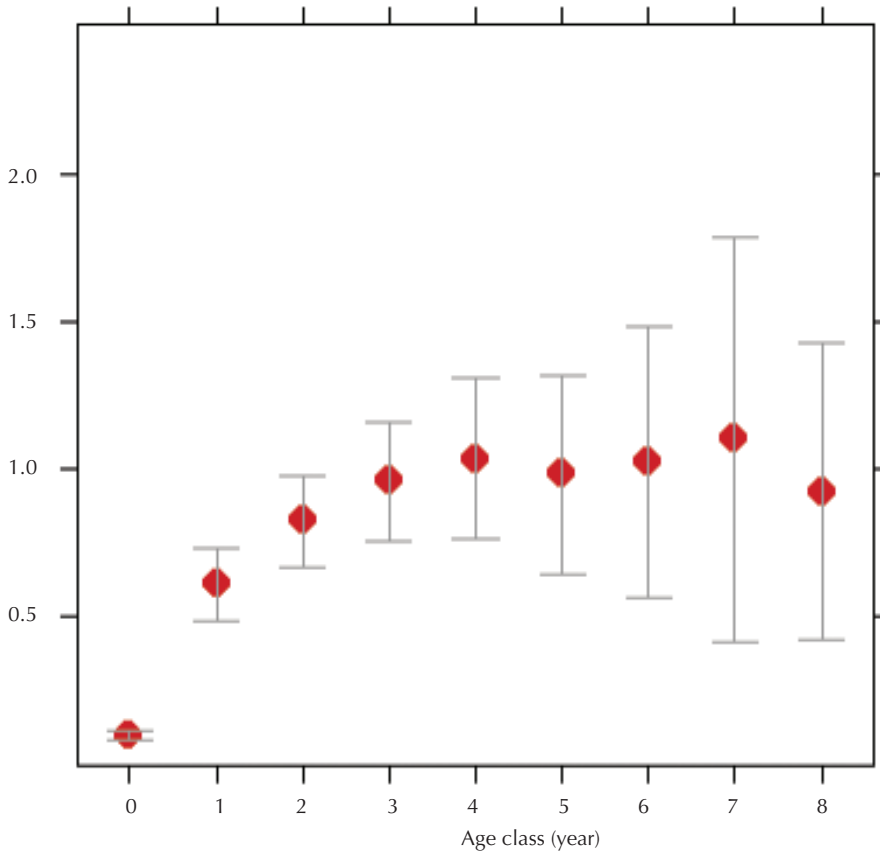
Age class (year)

Age class 0 = animals of ≤1 year of age, age class 1 = animals >1 year and ≤2 years of age etc. Goats of age class >8 were combined into age class 8.

Figure 17. *Annual parturition rates of female goat, with 95% confidence intervals indicated.*

Table 13. *Various estimates of the annual parturition rates for female goat*

Data	Annual parturition rate (standard error)	Interval between parturitions, in days (year)[3]
12 months, all females ≥1 years of age[1]	0.86 (0.04)	424 (1.2)
12 months, all females ≥2 years of age[1]	0.94 (0.05)	388 (1.1)
12 months, all females ≥3 years of age[1]	0.99 (0.07)	369 (1.0)
Lifetime reproductive history of females[2]	0.70 (0.02)	521 (1.2)

1. Based on number of parturitions of all females ≥1 years during the last 12 months.
2. Based on total number of parturitions of all females born in herd, and ≤8 years of age.
3. Calculated in days as 365/parturition rate.

Other reproductive parameters

Estimates of other reproductive parameters (i.e. abortion, stillbirth, prolificacy and fecundity rates) are given in Table 14. Of note is that the abortion rate was high (0.11), and that the prolificacy rate was 1.28 as a result of 23% twin births and 2% triplet births. The latter is slightly lower than the prolificacy rate of 1.5 found in Senegal (Wilson 1991) and 1.4 found in sub-Saharan Africa (Otte and Chilonda 2002).

Table 14. *Estimates of abortion, stillbirth, prolificacy and fecundity rates of goats (standard errors)*

Parameter	Data source	Value
Annual abortion rate	12 months, all females ≥1 years of age[1,2]	0.11 (0.01)
	Lifetime reproductive history of females[3]	0.12 (0.01)
Stillbirth rate	12 month	0.06 (0.01)
Prolificacy rate	12 month	1.28 (0.03)
Net prolificacy rate	12 month	1.20 (0.03)
Annual fecundity rate	12 months, all females ≥1 years of age	1.10 (0.06)
Annual net fecundity rate	12 months, all females ≥1 years of age	1.03 (0.06)

1. Similar values were obtained for all females ≥3 years of age.
2. Based on number of abortions of all females ≥1 years during the last 12 months.
3. Based on total number of abortions of all females born in herd, and ≤8 years of age.

5.3   Natural mortality

The mortality rates are shown in Figure 18, and Table 15 in subsection 5.4. They were extremely high for all sex/age group combinations, ranging from 0.25 for females >1 year of age to 0.53 for males >1 year of age. The overall mortality rate was 0.34 (SE 0.02), meaning that for a flock with a constant size of 8 animals over the year, 2.8 deaths would be expected annually. It can be noted that, although high, the mortality rate for females >1 year of age was considerably lower than for the other age groups. Recalculated to probabilities[3] (see Appendix 1), the mortality rate was 0.34–0.36 for kids, while doe mortality was 0.22 and male mortality was 0.41. This is higher than the 24–28% kid mortality and 14–16% adult mortality found in other studies in Mali (Ba et al. 1996) and sub-Saharan Africa (Otte and Chilonda 2002).

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3. Effect of offtake rates not included.

Mortality rate (/year)
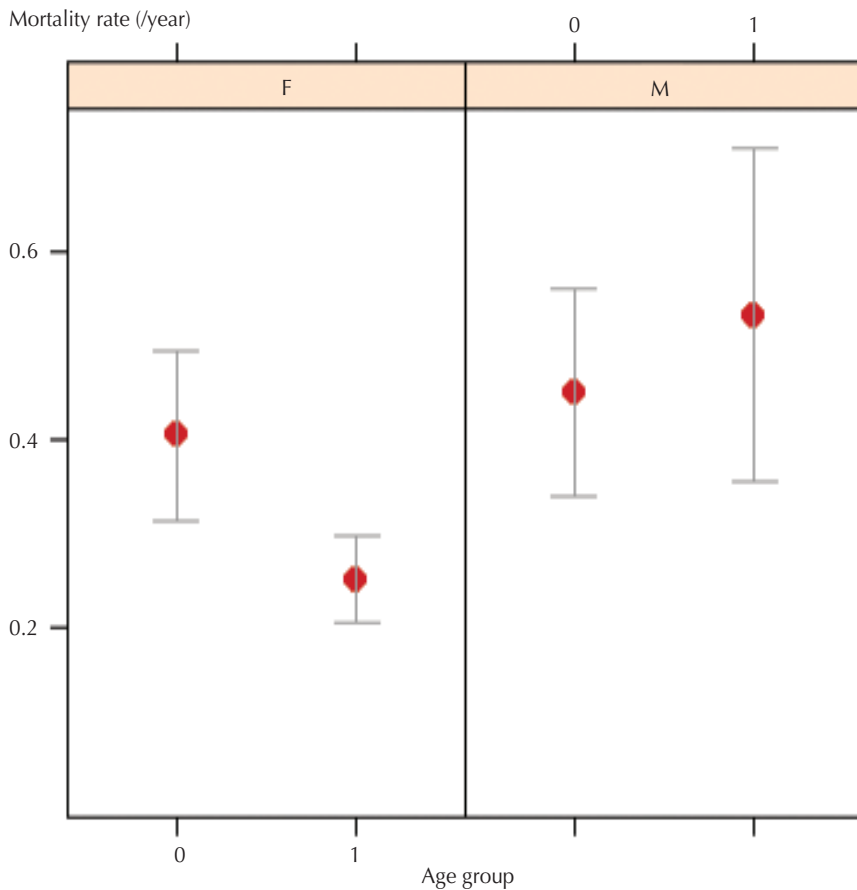
Age group 0 = animals ≤1 year of age, and age group 1 = animals >1 year.
Figure 18. *Annual mortality rates for natural death of goats, for females (F) and males (M), with 95% confidence intervals indicated.*

5.4   Offtake and intake
Offtake rates

Overall offtake rates, as well as offtake rates by individual events (i.e. slaughtering, sales/barter, loans/contracts, gifts/dowry, withdrawal/theft) are given in Table 15. Rates of natural death (mortality) are included in this table for comparison purposes. The overall rate of annual offtake was 0.21, meaning that for a flock with a constant size of 8 animals over the year, 1.7 exits would be expected annually. It is of note that the overall rate of offtake is much lower than the overall mortality rate. If withdrawal/theft is excluded, the overall rate of annual offtake is 0.18. The highest offtake rates were for sale/barter animals, followed by slaughter, and gift/dowry.

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Table 15. *Annual offtake rates (standard errors) for goats, for different offtake events*

Sex	Age	Offtake event						Natural death
		Slaughter	Sales, barters	Loans, contracts	Gift, dowry	Withdrawal, theft	Overall	
Female	≤1 year	0.03 (0.01)	0.04 (0.01)	0	0.01 (0.01)	0.01 (0.01)	0.08 (0.02)	0.41 (0.05)
	>1 year	0.06 (0.01)	0.04 (0.01)	0.01 (0.01)	0.02 (0.01)	0.03 (0.01)	0.17 (0.02)	0.25 (0.02)
Male	≤1 year	0.05 (0.02)	0.09 (0.03)	0	0.04 (0.02)	0.01 (0.01)	0.19 (0.04)	0.45 (0.06)
	>1 year	0.24 (0.06)	0.35 (0.07)	0.09 (0.04)	0.15 (0.05)	0.06 (0.03)	0.90 (0.12)	0.53 (0.09)
Overall		0.07 (0.01)	0.07 (0.01)	0.01 (0.00)	0.03 (0.01)	0.02 (0.01)	0.21 (0.02)	0.34 (0.02)

The main reasons for slaughter of animals was 'emergency disease (34 out of the 60 animals were recorded as being slaughtered, 82% of these were male), followed by 'ordinary' (21 out of 60, 71% male). The main reasons for sale of animals were 'ordinary' (59 out of 65, 51% male).

Intake rates

The overall rate of annual intake was 0.06, meaning that for a flock with a constant size of 8 animals over the year, 0.5 intake would be expected annually. Table 16 gives a breakdown of input rate by event (i.e. purchase/barters, loans/contracts, gifts/dowry/inheritance). As expected, the highest intake rate was for purchase/barter of animals. It is of note that the intake rate of males is considerably lower than the intake rate of females.

Table 16. *Annual intake rates (standard errors) for goats, for different intake events*

Sex	Age	Intake event			
		Purchases, barters	Loans, contracts	Gift, dowry, inheritance	Overall
Female	≤1 year	0.02 (0.01)	0.03 (0.01)	0	0.04 (0.02)
	>1 year	0.07 (0.01)	0.02 (0.01)	0	0.09 (0.01)
Male	≤1 year	0	0.01 (0.01)	0	0.01 (0.00)
	>1 year	0	0	0	0
Overall		0.04 (0.01)	0.02 (0.00)	0	0.06 (0.01)

Net offtake

Table 17 summarizes the annual offtake and intake rates, combined for all events, by sex and age class. The highest rate of net offtake (at 0.9) was for males >1 year of age: from Table 15 it can be observed that this is primarily through sales/barter. The overall rate was 0.15, meaning that for a flock with a constant size of 8 animals over the year, a net offtake of 1.2 animals is expected annually.

Table 17. *Net offtake rates for goats, as well as the underlying offtake and intake rates (standard errors)*

	Female		Male		Total
	≤1 year of age	>1 year of age	≤1 year of age	>1 year of age	
Offtake	0.08 (0.02)	0.17 (0.02)	0.19 (0.04)	0.90 (0.12)	0.21 (0.02)
Intake	0.04 (0.02)	0.08 (0.01)	0.01 (0.00)	0	0.06 (0.01)
Net offtake	0.04 (0.03)	0.09 (0.02)	0.18 (0.04)	0.90 (0.12)	0.15 (0.02)

5.5   Overall demographic indicators

The annual population multiplication rate, as the total herd size at the date of this survey (945) divided by the total herd size 12 months ago (856) was calculated to be 1.10. This indicates a positive growth rate of 10% for the year. Annual herd productivity, as the balance between total births and deaths (202) divided by the mean total herd size (901) was 0.22.

6   Discussion

The purposes of this survey were, as mentioned: i) to estimate demographic parameters for herds/flocks in the PROGEBE-Gambia project sites, which combined with other information sources, could be used for prioritizing project interventions; ii) compare demographic productive parameters between ERL and non-ERL; and iii) to be used as a baseline for evaluating impacts of project interventions. The survey was not designed to evaluate demographic productivity parameters over the long-term, which should be kept in mind when reading the discussion. For validation of the results and evaluation of demographic productivity parameters over the long-term, a long-term longitudinal survey is recommended.

The major results found and their implication for prioritizing future project interventions are discussed, as well as the suitability of using the data as a baseline for evaluating impact of project interventions. Due to the very low number of non-ERL found within the surveyed sites (0.2–4.6% of surveyed animals), a comparative analysis of ERL and non-ERL demographic parameters was not possible. However, the implications of this finding on project priorities and future breeding strategies are discussed in brief.

Key demographic parameters

Of all results presented the most striking was the high mortality rates, for cattle ≤1 year of age, as well as sheep and goat across all ages. This was in general found to be similar to the findings of other studies, although variation between studies were found, especially for sheep and goats (Wilson 1991; Ba et al. 1996; Agyemang et al. 1997; Lesnoff 1999; Otte and Chilonda 2002; Ba et al. 2011). For cattle, the overall mortality rate equalled the overall offtake rate for all other events (slaughter, sale etc.) combined, whilst for the small ruminants the overall mortality rate by far exceeded the overall offtake rate for all other events combined. Estimated losses for a typical herd/flock of 40 cattle, 6 sheep or 8 goats (assuming constant herd/flock size over the year) are 3.2, 1.9 and 2.8 animals, respectively, per annum. It is thus suggested that addressing mortality should be one of PROGEBE's priority interventions.

The data interviewee perception of the 12-month study period suggest that the major cause of mortality could be disease for all three species (mainly PPR for sheep and goats), while lack of feed resources also could have some importance, especially to cattle herds. This is supported by the fact that 'emergency disease' was cited as a main reason for slaughter of ERL in this survey. However, additional investigations on the major constraints to livestock production by the PROGEBE-Gambia PRA survey indicate that water shortage and lack of feed resources are at least as important constraints to livestock production as disease (ILRI 2010). This could possibly be due to the fact that this survey is confined to the previous 12

months, whereas the PRA survey was based on lifetime recollection. It should therefore be safe to assume that all three constraints will, directly or indirectly, be of importance in the project sites over time and should therefore all be prioritized. Further details on disease, water and feed constraints can be found in the PROGEBE-Gambia Baseline Report (ILRI 2010).

In the short to medium term (next few to 20 years) the high mortality rates are likely best addressed through changes to management practices, especially in relation to feed/water resources and diseases. In the much longer term (20 to 50 years) it may be possible to reduce mortality by genetically improving disease resistance of the animals through breeding programs. Inclusion of disease resistance as a breeding objective in a breeding program (which should occur along with other traits of interest such as reproductive ability, growth rate etc.) requires an appropriate selection criteria (quantifiable variable) to be identified, and some work would be required in this area. It is also important to know the genetic and phenotypic correlations (relationships) between disease resistance and other breeding objective traits, however, literature estimates of these could be used in the interim. Note that the long-term approach to genetic improvement is essential as within a typical breeding nucleus only about 1 to 3% change in mean performance can be affected per annum (Falconer and Mackay-Longman 1996). Further there is a 'dilution' of, and time-lag related to, this improvement if nucleus animals are mated to (non-genetically improved) animals from the multiplier tier, and as animals from this mating are subsequently mated to (non-genetically improved) animals from the commercial tier.

There was wide variation in the age at first calving for cattle (generally 4 to 6 years), as well as the age at first lambing/kidding for small ruminants (generally 1 to 3 years). This points towards a considerably higher average age of first parturition compared to other studies for all species (Wilson 1991; Agyemang et al. 1997; Lesnoff 1999; Otte and Chilonda 2002) and could potentially be due to inaccurate recall of female age and number of parturition. However, it could also in part be due to differences in management practices. Improved management to decrease the average age at first parturition, as well as reduce the interval between parturitions (e.g. feed supplementation), should also be considered as a potential PROGEBE intervention.

The abortion rate was found to be high for sheep (0.07) and especially goats (0.11). The stillbirth rate for goats was also relatively high at 0.06. Abortion and stillbirths in sheep and goats in the humid tropics of West Africa have been found to mainly be associated with starvation and diseases (Oppong 1988). Improved management of feed resources and diseases for sheep and goats in order to decrease the abortion and stillbirth rate should therefore also be considered.

The net prolificacy rate of sheep and goat was found to be approximately 1.1 and 1.2, respectively. This is lower than found in other studies (Wilson 1991; Lesnoff 1999; Otte and Chilonda 2002) and could as well be improved through better management practices, and in the long-term via genetic improvement. A recommendation is that all breeding programs (cattle, sheep and goat) include either the maintenance of, or improvement of, reproductive performance as a breeding objective. This is because there is a risk of lowering reproductive performance over time if it is not included in the breeding objective, should a negative genotypic or phenotypic correlation to other breeding objective traits exist. Further the Gambia PRA (ILRI 2010) indicated the primary reason smallholders' keep livestock is for 'savings and insurance', meaning that it is important for animals to both reproduce and survive.

Findings on existing breeding strategies

All three ERL had animals not born within the herd/flock. The proportion of introduced animals was reasonable for females (14 to 18%, dependant on species and age class) and male cattle (13%), but low for male sheep (8%) and male goat (2%). This is somehow consistent with the findings from the PROGEBE-Gambia household survey (ILRI 2010). The use of 'outside' animals as breeding animals is important to keep the rate of inbreeding to an acceptable level (inbreeding is caused by the mating of relatives and typically results in reduced fitness and reproductive ability). Continuation of this practice should be encouraged.

It was also found that males only make up to 5–7% of the herds/flocks, which is indicated for a great part be due to a higher offtake via sales or slaughter of adult males compared to adult females for all species. The reasons for this could be many (e.g. that males fetch higher prices due to larger body size [Nwafor 2004] or that livestock keepers prefer to keep females, since the number of progeny is directly related to number of females and not males) and require further investigation. This, however, suggests that controlled breeding is used across species, whether with a specific breeding strategy in mind or not. It is uncertain whether the males remaining in the flock are genetically superior, or whether the genetically superior males are sold (as e.g. they can fetch higher market prices due to corresponding phenotypic superiority) leaving the inferior males as breeding animals.

The PROGEBE-Gambia household survey results found knowledge and use of breeding strategies to be relatively low (i.e. 17–36% of households in each site were knowledgeable about inbreeding, 11–41% used controlled breeding and 5–21% of households had sought information in relation to breeding). However, the results of this survey could suggest that the use of breeding strategies, such as avoiding inbreeding and use of controlled breeding, is common across species and especially for cattle and sheep, whether recognized or not.

Capacity building programs on basic principles and practices of breeding, as well as management practices to reduce mortality and improve other key parameters, are thus recommended to improve awareness of traditional and alternate breeding and management practices on livestock performance.

Considerations for future breeding strategies

The finding that almost all ruminant livestock within the surveyed sites were ERL (99.1, 95.4 and 99.8% for cattle, sheep and goats, respectively) is supported by the results of the PROGEBE-Gambia household survey (99.5, 96.9 and 100%, respectively) and a Gambian livestock census from 2009 (99.7, 96.5 and 99.9%, respectively) (ILRI 2010). These results clearly indicate that the populations of ERL in the project intervention sites are currently not marginalized due to the introduction of non-ERL.

The above results also show that non-ERL are mainly found in sheep flocks and to a lesser extent cattle herds, while the presence of non-ERL is insignificant in goats flocks. This difference between species could be due to a range of factors such as: gender differentiated ownership; availability and suitability of non-ERL breeds; external support etc.

The population growth rate over the 12 months period was positive for all three ERL, at about 16% for cattle, 6% for sheep, and 10% for goats (relative to numbers at the start of the period). While this could be considered a positive trend, it also calls for caution regarding the natural resources available. A positive population growth rate in an area with competition for land for cultivation and conservation could potentially lead to overstocking and/or conflicts over land (Zaibet et al. 2010). Project interventions to increase the survival and reproduction parameters will only amplify this effect. Any strategy aimed at increasing livestock population must consider current and future natural resource use patterns, and the possible trade-offs (see Zaibet et al. 2010). It could also be useful to consider improving productivity per animal, rather than increasing animal number *per se*.

Considerations for use of survey data

The demographic parameters presented here can be used as baseline parameters for PROGEBE but with care as they relate to a particular 12 months interval, which is subject to a particular set of environmental conditions. If a follow-up survey is performed in a year rated different to the baseline year it may be difficult to estimate the impact of project interventions. For example, if project interventions have had a positive impact on the demographic parameters reported here, but a follow-up survey is performed in an unusually poor year, the parameters will (artifactually) appear to have either stayed the same or become worse. Conversely, if project interventions have had no impact on the demographic

parameters reported here, but a follow-up survey is performed in an unusually good year, the parameters will (artifactually) appear to have improved. As the rating of the 12-month interval was indicated to be highly dependent on the disease incidence, attention should particularly be paid to this.

The demographic parameters estimated here, combined with other data (such as that from the household survey and livestock census), can also be used to model the expected impact of breeding interventions. For example, for a particular breeding strategy (e.g. with a given nucleus size, number of multiplier units etc.) it is possible to estimate the percent genetic improvement of the commercial animals in say 10, 20, 30 etc. years. Ideally the percent genetic improvement would then be translated to a more meaningful indicator such as value to households (e.g. increased income) or value to the livestock industry. Alternatively the model could be used to back-calculate the size of the breeding program required to give a pre-set level of genetic improvement (or improvement in an alternate indicator) in the commercial population within a certain time frame. It is strongly recommended that such an exercise be conducted in the near future to assist in the planning of PROGEBE breeding activities.

7 Conclusion and summary of main recommendations

The findings of this survey clearly indicate that N'Dama cattle, Djallonké sheep, and WAD goats are the prominent breeds in the PROGEBE-Gambia project areas and suggest that some level of controlled breeding seems to be applied in most herds/flocks, primarily through sire selection (although these may or may not be implemented with a specific breeding objective in mind). There seem to be a considerable scope for improvement of demographic parameters through improved herd/flock management in the short term, and breeding strategies in the long term. The single most striking result is the natural mortality rate, which was found to be very high for cattle less than one year of age and for sheep and goats across all age groups. The results from this survey were based on 12-month retrospective data and especially the mortality rate is likely to vary considerably from year to year (Lesnoff 1999). However, although the mortality rate may be found to be lower in other years these results still indicate that years with high mortality rates do occur.

Specifically, it can be recommended that PROGEBE consider/prioritize the following issues for future project activities or interventions:

• Interventions towards lowering the natural mortality, including vulnerability to external shocks such as drought and disease. In the short to medium term (next few to 20 years) this should mainly be through changes to management practices. The results of the interviewees' perception of the 12 months study period, as well as the PROGEBE PRA survey (ILRI 2010), suggest that the main areas of intervention should be in relation to feed/water resources and diseases. However, any scheme of interventions should be based on local conditions and further investigations are required in this regard. In the much longer term (20 to 50 years) it may be possible to reduce mortality by genetically improving disease resistance of the animals through a breeding program.

• Interventions to improve other demographic parameters could as well be worth prioritizing, namely, age at first parturition, parturition interval, prolificacy rates and abortion rates. Again, this should mainly be through changes in management practices in the short-term, while in the longer term these parameters could potentially be improved through genetic improvement. Required interventions are likely to be in the areas of disease control and access to feed and water resources, and should be location specific.

• A modelling study using the demographic parameters estimated here, combined with other data from the household survey, livestock census and literature to determine the expected impact of potential PROGEBE interventions (such as improved health-care, feeding and/or animal genetic improvement) over different time horizons.

• Capacity building programs to improve awareness of traditional and alternate husbandry and breeding management practices and the effect these have on livestock production and productivity.

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Appendix 1: Illustrative example of instantaneous hazard rates in relation to this survey

Assume a 12 months retrospective survey, from which we will calculate annual instantaneous hazard rates (referred to as rates below for short). The herd/flock structure, and events happening during the 12 months survey period, are as follows:

Sex, age	Number of animals at the start of the 12 months period	Events (each uniformly distributed across the year)	Number of animals at the end of the 12 months period, i.e. at time of survey
Females ≤1 year	3	2 deaths	2 (the 2 females born)
Females >1year	6	birth of 2 females and 1 male offspring (from females >1 year) one adult female purchased	8 (the 6 initial + the 1 remaining young female which is now >1 year of age + the 1 purchased)
Males ≤1 year			1 (the 1 male born)
Males >1year	1		1
Total	10		12

The hazard rate (h) for a particular category (sex and age class) is calculated as the number of events (m) divided by the time the animals have spent in that category (T): $h = m/T$. If all of the above data were available we would calculate T as the average of the number of animals in a particular category at the start and end of the 12 months period.

Examples:

- The overall mortality rate is equal to 2/11 = 0.18, as there were 2 mortalities across all age-sex classes and T = (10 + 12)/2 = 11. Thus for a herd with a constant size of 100 animals over the year, 18 deaths would be expected annually (as 0.18 * 100 = 18).
- The mortality rate for young females is 2/2.5 = 0.80, as there were 2 mortalities of young females, and T = (3+2)/2 = 2.5. Thus for a herd with a constant size of 20 young females over the year, 16 deaths of young females would be expected annually (as 0.80 * 20 = 16).
- The overall purchase rate is 1/11 = 0.09, as there was 1 purchase across all age-sex classes and T = (10 + 12)/2 = 11. Thus for a herd with a constant size of 50 animals over the year, 4.50 purchases would be expected annually (as 0.09 * 50 = 4.50).
- The parturition rate for females >1 year of age is 3/7 = 0.43, as there were 3 births to adult females and T = (6 + 8)/2. Thus for a herd with a constant size of 10 adult females over the year, 4.3 parturitions would be expected annually (as 0.43 * 10 = 4.3).

In reality, however, the number of animals at the start of the 12 months period is not known (as the survey is retrospective and being conducted at the end of the 12 months period). This is thus approximated as 'the number of animals present at the time of the survey – entries over the 12 months + exits over the 12 months'. For the above example, over all sex-age classes, it is:

[12 animals present at time of survey] – [3 births + 1 purchase] + [2 deaths] = 10.

This concept is extended to individual age classes. The number of animals within a particular age class (i) at the start of the survey is approximated as 'the number of animals present at the time of survey in age class$_{i+1}$ – 0.5 * (net entries for age class$_i$) – 0.5 * (net entries for age class $_{i+1}$)'. The 0.5 is because we assume that animals enter/exit age classes uniformly throughout the year, thus on average each animal spends half a year in the herd.

Relationship between hazard rates and probabilities

It is important to note that hazard rates are not the same as probabilities. The equation relating hazard rates to probabilities is as follows:

$$p = 1 - \exp(-h * \Delta t)_{\, p \,=\, 1}$$

where p is the probability, h the hazard rate, and $\Delta\Delta t$ the length of the decomposition unit. For example, in this survey an annual instantaneous mortality rate of 0.5, would correspond to an annual probability of death of 0.39, as:

$$p = 1 - \exp(-0.5 * 1) = 0.39$$

Thus 39% of animals (rather than 50%) would be expected to die within a year.

For more details in relation to this, including theoretical background, see Lesnoff et al (2010b).