Calf mortality and parasitism in periurban livestock production in Mali

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Dedicated to my beloved husband, my adorable children and my wonderful parents

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SUMMARY

Cattle production is very important for the Malian economy. However, the domestic milk production does not cover the local demand, so that 60% of consumed dairy products are imported. To increase local milk production, a modernisation of livestock management in periurban areas has taken place during the last few decades, especially around Bamako. This change from traditional to modernised management with crossbreeding with European breeds and increased investments in housing, nutrition and parasite control may have an impact on calf mortality, for example with regard to the occurrence of ecto- and endoparasites, the main causes for health problems of cows and calves around Bamako. Calf mortality has a crucial negative influence on milk production, as local breeds need the stimulus of their suckling calves for milk let down. West African studies with traditional and on-station managed herds report calf (0-12 months) mortality rates between 3% and 47%. Although modernised management becomes more and more important in periurban areas, no information had been available on calf mortality and its causes in modernised private periurban livestock production in West Africa. Neither had calf mortality in traditionally managed herds been compared to calf mortality in modernised managed herds in periurban areas. This is essential for the economical evaluation of the ongoing modernisation. The overall aim of this study was to determine mortality rates in different management systems and to elucidate causes and risk factors for calf mortality in the periurban area of Bamako, with an emphasis on the effects of endo- and ectoparasites on calf mortality.

Within a longitudinal cohort approach including 762 calves in 38 herds of the periurban zone of Bamako, newborn calves were followed up from November 2002 until March 2004. Repeated examination of tick and trypanosome burden and determination of gastrointestinal egg excretion was done on calves aged 0-1 month, 2-3 months and 5-6 months. If a calf died, cause of death was assigned based on its death history, postmortem inspection and routinely collected weight and parasitic data. Gastrointestinal parasite spectrum in dead calves was investigated as part of the postmortem examinations. Risk factor analysis for calf mortality stratified in age classes 0-1 month, 1-6 months and 6-12 months was done with demographic data, calf management-related questionnaire data and routinely collected parasitic and weight data. To account for clustering of calves in herds and repeated sampling of individual calves, survival analysis was done with a frailty model and a Bayesian model with two random factors for herd and calves was used for analysis of parasitic data.

Overall calf mortality rate during the first year of life was 17%. This leads to a partial loss of lactation of every 6th cow and a loss of one sixth of all potential slaughter cattle, draught oxen and future dairy and breeding stock. Much higher calf mortality rates occurred in modernised management (19% in modernised private and 25% in modernised on station) than in traditional (10%) management (Hazard ratio 2.2, CI 1.2-3.8, p=0.01). This is an alarming finding in view of the ongoing modernisation of management practices in the periurban zones. The causes of death were mainly management problems, consisting of accidental losses (14%), starvation (10%) and sepsis (5%); digestive disorders, consisting of gastrointestinal parasites (12%), non-parasitic diarrhoea (10%) and ileus (7%); and perinatal mortality (16%). Minor causes of death were vector-borne diseases (4%), respiratory disorders (4%) and nervous disorders (2%). The high number of management problems revealed a need for better herding, control of milk off-take and better hygiene. Digestive disorders were more frequent in modernised than in traditional management (p=0.02), and were to a large extent responsible for the higher mortality rates in modernised management. An obvious reason for the high occurrence of gastrointestinal problems was poor hygiene in stationary enclosures.

Risk factors for the age class 0-1 month were birth complications (Hazard ratio 18.4, CI 4.4-75.9, p<0.01), birth during the rainy season (Hazard ratio 7.1, CI 2.9-17.8, p<0.01), parity of dam with calves of multiparous cows having a higher risk of mortality (Hazard ratio 5.2, CI 1.2-22.1, p=0.03), no contact with chicken (Hazard ratio 8.9, CI 2.1-38.1, p<0.01) and large herd size (Hazard ratio 3.4, CI 1.0-11.7, p=0.05). The risk factor found for the age class 1-6 months was a low number of herdsmen (Hazard ratio 3.5, CI 1.8-6.6, p<0.01). The only risk factor to occur more often in modernised than in traditional management was a low number of herdsmen. The risk factors herd size and number of herdsmen underline the importance of good supervision for calf survival.

Livestock owners and herdsmen had reported trypanosomes to be an important cause of calf mortality in their herds in the year preceding the study. However their perception was not confirmed by a *Trypanosoma sp.* prevalence of 1% in calves aged 0-6 months and only one identified loss due to trypanosomes. Frequent tick control conducted by the herd owners probably lowered tsetse fly density and led to the low tick burden of calves aged 0-6 months. Mean geometric half-body tick count was 3.1 (range 0-65) with most calves being tick-free (76%). The most common tick genus was *Amblyomma sp.* (71%), followed by *Hyalomma sp.* (23%), *Boophilus sp.* (4%) and *Rhipicephalus sp.* (1%). Significant season, age and management effects on tick counts occurred, with *A. variegatum* being less frequent in modernised than in traditional management (Incidence rate ratio 0.4, CI 0.2-0.9). Tick-borne cowdriosis was not detected in autopsied calves.

The spectrum of gastrointestinal parasites was similar to that found in adult cattle. The spectrum included 11 nematodes, 1 trematode, 3 cestodes and 1 protozoan parasite. Calves in the age class 4-13 months carried up to 8 different parasite species. The most frequent parasites were *Haemonchus sp*. (Age class 0-1 month: 7%, 1-4 months: 38%, 4-13 months: 69%), *Cooperia pectinata* (0%, 33%, 44%), *Cooperia punctata* (0%, 33%, 38%) and *Moniezia sp.* (0%, 24%, 38%). Routine coprological examinations of live calves have shown a moderate prevalence of eggs of *Strongyloides papillosus* (Age class 0-1 month: 39%, 2-3 months: 59%, 5-6 months: 42%) and strongyle-type (14%, 24%, 36%) and coccidian oocysts (37%, 68%, 64%) and at low prevalence eggs of *Toxocara vitulorum, Moniezia sp, Trichuris sp.* and *Paramphistomum sp*. Significant season and age effects on egg counts of strongyle-type eggs, *S. papillosus* and *T. vitulorum* and on coccidian oocyst counts were found. Transmission occurred all year round but was lowest during the dry seasons. Gastrointestinal parasite control was more intensive in modernised than in traditional management. Even though hygienic conditions were poorer in modernised management, no management effect on egg counts in living calves was found

In conclusion, overall calf mortality in periurban livestock production is high and has doubled with modernisation of livestock keeping. Main management problems were hygiene, surveillance and milk off-take. Vector and vector-borne diseases were of low importance, while gastrointestinal parasites were important causes of death in modernised management.

ZUSAMMENFASSUNG

Die Rinderproduktion ist von grosser Bedeutung für die Malische Wirtschaft. Die inländische Milchproduktion kann jedoch den lokalen Bedarf an Milchprodukten nicht decken, so dass 60% der konsumierten Milchprodukte importiert werden. Zur Steigerung der lokalen Milchproduktion fand in den letzten Jahrzehnten eine Modernisierung der Viehhaltung in periurbanen Gebieten statt, insbesondere in der Umgebung von Bamako. Dieser Wechsel von traditioneller zu modernisierter Haltung, mit Einkreuzung von europäischen Rassen und erhöhten Investitionen in Unterbringung, Ernährung und Parasitenkontrolle, kann einen Einfluss auf die Sterblichkeit von Kälbern haben. Zum Beispiel in Bezug auf das Vorkommen von Endo- und Ektoparasiten, den wichtigsten Ursachen von Gesundheitsproblemen von Kühen und Kälbern rund um Bamako. Kälbersterblichkeit hat einen entscheidenden Einfluss auf die Milchproduktion, da Lokalrassen die Stimulation ihres saugenden Kalbes für den Milcheinschuss benötigen. West-Afrikanische Studien in traditionellen Haltungssystemen und auf Zuchtstationen berichten Sterblichkeitsraten für Kälber (0-12 Monate) zwischen 3% und 47%. Obwohl die modernisierte Viehhaltung in periurbanen Zonen zunehmend an Bedeutung gewinnt, waren weder Angaben über Kälbersterblichkeit und deren Ursachen in modernisierter privater Viehzucht in West Afrika vorhanden, noch wurde die Kälbersterblichkeit in traditioneller Haltung mit der Kälbersterblichkeit in modernisierter Haltung verglichen. Dies ist aber für die wirtschaftliche Analyse der fortschreitenden Modernisierung unerlässlich. Das Hauptziel dieser Studie war die Bestimmung von Sterblichkeitsraten in den verschiedenen Haltungssystemen und die Aufklärung der Ursachen und Risikofaktoren für die Kälbersterblichkeit in der periurbanen Zone von Bamako, mit Schwerpunkt auf der Wirkung von Endo- und Ektoparasiten auf die Kälbersterblichkeit.

Im Rahmen einer longitudinalen Kohortenstudie mit 762 Kälbern in 38 Herden in der periurbanen Zone von Bamako wurden neugeborene Kälber von November 2002 bis März 2004 beobachtet. An Kälbern im Alter von 0-1 Monat, 2-3 Monaten und 5-6 Monaten wurden wiederholte Untersuchungen der Zecken und Trypanosomenbürde durchgeführt und die Ausscheidungen von Magendarmparasiteneiern bestimmt. Verstarb ein Kalb, wurde seine Todesursache beruhend auf der Anamnese, Obduktionsbefunden und routinemässig gesammelten Parasitendaten und Gewichtsdaten diagnostiziert. Das Spektrum der Magendarmparasiten in verstorbenen Kälbern wurde als Teil der Obduktion mituntersucht. Eine Risikofaktorenanalyse der Kälbersterblichkeit wurde mit demographischen Daten, Interviewdaten über die Haltungsbedingungen und routinemässig gesammelten Parasitendaten durchgeführt. Das Vorkommen von Kälbern in Herden und wiederholtes Sammeln von Daten

auf dem gleichen Kalb wurden in der Überlebensanalyse mit einem Frailty Model und bei der Analyse der Parasitendaten mit einem Bayesianischen Model mit negativer Binomialverteilung und zwei Zufallsvariablen für Herde und Kälber berücksichtigt.

Die Kälbersterblichkeit während dem ersten Lebensjahr betrug 17%. Dies führt zu einem teilweisen Verlust jeder 6. Laktationsperiode und bewirkt den Verlust von 1/6 aller potentiellen Schlachttiere, Pflugochsen, zukünftigen Milchkühen und Zuchttieren. Eine höhere Sterblichkeit als in traditioneller Viehhaltung (10%) trat in modernisierter Viehhaltung auf (19% in privaten modernisierten Betrieben, 25% auf Zuchtstationen) (Risikorate 2.2, Konfidenzintervall 1.2-3.8, p=0.01). Dies ist ein alarmierendes Ergebnis in Hinsicht auf die fortlaufende Modernisierung der Viehzucht in periurbanen Zonen.

Die wichtigsten Todesursachen waren Haltungsprobleme, bestehend aus Unfällen und Verlusten (14%), Hungertod (10%) und Sepsis (5%); Magendarmprobleme, bestehend aus Magendarm-Parasiten (12%), nicht parasitär-bedingten Durchfällen (10%) und Magenverschluss (7%); und perinataler Sterblichkeit (16%). Von geringer Bedeutung waren Verluste durch Vektor übertragene Krankheiten (4%), Atemwegserkrankungen (4%) und Nervensystemerkrankungen (2%). Der hohe Anteil an Verlusten durch Haltungsprobleme deckt ein Bedürfnis nach besserer Betreuung, Kontrolle der Milchabnahme und besserer Hygiene auf. Magendarmprobleme waren häufiger in modernisierter als in traditioneller Viehzucht (p=0.02) und waren grösstenteils für die höhere Sterblichkeitsrate in modernisierter Viehzucht verantwortlich. Klar ersichtliche Ursache für das häufige Vorkommen von Magendarmproblemen war die schlechte Hygiene in stationären Gehegen.

Risikofaktoren für die Altersgruppe 0-1 Monat waren Geburtskomplikationen (Risikorate 18.4, KI 4.4-75.9, p<0.01), Geburt während der Regenzeit (Risikorate 7.1, KI 2.9-17.8, p<0.01), Parität der Kuh mit einem höheren Risiko für Kälber von multiparen Müttern (Risikorate 5.2, KI 1.2-22.1, p=0.03), kein Kontakt zu Hühnern (Risikorate 8.9, KI 2.1-38.1, p<0.01) und grosse Herdengrösse (Risikorate 3.4, KI 1.0-11.7, p=0.05). Der Risikofaktor für die Altersklasse 1-6 Monate war eine geringe Anzahl Hirten (Risikorate 3.5, KI 1.8-6.6, p<0.01). Der einzige Risikofaktor der häufiger in modernisierter als in traditioneller Viehzucht vorkam war eine geringe Anzahl Hirten. Die Risikofaktoren Herdengrösse und Anzahl Hirten betonen die Bedeutung einer guten Betreuung für das Überleben der Kälber.

Herdenbesitzer und Hirten berichteten das Trypanosomen eine wichtige Ursache der Kälbersterblichkeit in ihren Herden in dem der Studie vorangehenden Jahr gewesen wären. Diese Wahrnehmung wurde jedoch nicht durch die Häufigkeit von 1% von *Trypanosoma sp.* in Kälbern im Alter von 0-6 Monaten und nur einem identifizierten Verlust durch

Trypanosomen bestätigt. Häufige Zeckenkontrollen in den Herden haben eventuell auch die Tsetsefliegen reduziert und führten zu den tiefen Zeckenbürden auf Kälbern (0-6 Monaten). Die durchschnittliche geometrische Halbkörper-Zeckenanzahl war 3.1 (Spannweite 0-65) und die meisten Kälber hatten keine Zecken (76%). Die häufigste Zeckengattung war *Amblyomma sp*. (71%), gefolgt von *Hyalomma sp*. (23%), *Boophilus sp.* (4%) und *Rhipicephalus sp.* (1%). Signifikante Jahreszeiten-, Alters- und Haltungseffekte auf Zeckenbürden wurden gefunden, mit einer geringeren Häufigkeit von *A. variegatum* in modernisierter als in traditioneller Haltung (Inzidenzrate 0.4, KI 02-0.9). Zeckenübertragene Kowdriose konnte in den Kälberobduktionen nicht festgestellt werden.

Das Spektrum von Magendarmparasiten war ähnlich dem in erwachsenen Rindern. Das Spektrum bestand aus 11 Nematoden, 1 Trematoden, 3 Cestoden und 1 Protozoen. Kälber in der Altersklasse 4-13 Monate waren bereits mit bis zu 8 verschiedenen Magendarmparasitenarten befallen. Die häufigsten Parasitenarten waren *Haemonchus sp*. (Altersklasse 0-1 Monat: 7%, 1-4 Monate: 38%, 4-13 Monate: 69%), *Cooperia pectinata* (0%, 33%, 44%), *Cooperia punctata* (0%, 33%, 38%) und *Moniezia sp.* (0%, 24%, 38%). Routinemässige koprologische Untersuchungen an lebenden Kälbern zeigten eine moderate Häufigkeit von Eiern von *Strongyloides papillosus* (Altersklasse 0-1 Monat: 39%, 2-3 Monate: 59%, 5-6 Monate: 42%) und Strongyliden (14%, 24%, 36%) und Oozysten von Kokzidien. (37%, 68%, 64%). In geringer Häufigkeit kamen Eier von *Toxocara vitulorum, Moniezia sp., Trichuris sp.* und *Paramphistomum sp*. vor. Signifikante Jahreszeiten- und Alterseffekte auf die Exkretionshäufigkeit von Strongyliden, *S. papillosus* und *T. vitulorum* Eiern und Oozysten von Kokzidien wurden gefunden. Übertragung fand das ganze Jahr über statt, war aber geringer während der Trockenzeit. Kontrollmassnahmen von Magendarmparasiten waren in modernisierter Viehhaltung häufiger, so dass, trotz schlechteren hygienischen Bedingungen in modernisierten Betrieben, kein Effekt des Haltungssystems auf die Eierexkretion in lebenden Kälbern gefunden wurde.

Zusammenfassend, mit der Modernisierung der Viehhaltung hat sich die Kälbersterblichkeit in periurbaner Viehzucht verdoppelt. Hauptprobleme sind die Hygiene, Betreuung und Milchverfügbarkeit. Vektor- und Vektorübertragene Krankheiten sind von niedriger Bedeutung, wohingegen Magendarmparasiten eine wichtige Todesursache in modernisierter Haltung sind.

RESUME

Le bétail bovin est très important dans l'économie Malienne. Mais la production locale des produits laitiers ne couvre pas la demande. Ainsi 60% des produits laitiers consommés sont importés. Pour augmenter la production laitière locale, une modernisation des pratiques d'élevage a été entreprise ces dernières décennies dans les zones périurbaines, notamment autour de Bamako. Ce changement de l'élevage traditionnel à l'élevage modernisé a eu lieu par croisements de races locales avec des races exotiques et l'augmentation des investissements dans les enclos stationnaires, l'alimentation et les soins vétérinaires. La mortalité des veaux a un effet négatif crucial sur la production laitière, parce que dans les races locales le stimulus de téter de leurs veaux est nécessaire pour l'excrétion du lait. Les pertes économiques liées à la mortalité des veaux dépendent du taux absolu entre les différents systèmes d'élevage. Des études effectuées en Afrique de l'Ouest sur l'élevage traditionnel et des stations de recherche ont montré des taux de mortalité des veaux (0-12 mois) entre 3% et 47%. Bien que l'élevage modernisé devient de plus en plus important, aucune information publiée n'est disponible ni sur la mortalité, ni sur les causes de la mortalité des veaux au niveau de l'élevage privé modernisé en milieu périurbain de l'Afrique de l'Ouest. De plus, il n'existe pas de comparaison de la mortalité des veaux en élevage traditionnel et modernisé. Cependant cette comparaison est nécessaire pour l'évaluation économique de la modernisation de l'élevage en cours. Le but principal de cette étude était de déterminer le taux de mortalité des veaux dans différents systèmes d'élevage et d'élucider les causes et les facteurs de risques de la mortalité des veaux en milieu périurbain de Bamako tout en mettant un accent sur les effets des parasitoses internes et externes.

Dans le cadre d'une étude de cohorte longitudinale, 762 veaux nés dans 38 troupeaux en milieu périurbain de Bamako de novembre 2002 à mars 2004 ont été suivis. Des examens répétés de la charge des tiques et des trypanosomes et la détermination de l'excrétion de parasites gastro-intestinaux des veaux ont été fait à l'âge de 0-1 mois, 2-3 mois et 5-6 mois. Si un veau mourait, la cause de sa mort était déterminée sur la base de l'histoire de sa mort, des résultats de son autopsie et les données de routine collectées sur son poids et les parasitoses. Le spectre des parasites gastro-intestinaux dans les veaux morts était déterminé au cours de l'autopsie. L'analyse des facteurs des risques pour les classes d'âge 0-1 mois, 1-6 mois et 6-12 mois était faite à l'aide des données démographiques, de gestion des veaux collectées par l'administration d'un questionnaire et des données sur les parasitoses. Afin de prendre en compte l'agrégation des veaux dans les troupeaux et de l'échantillonnage répété d'un même veau, un modèle «frailty» a été utilisé pour l'analyse de survie. Pour l'analyse des données sur les parasites, des modèles Bayesiens avec deux variables aléatoires, pour le classement des observations par troupeau et intra-individuelle, ont été utilisés.

Le taux global de mortalité des veaux pendant la première année de vie était de 17%. Ce taux de mortalité conduit à une perte partielle de la période de lactation de chaque 6ème vache et une perte d'un sixième des animaux potentiellement destinés à l'abattage, à la traction, à la production laitière ou à la procréation. Le taux de mortalité était plus élevé en élevage modernisé (19% en élevage modernisé privé et 25% en stations de recherche) qu'en élevage traditionnel (10%) (Hazard ratio 2.2, CI 1.2-3.8, p=0.01). Ce résultat est alarmant pour la modernisation de l'élevage en cours dans la zone périurbaine de Bamako.

Les causes des décès étaient surtout dues à des problèmes de gestion comprenant des pertes accidentelles (14%), de la malnutrition (10%) et de la septicémie (5%); des problèmes digestifs, comprenant des parasitoses gastro-intestinales (12%), des diarrhées d'origine non parasitaire (10%) et des obstructions intestinales (7%); et de la mortalité périnatale (16%). Des causes mineures étaient des maladies à transmission vectorielle (4%), des affections respiratoires (4%) et des affections nerveuses (2%). Le nombre élevé des problèmes de gestion montre un besoin d'amélioration de la supervision des troupeaux, un contrôle de la quantité de lait prélevé et de l'hygiène. Les problèmes digestifs étaient plus fréquents en élevage modernisé que traditionnel (p=0.02) et étaient pour une grande part responsable du taux de mortalité élevé observé en élevage modernisé. La mauvaise hygiène dans les enclos stationnaires était la raison apparente de la fréquence des problèmes digestifs.

Les facteurs de risques dans la catégorie d'âge de 0-1 mois étaient des complications obstétriques (Hazard ratio 18.4, CI 4.4-75.9, p<0.01), la naissance pendant la saison des pluies (Hazard ratio 7.1, CI 2.9-17.8, p<0.01), la parité de la vache avec un risque plus élevé chez les veaux des vaches multipares (Hazard ratio 5.2, CI 1.2-22.1, p=0.03), l'absence de contact avec des poules (Hazard ratio 8.9, CI 2.1-38.1, p<0.01) et la grande taille du troupeau (Hazard ratio 3.4, CI 1.0-11.7, p=0.05). Le facteur de risque dans la catégorie d'âge de 1-6 mois était le faible nombre des bergers (Hazard ratio 3.5, CI 1.8-6.6, p<0.01). Le seul facteur de risque qui était plus fréquent en élevage modernisé qu'en élevage traditionnel était le faible nombre des bergers. Les facteurs de risques nombre de bergers et taille de troupeau soulignent bien l'importance d'une bonne supervision pour la survie des veaux.

Les éleveurs et les bergers ont rapporté que la trypanosomiase était une cause importante de la mortalité des veaux dans leurs troupeaux l'année précédant notre étude. Mais cette perception n'était pas confirmée par la prévalence de seulemenet 1% de *Trypanosoma sp* observée chez les veaux âgés de 0-6 mois dont une seule perte était identifiée comme due aux trypanosomes. Le traitement fréquent contre les tiques par les éleveurs aurait probablement réduit la densité des glossines et le taux d'infestation des tiques chez les veaux âgés de 0-6 mois. La moyenne géométrique du nombre de tiques sur la moitié du corps des veaux était de 3.1 (0-65) avec la majorité des veaux n'ayant pas de tiques sur leur corps (76%). Les genres de tiques rencontrés étaient *Amblyomma sp.* (71%), *Hyalomma sp*. (23%), *Boophilus sp*. (4%) et *Rhipicephalus sp*. (1%). Des effets significatifs de la saison, de l'âge et du système d'élevage sur le nombre des tiques étaient observés, avec *A. variegatum* moins fréquent en élevage modernisé que en élevage traditionnel (Incidence rate ratio 0.4, CI 0.2-0.9). La cowdriose transmise par des tiques n'a pas été trouvé dans les autopsies.

Le spectre des parasites gastro-intestinaux était similaire à celui qu'on trouve dans les bovins adultes. Le spectre comprenait 11 nématodes, 1 trématode, 3 ténias et 1 parasite protozoaire. Les veaux âgés de 4 à 13 mois portaient jusqu'à 8 différentes espèces de parasites. Les parasites les plus fréquents étaient *Haemonchus sp*. (Catégorie d'âge 0-1 mois: 7%, 1-4 mois: 38%, 4-13 mois: 69%), *Cooperia pectinata* (0%, 33%, 44%), *Cooperia punctata* (0%, 33%, 38%) et *Moniezia sp.* (0%, 24%, 38%). Les examens coprologiques de routine des veaux vivants ont montré une prévalence moyenne modérée des oeufs de *Strongyloides papillosus* (Catégorie d'âge 0-1 mois: 39%, 2-3 mois: 59%, 5-6 mois: 42%) et de strongles (14%, 24%, 36%), des oocystes de *Eimeria sp*. (37%, 68%, 64%) et une faible prévalence des oeufs de *Toxocara vitulorum, Moniezia sp., Trichuris sp.* et *Paramphistomum sp*. Transmission a eu lieu pendant toute l'année, mais elle était plus basse en saison sèche. La lutte contre les parasites gastro-intestinaux était plus fréquent en élevage modernisé qu'en élevage traditionnel de sorte qu'en dépit des mauvaises conditions hygièniques observés en élevage modernisé, aucun effet significatif du système d'élevage sur l'excrétion des oeufs des veaux vivants n'était trouvé.

En conclusion, le taux de mortalité des veaux en zone périurbaine est élevé et a doublé avec la modernisation de l'élevage. Les causes majeures de la mortalité étaient dues à des problèmes liés à l'hygiene, la supervision des troupeaux et la quantité du lait prélevé. Les vecteurs et les maladies transmises par les vecteurs étaient d'une moindre importance alors que les parasitoses gastro-intestinaux étaient des causes majeures en élevage modernisé.

OUTLINE OF THE THESIS

Chapter 1 gives a general introduction to livestock production in the periurban zone of Bamako and explains the importance of calf mortality for milk production. Mortality rates and causes of death found for calves in West Africa are presented and the occurrence and importance of ecto- and endoparasites as important factors constraining livestock production described.

Chapter 2 states the aim and objectives of the PhD thesis.

Chapter 3 gives an overview of the PhD history and collaborations, with a special focus on the project “Healthy milk for the Sahel”.

Chapter 4 describes the study zone and the methods used.

Chapter 5 presents the results on management dependent mortality rates and causes of death.

Chapter 6 presents the results on risk factors for calf mortality.

Chapter 7 presents the spectrum of gastrointestinal parasites found in postmortems of dead calves.

Chapter 8 presents seasonal and age dependent patterns of gastrointestinal parasite egg excretion in calves.

Chapter 9 presents seasonal and age dependent patterns of tick and trypanosome burden in calves.

Chapter 10 gives a general discussion of the methodology and of the main results.

Chapter 11 provides general conclusions and recommendations.

References presents the list of references, which were pooled at the end to avoid repetitions in different chapters.

Appendix provides the interview about calf management, the interview about calf mortality and one version of the Bayesian model used in statistical analysis of tick and coprological data.

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Chapter 1

General Introduction

1. INTRODUCTION

1.1 Population growth and the importance of livestock production for the Malian economy

Mali is a landlocked country in West Africa (17 00 N, 4 00 W) with a territory of 1.2 Mio km^2. The population is estimated at 12,3 Mio inhabitants, of which 47% are less than 14 years old. Child mortality is 117/1000 live births and life expectancy at birth is comparatively low at 45.1 years. With a birth rate of 46.8/1000 inhabitants, a death rate of 19.1/1000 inhabitants and a net migration rate of -0.33 migrants/1000 inhabitants, population growth is 2.7% (Anonymous 2005).

Only 3.8% of the country's land surface is permanently arable, nearly all of it located along the two rivers Niger and Senegal. Nevertheless, Mali is an agricultural country with 80% of its population engaged in farming and fishing and agriculture contributes 45% to its Gross Domestic Product (Anonymous 2005). With approximately 7 Mio cattle, 19 Mio small ruminants and 0.4 Mio camels, Mali belongs to the most important producers of livestock in West Africa and livestock is one of the three main export commodities (Annual Statistics, DNS 2000). Export of live cattle provided in recent years a fluctuating yearly revenue of 38-98 Mio USD: 47 Mio USD (129'000 animals) in 1999, 98 Mio USD (279'000 animals) in 2000, 80 Mio USD (227'000 animals) in 2001 and 38 Mio USD (107'000 animals) in 2002 (Anonymous 2004). The main trading partner for cattle is the neighbouring country Côte d'Ivoire, which experienced civil unrest in 2002, leading to a decline in revenue through export of cattle.

Mali is currently among the poorest countries in the world, with 73% of its population living on less than 1 USD a day (Anonymous 2003). Large differences in income and expenditure between rural and urban areas exist (Konaré and Teme 1997). As a consequence, a drift to the cities occurs, leading to rapid urban growth. Bamako, the capital of the Republic of Mali, has doubled its population in the last decade and counts more than 1 Mio inhabitants in 2005. The city covers a surface of 18'200 ha and continues to grow rapidly. This rapid growth calls for efficient provisioning of the city centre with daily commodities like food and creates an increasing market opportunity for the sale of periurban livestock products. However, growth of the human population and livestock production causes conflicts over land utilisation. This is especially true for herds kept close to the capital where cattle owners face the problem of rapidly disappearing communal pastures due to the ongoing building boom (Coulibaly 2002).

1.2 Livestock production in the periurban zone of Bamako

1.2.1 Livestock production systems

The periurban zone of Bamako is the zone within 100 km around the capital, the so called "milk belt", with a potential of provisioning the city with fresh dairy products (Debrah et al. 1995). Within the periurban zone, an estimated 200'000 heads of cattle are kept (Coulibaly 2002). Two different sedentary livestock stakeholder systems can be differentiated, village herds and rural compounds (Debrah et al. 1995). Village herds belong to local agro-pastoralists who keep livestock for multiple purposes, like living savings account, traction power for field cultivation, production of manure as a fertiliser for fields, meat and milk production. Owners have regular contact with their animals and sometimes the night-holding place of animals is even within the family compound. Infrastructure for livestock keeping is low and animals are kept either tethered, in enclosures constructed of bushes, branches and wire-netting or unrestrained. Family members can participate in care-giving of cattle, although most often a herdsman is employed. He is paid in milk, agricultural products and rarely cash. Little is invested into veterinary care. Main feed sources are unimproved pasture and harvested fields, rarely supplemented with complementary alimentation (max. 0.5 kg/day) during the dry season (Coulibaly 2002). Animals kept are local Zebu breeds (*Bos taurus indicus*) and more rarely crossbreeds with N'Dama (*Bos taurus taurus*) or European breeds (*Bos taurus taurus*) like Montbéliard, Holstein and Rouge de Steppes. Due to rare veterinary care, feeding deficiencies and the low genetic potential for milk production of local breeds, milk production in traditionally managed herds is only 0.5-2 litres/cow/day (Debrah et al 1995). Most milk is auto-consumed or sold in the village and only minor quantities are delivered to the city. Slaughter and sale of cattle is mainly practiced at social events like weddings or for high expenditures, like health costs and taxes.

Rural compounds belong to wealthy people from Bamako, like rich merchants and civil servants. They live in Bamako and visit their herds irregularly. They keep cattle as a secondary income source through milk and meat production or for prestige. They have often more financial power than village agropastoralists and keep their animals under modernised management with more investments into health care and stationary enclosures built of brick or concrete. The main feed source is still unimproved pasture, but more supplementary alimentation (0.25-5.5 kg/day) is provided, mainly consisting of cotton residuals from the oil producing industry and harvest residuals (Coulibaly 2002). Many animals kept in rural compounds are crossbreeds of local breeds with European breeds. In Mali crossbreeding programs with European breeds started in 1960 at the Centre National de Recherches

Zootechniques de Sotuba (Tamboura et al. 1982). Nowadays most owners of modernised managed herds engage in crossbreeding by using crossbred bulls for natural insemination. Artificial insemination exists but is complicated by a low heat intensity of local Zebu and N'Dama breeds, which hampers recognition of the appropriate moment for insemination (Traore and Bako 1984). Milk production of crossbreeds under modernised management is above 5 litres/day (Debrah et al. 1995). Most of the milk produced in rural compounds is brought to the urban markets of Bamako for sale.

1.2.2 Economy of milk and meat production in the periurban zone

Milk production of the periurban zone is currently estimated at 36'000 tons/year (Coulibaly 2002). Sales prices for milk depend on sales location and season. Producer prices on farms are 225 to 250 CFA (0.41-0.45 USD, Sall 2002), the wholesale price of the big dairy company Mali-Lait Sa is 300 CFA (0.55 USD) and retail prices in downtown Bamako are 300 to 600 CFA (0.55-1.10 USD). Retail prices are highest during the dry season when milk production is lowest and the demand of consumers relatively high. Several studies have looked at the profitability of milk production in the periurban zone of Bamako. Recent mean gross profits reported are between 2-31 CFA/litre (0.004-0.06 USD, Ouattara 2001) and 141 CFA/litre (0.26 USD, Sall 2002), the latter calculation was based on production costs of 94 CFA/litre (0.17 USD). Production costs listed were feed (48%), manpower (44%) and health care (8%); (Sall 2002). Another study that added transportation costs to the production costs found differences in the composition of variable and fixed costs between management systems (Debrah et al. 1995). In modernised management in rural compounds, feed accounted for 51% of total costs, the second largest item was transportation with 29%, while manpower and health care only made up 6% and 7% of costs respectively. In traditional village herds manpower accounted for 50% of costs, feed only for 37% and transportation for 9% of costs (Debrah et al. 1995).

Prices for slaughter cattle vary between 65'000 and 90'000 CFA/animal (119.48-165.44 USD) and between 230 and 240 CFA/kg live-weight (0.42-0.44 USD), depending on carcass quality (Wooning 1992). Retail prices on the market are 800 CFA/kg (1.47 USD) for cattle meat with bones and 1000-1100 CFA/kg (1.84-2.02 USD) for meat without bones (Wooning 1992, Konaré and Teme 1997). Prices can double before religious festivities like the end of Ramadan. Value of breeding stock is much higher than for slaughter animals and varies according to sex, breed, condition of animal, beauty and gestation length in females. The most expensive animals are European crossbreeds, for which prices of 250'000 to 500'000 CFA

(460-920 USD) are paid (personal enquiries on the livestock market of Dalal in 2004). Healthy calves are normally not slaughtered and only sold together with their dam.

1.2.3 Market opportunities for meat and milk production

In Bamako, meat consumption per capita is 42 kg/year, of which 36 kg (86%) is bovine meat (Konaré and Teme 1997). Milk consumption is lower and estimated at 10 to 30 kg/person/year (Bonfoh 2005), which is far below the norm set by the FAO at 60 kg/person/year. But not even this low local consumption of dairy products can be covered by domestic production. Currently approx. 60% of the consumed dairy products for a total of 15.5 Mia CFA (28.5 Mio USD) are imported (DNS 1999). The ongoing population growth will further augment demand for dairy products. To reduce trade deficit, domestic milk production must be increased. Not only the quantity produced must be enlarged, also the quality of milk products needs to be improved and production costs decreased to improve international competitiveness. Then imported milk powder and frozen meat is currently cheaper than locally produced products. This international competition impedes the development of domestic meat and milk production. The problem of comparable high prices of locally produced milk will even become more relevant with the upcoming reduction of import taxes on dairy products (Bonfoh, personal communication). Hence, subsidized milk production in European countries has a direct negative effect on milk production in Mali.

1.2.4 Milking procedure in West Africa

In both traditional and modernised management, cows are milked with the calf at foot. Calves are kept separated from their dams and only let to them during milking. Before the milking starts, the calf is allowed to suckle its dam for 2 to 5 minutes for stimulation of milk let down. It is then bound to one of the cow’s forelegs while the herdsman hand-milks the cow. When milk flow starts to reduce or 3 of the 4 teats have been milked, the calf is released and allowed to drink the remaining milk in the udder. If a calf dies, some herdsmen try to give another calf to the cow for adoption or try to milk the cow without the calf. However, most Zebu and N’Dama cows and some of their F1 crosses with European breeds can only hardly be milked without the stimulus of their suckling calf (Ugarte and Preston 1972). Even if they can be milked without their calf, restricted suckling is advantageous in traditional production systems, because it increases milk production of local breeds to such an extent that the quantity of milk off-take is larger than in cows milked without their calves. Suckling in local breeds increases milk production through improved udder evacuation and stimulation of prolactin release, and reduces risk of mastitis (Alvarez et al. 1980, Ryle and Orskov 1990). High mortality of calves is therefore directly correlated with low milk production and improvement of calf survival with an increase of milk production.

1.3 Calf mortality

1.3.1 Calf mortality in West Africa

Calf mortality is a permanent problem for livestock producers. Death of calves implies a loss of future breeding stock and replacement dairy cows, a loss of slaughter cattle, a loss of future draught oxen and a loss of milk production in breeds milked with the calf at foot. Time of death during the lactation period determines the quantity of milk lost. Early losses shortly after parturition may lead to the complete loss of the lactation period, while calf losses towards weaning (10-12 months) will only mildly affect milk production. Investments in the deceased calf for health care, nutrition and herding are also of no avail.

The scale of the problem depends on the absolute numbers of losses and on the age at which most deaths occur. Studies conducted in Mali and more recent studies from other West African countries report a wide range of calf mortality rates between 3% and 47% during the first year of life (Table 1.1). The majority of deaths occur during the first 3 months of life. Although on-going modernisation of management practices takes place in periurban zones, which increases the importance of modernised management in comparison to traditional management, no in-depth information on calf mortality rates and causes of death for calves kept under modernised private management has been obtainable for West Africa. Comparable information is available from East Africa, for example from Kenya, with a calf mortality rate of 16% in large scale modernised dairy farms in comparison to 10-33% in traditional small scale dairy farms (Bebe et al. 2001). In comparison, calf mortality rate until weaning (8-10 months) in extensive beef farms in Switzerland is 5% (Busato et al. 1997).

Table 1-1 Calf mortality rates (0-12 months) in West Africa

Study	**Country**	**Management type**	**Mortality rate**
Youssao et al. 2000	Benin	on station	3%
Anonymous 1978	**Mali**	on station	**20%**
Planchenault et al. 1981	**Mali**	on station	**30%**
Achard & Chanono 1997	Niger	on station	5-11%
Wagenaar et al. 1986	**Mali**	traditional/nomadic	**19-47%**
Youssao et al. 2000	Benin	traditional/village	23%
Ganaba et al. 2002	Burkina Faso	traditional/village	6%
Njaya et al. 1998	Cameroon	traditional/village	7%
Knopf et al. 2000	Côte d'Ivoire	traditional/village	19%
Mourad & Magassouba 1996	Guinea	traditional/village	>38%
Traoré & Wilson 1988	**Mali**	traditional/village	**13%**
Kudi et al. 1998	Nigeria	traditional/village	46%
Fall et al. 1999	Senegal	traditional/village	12%
Zinsstag et al. 1997a	The Gambia	traditional/village	8-21%

1.3.2 Reported causes of calf mortality in West Africa

To plan effective strategies for improvement of calf survival, information about the causes of death and risk factors for calf mortality are needed. In central Mali, causes of calf and adult mortality reported were an outbreak of anthrax (46%), gastrointestinal problems (15%), malnutrition (10%), respiratory problems (7%), "paralysis" (5%) and liver fluke infections (4%) (Traoré and Wilson 1988). No differentiation between causes for adult and calf mortality is given. A report on causes of calf mortality in Klela in Mali lists potential causes of death, including ticks, trypanosomes, infectious diseases and management shortcomings, but no numbers are reported (Sanogo 1986). From the southern part of Mali, with a high tsetse fly density, 38% of calf deaths are reported to be caused by trypanosomes (Diall et al. 1992). Other West African studies reported as causes of calf mortality accidents, gastrointestinal problems, infectious diseases (black leg, anthrax, rinderpest), malnutrition, parasitic diseases (trypanosomes, anaplasmosis, fasciolosis), perinatal mortality, respiratory problems (pneumonia of unknown origin) and septicaemia (unknown origin) (Table 1.2). Comparing these different studies, main emerging causes for calf mortality are gastrointestinal problems, which include gastrointestinal parasite infections, and other parasitic diseases. Parasitic diseases are a reported problem in periurban livestock production around Bamako, where endo- and ectoparasites accounted for 50% of the health problems of dams and calves (Coulibaly 2002). Further in-depth studies are needed to assess the impact of ecto-and endoparasites on calf mortality in periurban livestock production.

Table 1-2 Causes of calf mortality in West Africa

	Mali	**Niger**	**Burkina Faso**	**Nigeria**	**Senegal**	**Guinea**	**Guinea**
	Diall et al. 1992	Achard & Chanono 1997	Ganaba et al. 2002	Kudi et al. 1998	Denis & Valenza 1972	Mourad & Magassouba 1996	Mourad & Magassouba 1996
	<1 year	<1 year	<1 year	<1 year	<1 year	<6 months	6-18 months
Accidental losses		6%	13%	5%	6%	14%	7%
Gastrointestinal problems		53%		47%		41%	59%
Infectious diseases					22%	4%	6%
Malnutrition				5%	19%		
Parasitic diseases	38%	(12%) a			7%	25%	27%
Perinatal mortality			21%				
Respiratory problems		(12%) a		25%		16%	
Septicaemia		(12%) a		15%	23%		

a) aggregated in category "disease"

1.4 Ecto- and Endoparasites in West Africa

1.4.1 Ticks and tick-borne diseases

1.4.1.1 Tick spectrum on cattle in Mali

Ticks, belonging to the family *Ixodidae*, are a problem for livestock production in Mali (Teel et al. 1988). An extensive nation-wide survey on ticks infesting livestock has found 17 species of ticks on bovines in Mali, belonging to the genera *Hyalomma* (46% of ticks found, 6 species), *Amblyomma* (26%, 1 species), *Boophilus* (22%, 3 species) and *Rhipicephalus* (6%, 7 species) (Teel et al. 1988). All 4 genera, *Amblyomma* (25%), *Hyalomma* (22%), *Boophilus* (44%) and *Rhipicephalus* (9%), occur in the periurban zone of Bamako (N'diaye 1989). Another two genera of the family Ixodidae, *Aponomma* and *Haemaphysalis*, are recorded for the region (Doss et al. 1978).

1.4.1.2 Life cycle of ticks of the family Ixodidae

Ticks of the family Ixodidae have commonly a 3 host-life cycle. From the egg hatches a 6-legged larva which finds a first vertebrate host for feeding. Fed larvae drop to the soil where they metamorphose into 8- legged nymphs which choose a next host for a second blood meal. Fed nymphs develop into mature females and males, which attach to a third host for blood consumption and copulation. Fed, inseminated females drop again to the ground for egg laying. Development of individual stages lasts weeks up to several months, depending on climatic conditions. Blood meals may last hours up to 2 weeks and adult *A. variegatum* females suck up to 10 ml of blood/individual (Kaufmann 1996).

1.4.1.3 Pathogenesis of tick infestation

A direct consequence of tick feeding is blood loss, which is substantial in heavy infestations and leads to serious anaemia. Tick bites provoke skin irritations and open bite wounds attract other insects causing secondary infections and myasis. In addition, some tick species have toxins in their saliva, which give rise to paralysis in the host and, especially in young calves, to an acute febrile toxicosis called sweating sickness. Some tick toxins have also a suppressive effect on the immune system which may reactivate other chronic infections. The most serious threat caused by ticks is their role as vectors for the important livestock diseases cowdriosis, babesiosis, theileriosis and anaplasmosis (Morel 1989, Kaufmann 1996).

1.4.1.4 Tick-borne diseases

Cowdriosis “Heartwater” is caused by the rickettsia *Ehrlichia ruminantium* (formerly *Cowdria ruminantium*), which is transmitted by *Amblyomma sp*. *Ehrlichia ruminantium* attacks the endothelial cells of the nervous system, heart muscle, kidney, spleen, lymph nodes and salivary glands, leading to digestive and nervous disorders. Losses due to this disease in European breeds are very high, but indigenous African breeds can also succumb if weakened by malnutrition, gestation or other diseases and parasites (Morel 1989, Kaufman 1996). Calves born in endemic areas receive protective antibodies with the colostrum and are relatively resistant during their first weeks of life (Norval et al. 1995, Deem et al. 1996). A Senegalese study inoculating sheep with tick solutions has found *E. ruminantium* in its local vector population at a prevalence of 8% in nymphs and 1% in adult *A. variegatum* (Gueye et al. 1993). In Côte d’Ivoire, rickettsiae were found with a haemolymph test in *A. variegatum* at a prevalence of 3% (Graf et al. 1981) and at a prevalence of 9% in nymphs and 13% in adult ticks (Humair 1994). Another study on *A. variegatum* ticks from Côte d'Ivoire used PCR methods with which they detected *E. ruminantium* in 7% of ticks (Di Mito and Mozzato 1994). In studies investigating the occurrence of *E. ruminantium* in cattle, prevalence varied between 0% to 65%, depending on locality and method used (Table 1.3). Occurrence of cowdriosis in livestock is reported for Mali but without specific details (Teel et al. 1988).

<u>Anaplasmosis</u> "Gall sickness" is caused by the rickettsia *Anaplasma marginale,* which is mainly transmitted by *Boophilus sp.* In its bovine host the parasite attacks erythrocytes, causing anaemia and anorexia. Transplacental transmission from dam to calf occurs. Normally, infections in calves are mild, whereas the fatality rate in adults is up to 50% (Morel 1989, Kaufmann 1996). In Mali, *A. marginale* has been found in the vector species *B. decoloratus* (Parola and Raoult, 2001). The reported prevalence of bovines with antibodies against *A. marginale* kept in the urban and periurban area of Bamako is 92% for adult cattle and 75% for animals aged less than 1.5 years (Miller 1984). Other West African studies have reported prevalence rates of *A. marginale* in bovines between 0% and 30% (Table 1.3).

<u>Babesiosis</u> "Redwater" is caused by the piroplasm *Babesia bigemina* and *B. bovis,* which are mainly transmitted by *Boophilus sp*. and *Rhipicephalus sp*. The parasites infect the bovine erythrocytes, causing anaemia, fever and haemogloburina. Abortions, loss of milk production, shock syndromes and nervous disorders are the outcomes. European breeds are more susceptible, with fatality rates of 70-80% if infected with *B. bovis* and 30% if infected with *B. bigemina* (Morel 1989, Kaufmann 1996). In Côte d'Ivoire, prevalence of *Babesia sp*. in its vector *Boophilus sp.* was determined with a haemolymph test at 0.1% (Graf et al., 1981). In Mali, reported prevalence of antibodies against *B. bovis* and *B. bigemina* in bovines kept in the urban and periurban area of Bamako is 38% respectively 54% in adult cattle and 15% respectively 53% in animals aged less than 1.5 years (Miller et al. 1984). Other West African studies have reported prevalence rates of *B. bovis* in bovines between 0% and 31% and of *B. bigemina* in bovines between 0% and 65% (Table 1.3)

<u>Theileriosis</u> is caused by *Theileria annulata* and *T. mutans,* which are transmitted by *Hyalomma sp*. and *Amblyomma sp*. The important species *T. parva,* which causes East Coast Fever, does not occur in West Africa. Infections with *T. annulata* are often fatal, while infections with the morphologically not distinguishable *T. mutans* cause only mild disease. The parasites are found in erythrocytes and in the lymphocytes of the spleen and lymph nodes. Disease symptoms are fever, swelling of lymph nodes, nasal discharge and emaciation (Kaufmann 1996). No information is available on the occurrence of Theileriosis in Mali. But

the potential vector species, *A. variegatum* for *T. mutans* and *H. truncatum* for *T. annulata,* are present in Mali (Teel et al. 1988).

Table 1-3 Prevalence of tick-borne parasites in cattle in West Africa

ELISA= Enzyme linked immunosorbent assay , IFA=Indirect Fluorescent Antibody Test

	Method	Parasite species				Cattle breed	N° of animals
		Babesia bovis	*Babesia bigemina*	*Ehrlichia ruminantium*	*Anaplasma marginale*		
Mattioli et al. 1997, The Gambia	Blood smears	0.1%	0.9%	0%	3%	N'Dama	1294
	ELISA	5%	45%	.	30%	N'Dama	648
Knopf et al. 2002, Côte d'Ivoire	Blood smears	<1%	0%	0%	0%	N'Dama	809
	ELISA	.	.	31%	.	N'Dama	314
Gueye et al. 1993, Senegal	IFAT	.	.	5-34%	.	Different breeds	1225
Mattioli et al. 2000a, The Gambia	ELISA	.	.	33-39%	.	N'Dama	<40
	ELISA	.	.	45-65%	.	Gobra	<40
Pangui & Salifou 1992, Benin	Blood smears	31%	14%	.	16%	Different breeds	368
Kuttler et al. 1988, The Gambia	IFAT	0%	65%	.	0%	N'Dama	184
Miller 1984, Mali	IFAT	15-38%	53-54%	.	75-92%	Different breeds	26-139

1.4.1.5 Tick control

To reduce direct and indirect losses due to tick infestation and to prevent the transmission of diseases, different tick control strategies are recommended. They comprise strategic or intensive treatments of cattle with chemical acaricides, manual tick picking-off and other biological control options like the use of tolerant livestock breeds or tick parasitoids (Chema 1990, Chizyuka and Mulilo 1990, Lawrence 1990, Mwangi et al. 1997, Mattioli et al. 2000b). Whatever strategy is used, its effectiveness and cost-benefit ratio will depend on various factors, such as tick species, tick density, climate, vegetation, host breed, host age and management system (Morel 1989). Due to the complex interaction of all these factors, success of tick control varies widely. Some studies assessing the effect of chemical tick control report improved live weight gain in older animals (Pegram and Chizyuka 1990, Stachurski et al. 1993, Mattioli et al. 1998) but no effect (Meltzer et al. 1995) or even a negative effect (Pegram and Chizyuka 1990) of tick control on live weight gain in young calves. A positive effect of tick control on milk production was found in the studies of Pegram and Chizyuka (1990), de Castro et al. (1997) and Norval et al. (1997a) but only a weak effect in another study by Norval et al. (1997b). Treated calves have a lower milk consumption in comparison to untreated calves (Meltzer et al. 1995). A delay in tick control treatments on young calves is suggested to allow for development of premunition to tick-borne diseases (Chema 1990).

1.4.2 Gastrointestinal parasites in West Africa

1.4.2.1 Gastrointetinal parasite spectrum in cattle in Mali

Gastrointestinal parasites are one of the known constraints on livestock production in West Africa (Zinsstag et al. 1998). They are very widespread and although often neglected, may cause serious losses in young animals. Gastrointestinal parasites consist of protozoan parasites like coccidies, and of the large group of helminths with numerous species of nematodes, cestodes and premature stages of trematodes. Two studies conducted in Mali have found 8 species of nematodes in bovines: *Haemonchus sp, Cooperia pectinata, C. punctata, Oesophagostomum radiatum, Trichostrongylus axei, Trichostrongylus colubriformis, Strongyloides papillosus, Bunostomum phlebotonum*; 5 species of trematodes*: Fasciola gigantica, Dicrocoelium hospes, Schistosoma bovis, Paramphistomum sp, Carmyerius sp.;* and one cestode*: Moniezia sp.* (Tembely 1986, Tembely et al. 1995). A coprological study conducted in the urban area of Bamako reports that 61% to 90% of calves aged less than a year were excreting strongyle-type eggs during the rainy and hot dry season (Dara 1985).

Several other West African studies have investigated gastrointestinal parasite burden and species diversity in postmortems of bovines (e.g. Côte d'Ivoire: Komoin-Oka et al. 2000, Achi et al. 2003; Guinea: Ankers et al. 1997; Senegal: Ndao et al. 1995; The Gambia: Kaufmann and Pfister 1990). Like the Malian study of Tembely (1986), they were done on carcasses of slaughtered cattle in abattoirs. Calves are normally not slaughtered in West Africa because they are needed for milk production. As a consequence, very few information about parasite burden in young calves is available. Only one of the above studies has looked at parasite burden in young calves that have died due to accidents or diseases (Kaufmann and

Pfister 1990). They concluded that worm burden in suckling calves is very low. Unfortunately, this study does not report the actual worm burden in young suckling calves, but instead gives the parasite spectrum and burden for all "calves" with an average age of 27 months without further stratification. More data on calves is available from coprological studies, which examined egg excretion in faeces of calves (Mishra et al. 1979, Anene et al. 1994, Ankers et al. 1997, Knopf et al. 2000). To determine acquisition dynamics of different gastrointestinal parasite species and level of multiparasitism in young calves, more information on parasite spectrum in young suckling calves, obtained through postmortem examinations, is needed.

1.4.2.2 Life cycle of gastrointestinal parasites

The life cycle of most nematodes is direct, with sexual forms in the vertebrate host. Adults in the host produce eggs, which are passed into the environment. Normally 4 larval stages (L1-L4) occur, with the L3 being the infective stage for a new host. Larvae of most species are passively taken in by their host during grazing (e.g. *Haemonchus sp., Trichuris sp., Oesophagostomum sp., Trichostrongylus sp., Cooperia sp*.). Some parasites have L3 which can enter their new host by active skin penetration, followed by a journey through the blood and lymphatic system over the lungs and trachea into the oesophagus and gastrointestinal tract (e.g. *Bunostomum sp., Strongyloides sp*.). Few parasites have a vertical transmission from dam to calf over the placenta or through the colostrum (*Toxocara sp., Strongyloides sp*.). The West African hot dry environment during the long dry season is not suitable for larval development of some nematode species (e.g. *Haemonchus sp., Ostertagia sp*.) (Troncy 1989, Kaufman 1996). These parasites survive the dry season in hypobiosis, an arrested development of the L4 stage, and resume their activity before the onset of the rainy season (Kaufmann and Pfister 1990, Ankers et al. 1994, Zinsstag et al. 1994). This survival strategy of parasites was also found in central Mali (Tembely 1986).

Life cycle of cestodes is indirect, with shed eggs being eaten by oribatid mites. In the intermediate host, the larva (cysticercoid) hatches and penetrates the body cavity, where it awaits the intake of the mite by its final host. In the bovine, the mite is digested together with the consumed herbage and the cysticercoids are released, which develop into the adult stage producing new eggs (Kaufman 1996).

Life cycle of trematodes is also indirect with a snail as an intermediate host. For example out of a *Fasciola gigantica* egg hatches a miracidium which penetrates a freshwater snail (*Bulinus* *sp., Planorbis sp*.). In its intermediate host, it develops into a sporocyst, which through polyembryony reproduces rediae. Redia develop into cercaria which leave the freshwater snail and encyst into metacercaria, the infective stage for the vertebrate host. Metacercaria are consumed with plant material by animals feeding in and around water bodies. Immature worms hatch in the intestine, damaging the mucous membrane, before moving to their host target organ (liver, rumen, mesenteric veins) (Kaufman 1996).

Life cycle of coccidia, protozoan parasites which belong to the genera *Eimeria sp*. and *Isospora sp*., is direct. Bovines get infected through uptake of infective oocysts with food and water. In the host the parasites stay in the intestinal mucous membrane where they produce new oocysts, which are passed out in the faeces. Coccidia are very common and all cattle usually excrete some oocysts. The condition coccidiosis is only given if large numbers of oocysts occur, damaging the mucous membrane (Kaufman 1996, The Merck Vet. Manual 1998).

1.4.2.3 Pathogenesis of gastrointestinal parasite infections

Pathogenesis of the different species varies greatly and also depends on parasite load, mode of transmission and the presence of concomitant infections. For newborn calves important are parasites with vertical transmission and active skin penetration ability, which cause very early infections. The other parasites gain in importance with onset of rumination, when animals start to eat larger quantities of fodder thereby taking in infective parasite stages. Weaned calves are reported to harbour the largest number of parasites (Kaufmann and Pfister 1990). Some of the damaging effects caused by gastrointestinal parasites are irritations of the mucosa and destruction of intestinal cells, blood consumption by haemophagous parasites (e.g. *Bunostomum sp., Haemonchus sp., Oesophagostomum sp*., *Trichuris sp*.), irritation of the lung tissue during migration of larvae and loss of nutrients. Main symptoms observed are diarrhoea, weight loss, growth retardation, oedema, anaemia, rough hair coat, dehydration and death. Lethal parasite burden is low for some species (i.e. 200 *O. radiatum* or 50 *B. phlebotonum*) while other less pathogenic species can occur in very high numbers (Kaufman 1996). The effect of nematodes on cattle health depends on nutritional status of the host and on the occurrence of concomitant infections with other parasites like trypanosomes (Vassiliades 1978, Dwinger et al. 1994, Kaufmann et al. 1992).

1.4.2.4 Gastrointestinal parasite control

To control gastrointestinal parasites, different management and chemotherapeutic options are available. Management should aim at minimizing transmission by reducing exposure of animals to faeces. Proposed are systems of pasture rotation, regular change of night-holding places, good hygiene and low stocking density (Kaufmann et al. 1992, Waller and Thamsborg 2004). Differences in parasite burden between nomadic and sedentary cattle in Mali may be partially explained by lower exposure of nomadic cattle to their faeces (Tembely 1986). A large spectrum of anthelmintic drugs is available, but development of resistance to some products has been reported (Bâ and Geerts 1998). The benefit of gastrointestinal nematode control depends on various factors like parasite density, parasite spectrum, nutritional condition, age and breed of the host and control strategy used. As a consequence, results of different studies investigating the effects of gastrointestinal parasite control on productivity vary. Dwinger et al. (1994) found improved weight gain in treated animals aged more than 2 years but not in younger animals and N'Dao et al. (1995) found an increase in live weight in treated bovines aged 1-3 years. Zinsstag et al. (1997b) found no effect with one annual treatment on live weight, while two annual treatments increased live weight of animals aged 1-3 years but not of animals aged less than a year. Gastrointestinal parasite control applied twice yearly reduced age at first conception (Zinsstag et al. 1997a) but increased calf mortality (0-12 months). Suckling calves treated against gastrointestinal parasites consumed less milk than untreated controls (Agyemang et al. 1991).

1.4.3 Trypanosomes in West Africa

1.4.3.1 Parasite spectrum: Tsetse flies in Mali

Trypanosomiasis "Nagana" causes a major constraint on livestock production within the tsetse-belt (15°N to 29°S), to which the southern parts of Mali belong. Four species of tsetse flies are reported for Mali, *Glossina palpalis gambiensis* and *G. tachinoides*, both belonging to the riverine group, and *G. morsitans submorsitans* and *G. longipalis*, both belonging to the savannah group. Of these 4 species, only the first three have been found in Mali in recent years (Djiteye et al. 1997b). In the periurban zone of Bamako, the only species currently occurring is *G. palpalis gambiensis*, whose habitat is found along the River Niger and its tributaries (Djiteye et al. 1997b). Tsetse fly densities reported for the periurban zone vary according to season and locality. Maximum densities on the right side of the River Niger are reported to occur during the dry season with an apparent density of 9 (Number of flies captured daily per trap) while the maximum on the left side of the river is reached during the rainy season with an apparent density of 22 (Djiteye et al. 1997a).

1.4.3.2 Parasite spectrum: Trypanosomes in Mali

Four species of trypanosomes are reported to occur in Malian cattle, *T. congolense, T. vivax, T. brucei brucei* and *T. theileri* (Diall et al. 1986, Djitey et al. 1997a). In the periurban zone of Bamako, maximum infection rate of *G. palpalis gambiensis* with *T. vivax* was found towards the end of the rainy season with 7% to 11% of caught flies being infected. Lowest infection rate occurred during the dry season with 0.5-1.5% of flies being infected. No *T. brucei* or *T. congolense* had been found in the vector population in this study, but *T. brucei* is reported to be present in the periurban zone of Bamako (Djiteye et al. 1997a). Infection rates of tsetse flies with trypanosomes are much higher (13-25%) in the more humid southern parts of Mali, where trypanosome infections cause a serious problem for livestock production. In an experimental study conducted at the research station of Madina Diassa, over 55% of N'Dama cows became naturally infected within a year (Diall et al. 1986). Another study focusing on primary infections with trypanosomes in calves born at Madina Diassa during the rainy season, reported an infection rate of 49% during the first 8 weeks of life (Diarra 1983). In neighbouring Senegal, higher prevalence of trypanosomes was found in calves aged less than a year than in adult bovines (Fall et al. 1999).

1.4.3.3 Life cycle of bovine trypanosomes

Bovine trypanosomes are cyclically transmitted by blood sucking tsetse flies. In addition, *T. vivax* can also be mechanically transmitted by biting flies. The normal trypanosome cycle starts with a blood meal by the tsetse fly. The parasites ingested with the blood loose their surface coat and multiply as procyclic forms. The metacyclic forms have a new surface coat and are the infective stage, which for *T. b. brucei* can be found in the salivary glands of the fly. They are transmitted at a next blood meal of the tsetse fly into the skin of a new vertebrate host. The trypanosomes enter the lymph nodes and from there the blood stream, where they multiply by binary fission (Morel 1989, Kaufmann 1996).

1.4.3.4 Pathogenesis of trypanosome infections

The most pathogenic form, *T. congolense*, attaches to endothelial cells in capillaries, while *T. vivax* and *T. b. brucei* enter tissues and cause organ damages. Antigenic variations of the surface coat glycoproteins enable the parasites to evade the immune response and persist in their host. Symptoms of trypanosome infections are swollen lymph nodes, loss of condition and anaemia. Trypanosome infections trigger a strong immune response by the host which adds to the damaging effect of the parasites. Simultaneous infections with gastrointestinal parasites and malnutrition lead to increased susceptibility for trypanosome infections and higher fatality rates (Morel 1989, Dwinger et al. 1994, Kaufmann 1996).

1.4.3.5 Trypanosome control

Various trypanosome control strategies are applied. Most of them target the vector. For example by destroying the tsetse fly habitat, by spraying wide areas or corridors with trypanocides, by using trypanocide impregnated traps and shields, or by applying sterile male techniques. Other strategies aim at reducing the effects of transmission by strategic prophylactic and curative treatments of individual animals or the whole herd with trypanocidal drugs or by breeding of trypanotolerant livestock (pure indigenous *Bos taurus taurus* breeds like N'Dama or Baoulé) (D'Ieteren and Kimani 2002). Good nutrition and control of gastrointestinal parasites help animals to resist and survive infections. Around Bamako, some herd owners are treating their animals on a regular basis with trypanocidal drugs, which are estimated to cost 3'000 CFA (5.54 USD)/animal (Djitey et al. 1998). An effective control program with deltamethrin impregnated traps had been implemented in the periurban zone of Bamako, reducing tsetse fly prevalence during implementation by 87%. Costs of this control method were estimated at 1495-3830 CFA (2.76-7.07 USD)/km^2. However, one of the main problems encountered was the loss and destruction of traps due to livestock, humans and flooding (Djiteye et al. 1998). Trypanotolerant livestock like N'Dama and their crosses occur at a low frequency around Bamako, indicating a relatively low tsetse fly pressure.

Chapter 2

Aim and Objectives

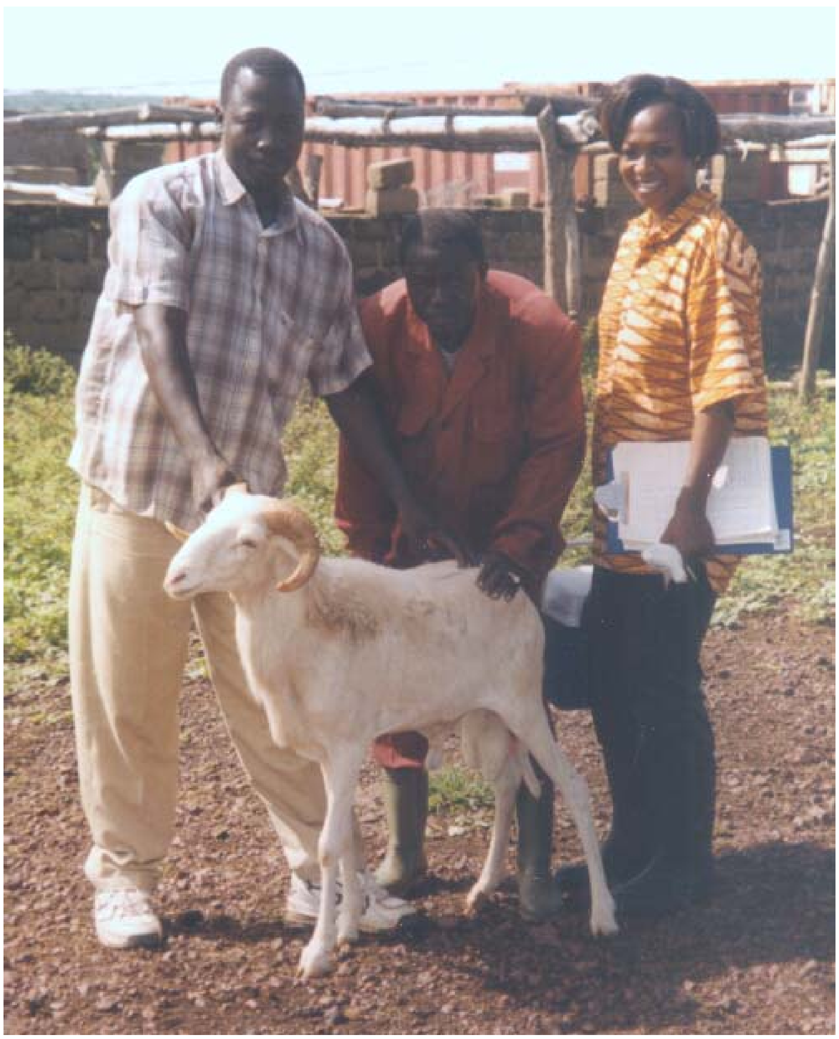
2 AIM AND OBJECTIVES

The **aim** of this study was to investigate causes and risk factors of calf mortality for improvement of milk and meat production in the periurban zone of Bamako, Mali.

- **Objective 1**: To determine calf mortality rates in traditional and modernised management systems
- **Objective 2**: To determine causes of calf mortality in traditional and modernised management systems
- **Objective 3**: To determine risk factors of calf mortality
- **Objective 4**: To determine the seasonal and age-dependent prevalences of gastro-intestinal parasites in calves
- **Objective 5**: To determine the seasonal and age-dependent prevalences of ticks on calves
- **Objective 6**: To determine the seasonal and age-dependent prevalences of trypanosomes in calves
- **Objective 7**: To determine acquisition dynamics of gastrointestinal parasites in calves
- **Objective 8**: To determine the effect of endo- and ectoparasites on calf mortality

Chapter 3

PhD history and collaborations



3 PhD HISTORY AND COLLABORATIONS

3.1 PhD history, collaborations and work distribution

Originally this PhD work started as a research partnership with an Ivorian partner on calf mortality and parasites of calves in traditionally managed herds in the humid Savannah of Côte d'Ivoire. It should have been a collaboration between the Swiss Tropical Institute (STI), Basel, the Swiss Centre for Scientific Research in Côte d'Ivoire (CSSR), Abidjan, the Zoological Institute of the University of Cocody, Abidjan, the National Laboratory for Agricultural Development, Abidjan, and the Diagnostic Unit of the Vetsuisse Faculty of the University of Zurich. But the outbreak of a civil war in Côte d'Ivoire in September 2002 interrupted the started field work. As the political situation did not improve, the Swiss part of the project had to withdraw and a new project was initiated in the neighbouring country Mali. In Mali, this study had the chance to become linked to the research partnership "Healthy milk for the Sahel" and to collaborate with the Central Veterinary Laboratory (L.C.V.) in Bamako. The activities of the "Healthy milk for the Sahel" project and the existing personal contacts with its scientific coordinator Dr. Bassirou Bonfoh (STI), allowed for a rapid re-initiation of field and laboratory work with a focus on calf mortality and parasites in periurban livestock production. Laboratory work was conducted at the L.C.V., in collaboration with Dr. Sékouba Bengaly, head of the tick section, and Dr. Koniba Traoré, head of the helminthological section. Field and laboratory work were carried out with the help of Mr. N'Tio Samaké (Field and laboratory work, interviews), Mrs. Ascofare Dicko Niafatoumata (Field and laboratory work, interviews), Mr. Aguibou Sall (interviews) and Mr. Lassine Zerbo (Field work and transportation). Field work was done in collaboration with the Institut d'Economie Rurale, Sotuba (IER), private livestock owners, their herdsmen and local veterinarians active in the periurban zone. Death causes were elaborated by PD Dr. Jakob Zinsstag (STI), Dr. Bassirou Bonfoh and Dr. Esther Schelling (STI). Statistical analysis was supported by the expertise of Dr. Penelope Vounatsou (STI) and PD Dr. Tom Smith (STI).

3.2 Project "Healthy milk for the Sahel"

This PhD work on calf mortality and parasites, as important factors influencing milk production, was conducted under the patronage of the project "Healthy milk for the Sahel". The "Healthy milk for the Sahel" was a research partnership between the L.C.V. and the Institute for the Sahel (INSAH) in Bamako, the STI and the Federal Polytechnical School (ETH), Zurich. The general aim of the project "Healthy milk for the Sahel" was to improve milk quality as a contribution to income generation, food security and public health in Sahelian countries. Specific objectives were to describe and analyse the traditional methods of milk production and transformation, to evaluate the risk of locally produced milk on consumer health with regard to transmission of bovine tuberculosis and brucellosis, and to develop and test techniques of milk transformation and conservation. Results of the project were presented at a first workshop held in Bamako, Mali, in 2002 (Bonfoh 2002) and at a second workshop in 2003 (Bonfoh 2003). Within the project, studies had been conducted on milk market and production systems (Sall 2002), microbiological quality of raw milk (Bonfoh et al. 2002a, Bonfoh et al. 2002c, Bonfoh et al. 2003a, Bonfoh et al. 2003b), contamination of the milk chain (Bonfoh et al. 2002b), health risks of milk consumption to consumers (Hetzel et al. 2004), raw milk composition of Zebu cows (Bonfoh et al. 2005a), seroprevalence of Q-fever in febrile patients in Mali (Steinmann et al. 2005) and improvement of microbiological quality of milk by washing and disinfecting milk containers (Bonfoh et al. 2005b).

Chapter 4

Methods

4 METHODS

4.1 Study area and time period

Field work was implemented in January 2003 and lasted until March 2004. Study animals were born from November 2002 until March 2004. The study was conducted in 4 zones of the urban and periurban area of Bamako. They were located within a radius of 40 km from Bamako. Zone 1 was at the periphery of the city (Sotuba), zone 2 was situated 10-20 km away from Bamako in the direction of Koulikoro (villages Moribabougou, Sala, Markafourou, Keramokobougou), zone 3 was 40 km away from Bamako in the direction of Ségou (villages Kasséla, Digo) and zone 4 was 30 km away from Bamako in the direction of Sibi-Kangaba (village Samanko) (Figure 4-1). Vegetation type was Sudanese tree savannah, interrupted by gallery forests along the River Niger and its tributaries and tree plantations ("Fôrets classées"). The climate was characterised by one annual rainy season from June to September and a long dry season which can be subdivided into a cold dry season (October to January) and a hot dry season (February to May). Annual mean precipitation was 1037 mm and mean temperatures varied between 26°C and 35°C.

Source: Microsoft Encarta Encyclopedia Professional 2004

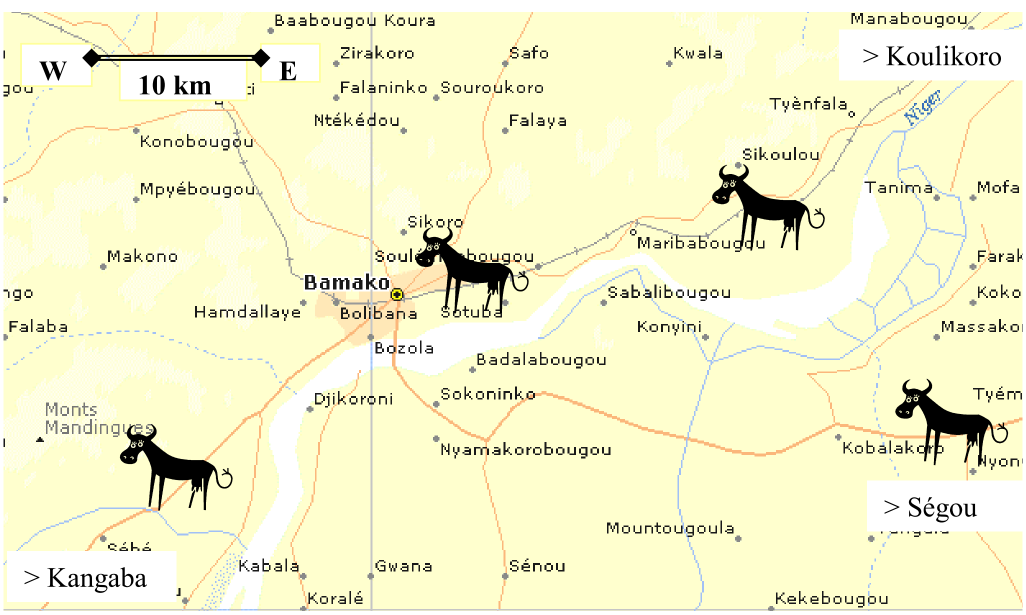


Figure 4-1 Map of the 4 study zones (indicated by cattle pictograms) in the periurban zone of Bamako

4.2 Study design

A longitudinal cohort approach with repeated sampling of parasitic data on individual calves in 38 participating herds was used. Study animals were born into the cohort during the course of the study and followed-up until the end of the study, premature death or sale. Potential observation periods for individual calves varied from 2 weeks to 17 months. Each herd was visited once a month and when a calf died. Regular herd visits were done between morning milking and onset of pasturing, when most herdsmen had some spare time. During herd visits, demographic changes and parasite control performed since the last visit were recorded. Newborn calves were individually marked and samples collected of all calves in the age categories 0-1 month, 2-3 months and 5-6 months. Sampling consisted of an assessment of tick burden, blood and faeces collection and weighing of the calves with a hanging weighing scale. In addition, interviews about calf management were conducted at the onset of the study and interviews on history of death whenever a calf died.

4.3 Sample size

Mortality rate during the first year of life was estimated at 20% (Knopf et al. 2000), of which approximately 14% (2/3) was supposed to occur during the first 6 months of life. With a mortality rate of 14%, 281 calves per group are needed to detect a minimal relative risk of 2.5 with a power of 80% and a confidence level of 95%. To this targeted sample size of 562 calves to be born from November 2002 until October 2003 (actual number born during this period was 542 calves), all calves born until March 2004 were added (adding up to 762 calves). With an estimated fertility rate of 0.7 calves/cow/year (Syrstad 1988), 803 reproductive cows and pregnant heifers needed to be included into the study to obtain the targeted number of births. A safety margin of 15% was added to account for sales and withdrawals of animals, resulting in a minimum number of 923 reproductive females (954 were finally included at onset of the study).

4.4 Herd and calf selection criteria

Herd selection criteria were a minimum herd size of 10 reproductive females, sedentary location of the herd within the study zone and the willingness of the herd owner to participate. For the purpose of our study, traditional and modernised managed herds were contacted. Because some village agropastoralists started to modernize livestock management and some rural compounds were managed more in a traditional way, classification of management type was not based on ownership but on infrastructure present. If calves were tethered or kept in an enclosure constructed of branches and wire-netting, management type was categorized as traditional. If calves were kept in calf enclosures built out of concrete or bricks, management type was defined as modernised. Management system of the 38 participating herds was traditional for 15 herds (374 reproductive females) and modernised for 23 herds (21 private herds with 465 reproductive females and 2 research stations with 115 reproductive females). Because owners of rural compounds were rarely present at the farms and difficult to reach, local veterinarians acted as intermediates and provided the first contacts with herds satisfying the selection criteria. Study animals were all calves born alive into the selected 38 herds from November 2002 to March 2004 (N=756).

4.5 Determination of tick burden

During the first two months of the study, only a semi-quantitative rapid assessment method of tick burden (Knopf et al. 2002) was used. In this rapid assessment, ticks present in a square of 7 cm-side length on the mid-dew lap were counted (square count). Due to very low square counts, half body counts were introduced as a second method. In this method, tick burden was determined by laying the calf on one side and examining the other side from snout to the tail in a visual and tactile way for ticks (half body count). For each tick, genera, sex and development stage was determined, if possible without removing the tick from its host. Only if identification in situ was impossible were ticks collected, stored in 70% ethanol and brought to the laboratory for further examination. This was done to prevent an influence of manual tick picking off on calf mortality. Individual calves (N=667) were sampled 1 to 3 times, yielding a total of 1244 half body counts and 1607 square counts.

4.6 Postmortem examinations

When a study calf died, herdsmen were asked to inform the research team immediately by telephone about its death. If information about death of animals was given within 24 hours and decomposition was not too far advanced, a postmortem examination of the carcass (N=51) was conducted either on the spot (herd holding place or pasture) or at the laboratory. If sick or injured animals had to be killed to end their suffering, herdsmen were asked to call if possible before butchering to ensure good quality of the carcass. If upon arrival the animal was still living, a blood sample was collected for the determination of a trypanosome infection.

During postmortem inspections, the calf was first examined externally, with a focus on body condition, skin, fur and colour of the conjunctiva. The carcass was then opened along the linea alba. The amount and type of liquids contained in the abdominal and thoracic cavity and the pericardium were examined. Heart, lung, liver, spleen and kidneys were first assessed in situ before being taken out of the body for closer pathological and parasitological examination. No bacterial or viral examinations were conducted. Ligatures where placed at the oesophagus and the anus, and the whole gastrointestinal tract was taken out of the body cavity. A faecal sample was collected from the rectum (section 4.7.2). Each part of the gastrointestinal tract was then separated by 2 ligatures. The rumen, reticulum and the omasum were opened and examined for pathologies, foreign bodies and parasites. The abomasum, the small intestine and the large intestine were brought in an ice box to the laboratory for examination and collection of parasites (section 4.7.1). The head was separated from the body and also brought to the laboratory for detection of *E. ruminantium* (section 4.8)

4.7 Determination of gastrointestinal parasite spectrum and burden

Two methods were used to assess gastrointestinal parasite spectrum and burden. The first method consisted of collection and identification of parasites within the gastrointestinal tract of dead calves. The second method was the quantitative determination of egg and oocyst burden in routinely collected faecal samples of live calves.

4.7.1 Helminthological autopsy

Abomasum, small intestine and large intestine were collected of dead calves during post-mortem examinations (N=51). They were first examined externally with a special focus on the mesenteric veins of the small intestine, which were inspected against a light source for *Schistosoma sp*. The abomasum, small and large intestine were then processed separately. Each part was opened along its length and its content washed out with tap water into a bucket. All large cestodes and *Toxocara sp.* found during washing were immediately collected, counted and stored in 70% ethanol. The washing solution was passed trough a sieve with an aperture size of 200 µm. The sieve residual was re-suspended in 3 l of tap water. Of the thoroughly mixed solution an aliquot of 200 ml was collected, which was examined for parasites. All parasites were counted, collected and stored in 70% ethanol. Genus (females) and species (males) of collected parasites were identified under a microscope after adding a drop of lacto-phenol to lighten the internal structures. If parasite number in a sample was high, only 20 male specimens of each similar looking group of parasites was examined and total numbers in the sample derived by extrapolation. To account for the sampling of an aliquot of 200 ml of the total solution of 3 l, parasite numbers (with the exception of the cestodes and *T. vitulorum*) were multiplied by 15 to estimate the total burden. All fat was removed from the abomasum and half of the abomasal mucosa scraped off. These mucosal scrapings were mixed 1: 3 with a pepsin solution (5 g Pepsin from hog stomach (1200 U/g), 8.5 g NaCl, 16 ml HCl (37%), 1 l H_2O_{dest}) and incubated for a minimum of 16 hours at 30°C to 37°C. The artificially digested mucosa was centrifuged and the sediment examined for hypobiotic larvae (Anonymous 1986). Number of hypobiotic larvae was multiplied by 2, to estimate the total burden.

4.7.2 Coprology

One to 3 faecal samples per calf were collected during routine herd visits of live calves (N=694) and one sample each of dams of newborn calves (N=156), of autopsied dead calves (N=51) and of sheep kept together with calves (N=78), resulting in a total number of 1582 faecal samples. The faecal sample was obtained by introducing a finger wrapped in a small plastic bag into the rectum or by catching faeces when the animal was defecating. The faecal samples were transported in an ice box to the laboratory. A modified McMaster technique was used for quantitative determination of excreted egg burden (Boch et al. 1983). Of each sample, 3 g of faeces were mixed with 42 ml of tap water and homogenized. To remove large particles, the solution was sieved with a tea sieve or gaze tissue and 14 ml of the sieved solution centrifuged. The supernatant was discarded and replaced by the same amount of saturated NaCL solution (approx. 1200g/l), which was gently mixed with the sediment. Liquid from the upper middle of the solution column was filled into 2 chambers of a McMaster cell and examined under a microscope. All parasite eggs and coccidian oocysts occurring in the two cells were counted and the counts multiplied by 50 to obtain the total number of eggs per gram of faecal matter.

4.8 Determination of infections with *Ehrlichia ruminantium*

The head of dead calves was cut off and brought to the laboratory (N=46). There the fur together with the skin on the front was removed and the skull-cap opened. A small quantity of the cortex was sampled for squash smears. The smears were coloured in a Giemsa solution and the cytoplasm of the capillary endothelial cells investigated for colonies of *E. ruminantium* (CIRDES 1998).

4.9 Determination of trypanosome infections

One to three blood samples were collected during routine herd visits of live calves (N=705 calves) and 1 sample of calves to be killed (N=4 calves), resulting in a total of 1580 blood samples. Two to 3 ml of blood were collected from the jugular vein with sterile single-use needles into EDTA coated vacuum tubes (Vacuette®). Blood samples were transported in an ice box to the laboratory. There a hematocrit tube was filled with blood, centrifuged and the packed cell volume level determined. The buffy coat region was then examined for trypanosomes. First differentiation of trypanosomes was done on morphological features and motility. In addition, thin blood smears were prepared, fixed in methanol and coloured in a Giemsa-solution, for species confirmation of trypanosomes (Kaufmann 1996).

4.10 Interview about calf management

The aim of this questionnaire was to collect information about calf rearing practices and potential factors influencing calf survival. The questionnaire was elaborated in French and translated into Bambara and Peul. For validation the questionnaires were retranslated into French by two other translators and pre-tested with two herdsmen of non-participating herds. The herdsmen of the 38 participating herds were interviewed either in Bambara or Peul, depending on their mother tongue. If the herd owner or the respective veterinarian was present during interviews, some of the questions were asked to them in either French or Bambara. The interviews were conducted by two interviewers belonging to the two ethnic groups Songhay and Peul, who spoke Bambara respectively Peul as their mother tongue. All answers were recorded in French. Interviews were conducted in mid-morning, after the herdsmen had finished the milking but before they left for herding their animals. Duration of each interview was 20 to 30 minutes. The questionnaire consisted of sections about housing, alimentation, watering, milking, reproduction, herd health and calf mortality. For further details see the French questionnaire in the Appendix (13.1).

4.11 Interview about the history of death

Interviews on perceived causes of death were conducted with the herdsmen or owners of succumbed calves (N=93). Each interview was done within a month after the calf's death either as part of the postmortem examination or during monthly follow-up visits. The questionnaire was elaborated in French and translated-retranslated into Bambara. The questions were asked in Bambara. If questions about treatments of sick calves could not be answered by the herdsmen, the herd veterinarian was contacted and questioned. All answers were recorded in French. The questionnaire consisted of an open question about history of death according to which the perceived cause of death was classified and death category specific sections. For further details see the French questionnaire in the Appendix (13.2). Depending on history of death, each interview lasted 5 to 10 minutes.

4.12 Determination of causes of death

For each dead calf, all available information was compiled, consisting of demographic data, the interview about the history of death, information about parasite burden and weight collected during the monthly follow-up visits and the findings of the postmortem examination. The assembled information was presented to two independent veterinarians who had not been involved in data collection. They were asked for their diagnosis. If these two veterinarians made the same diagnosis for the primary cause of death, their diagnosis was accepted as cause of death. If the two disagreed upon the cause or one of them could not provide a diagnosis based on the data available, a third veterinarian was given the information and asked for his diagnosis. If his diagnosis matched the diagnosis of one of the two other veterinarians, this cause was registered. If all three veterinarians disagreed upon the cause of death or at least two of them had no diagnosis, the cause of death was defined as unknown. The registered causes were the most likely causes of death based on the different amount of information available for each case.

Chapter 5

Calf mortality rate and causes of death under different herd management systems in periurban Bamako, Mali

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5 CALF MORTALITY RATE AND CAUSES OF DEATH UNDER DIFFERENT HERD MANAGEMENT SYSTEMS IN PERIURBAN BAMAKO, MALI

5.1 Abstract

Calf mortality rate and causes of death were studied in periurban livestock production systems in Bamako, Mali, for calves born and dying from November 2002 to March 2004. Causes of death for 93 deceased calves were diagnosed from clinical autopsies, reported history of death and parasitic information. Calves originated from traditional, modernised and station management systems. Overall mortality rate was 17% (N=756 live-births) during the first year of life. Mortality rate was significantly lower for traditionally (10%) compared to modernised (19%) or to station managed calves (25%) (p=0.01). Total perinatal loss (abortions + stillbirths + perinatal mortality) was 5% (N=784 gestations). The most important death categories were digestive tract disorders (28%), perinatal losses (16%) and accidents (14%). Vector-borne and infectious diseases were of low importance. Digestive tract disorders and perinatal mortality were main causes of death in modernised management while accidents and starvation were main causes of death in traditional management. Digestive tract disorders were more common in modernised than in traditional management (p=0.02), revealing a serious problem with hygiene in stationary enclosures. With better calf management in regard to hygiene, surveillance and control of milk off-take, overall calf survival may be increased and periurban livestock production made more profitable.

5.2 Introduction

Although livestock is the 3rd most important export commodity of Mali, local milk production does not cover the domestic demand for dairy products. In West Africa milk production depends on calf survival, as local Zebu (*Bos taurus indicus*) and N'Dama (*Bos taurus taurus*) cows often need the stimulus of their suckling calf for milk let down (Ugarte and Preston 1972). Even in cows that can be milked in the absence of their calves, duration of lactation and milk yield are higher and the risk of mastitis lower when suckled than when not suckled (Alvarez et al. 1980). As a consequence, a cow's milk production is reduced after the death of its calf. Furthermore calf mortality causes a reduction of animals for slaughter, a loss of future breeding stock and a waste of investment in feed and treatments. The scale of the economic loss depends on the actual mortality rate. Recent studies from West Africa report a wide range of calf mortality rates (0-12 months): For station managed calves 5%-11% in

Niger (Achard and Chanono 1997) and 3% in Benin (Youssao et al. 2000) and for traditionally managed calves 46% in Nigeria (Kudi et al. 1998), >38% in Guinea (Mourad and Magassouba 1996), 8%-21% in The Gambia (Zinsstag et al. 1997), 19% in the Côte d'Ivoire (Knopf et al. 2000) and 6% in Burkina Faso (Ganaba et al. 2002). Older studies from Mali report calf mortality rates of 20% (Anonymous 1978) and 30% (Planchenault et al. 1981) for station-managed calves, 10% for traditionally managed calves (Traore and Wilson 1988) and 19%-47% for nomadic cattle (Wagenaar et al. 1986). But although modernised management gains more and more in importance in periurban areas, no information is available on calf mortality in private modernised herds in West Africa, which is needed for the economical evaluation of the ongoing modernisation. This study investigated the causes of calf mortality in different management systems in the periurban zone of Bamako with the aim to define intervention targets for improving calf survival and thereby increasing reproduction and local milk production. The study is part of a cohort study about parasitism and calf mortality.

5.3 Methods

Study area

The study was conducted in the periurban zone of Bamako, Mali. Bamako lies at the foothills of the Manding Mountains with an average altitude of 381 m. It is within the Sahelian zone with one annual rainy season from June to September, a dry cold season from October to February and a hot dry season from March to May. Study animals originated from 38 herds, which were distributed over 4 zones in a 40 km radius around the capital.

Herd management systems

Currently 3 different sedentary herd management systems can be distinguished in the vicinity of Bamako. In the traditional system, local Zebu and N'Dama breeds are kept by village agro-pastoralists on natural unimproved pastures or harvested fields with few supplementation. They receive few anti-parasitic treatments or vaccinations. Calves are tethered to a rope or kept in mobile enclosures constructed with bushes and branches. Cows are milked once or twice a day and daily milk production is 0.5-2 litres/cow (Debrah et al. 1995). Owners have regular contact with their animals and sometimes the night-holding place of animals is within the family compound. In the modernised management system more resources are invested to increase milk production. Most animals are vaccinated against blackleg, anthrax, pasteurellosis and contagious bovine pleuropneumonia and are treated against ticks and gastrointestinal parasites. They are pastured and receive supplementation during the dry season. Crossbreeding of local breeds with European breeds (*Bos taurus taurus),* like Montbéliard, Holstein, or Rouge de Steppes, has been done to increase genetic potential for milk production. Calves are kept in stationary enclosures built of bricks or concrete with natural or concrete floors. Cows are milked twice a day and daily milk production is above 5 litres/cow (Debrah et al. 1995). Modernised livestock production is mainly done as a secondary activity by wealthy merchants and civil servants residing in Bamako. In addition animals are kept under station-management on two state-owned research farms (Institut d'Economie Rural-Sotuba, Laboratoire Central Vétérinaire-Sotuba), where crossbreeds and indigenous breeds are kept for research purposes and production of breeding stock in a modernised system with stationary enclosures and supplementation. Family members of the herd owners may participate in care-giving in a few traditional herds, but commonly herdsmen are employed for herding in all three systems. They are paid in milk and agricultural products and rarely cash. Renumeration is low and income of herdsmen depends mainly on the quantity of milk off-take.

Study period, herd selection and animals

Herd owners were contacted by the agency of local veterinarians active in the 4 different zones. Herd selection was based on the willingness of the owner to participate, a minimum herd size of 10 reproductive females and a sedentary location within the study zone. For the selected 38 herds, management system was traditional in 15 herds (374 reproductive females), modernised in 21 herds (465 reproductive females) and on-station in 2 herds (115 reproductive females). All known gestations (N=784) in the participating study herds, including late abortions, stillbirths and live-births, were recorded from November 2002 to March 2004. From January 2003 to March 2004, all calves born alive since November 2002 were individually ear-tagged and followed-up monthly (N=756). At the age of 0-1, 2-3 and 5-6 months faeces and blood samples were collected for determination of gastrointestinal egg excretion and infections with vector-borne diseases, and the animals weighed. All calves born alive and dead during the course of the study were subjected to further investigations (N=93). Animals died or were killed to reduce agony and to save the meat for human consumption. No slaughter of healthy calves occurred, as the presence of the suckling calf is needed for milk production and the value of the animal increases with age. Causes of death determined included the causes which had led to the killing of terminally ill or injured calves.

Postmortem examinations and reported history of death

Herdsmen and cattle owners alerted the team whenever one of their calves was dying or had died. In addition, during each monthly herd visit, presence of all registered calves was controlled and herdsmen were questioned about the whereabouts of missing animals. Abortions, births and deaths that had occurred since the last visit were recorded. If information about a loss was given within 24 hours after death, the carcass was bought to conduct a clinical autopsy (N=51). The carcasses were dissected and inspected for gastrointestinal parasites. No viral or bacterial tests were done. History of death was recorded for all dead animals (N=93). This was a structured interview with the herdsmen and/or cattle owner about their perception of the cause of death. The interview started with an open question which gave the respondents the opportunity to tell the whole history of the dead calf from their point of view. Based on this history the perceived category of the loss was defined (disease, accident, poisoning, starvation, weakness, lost/stolen). Further category specific questions were asked to gain more detailed information, e.g. if category was disease, questions about symptoms observed and treatments applied were asked, or if no treatment had been done, what the reason had been for not treating the sick animal. The questionnaire was elaborated in French and forward-backward translated into Bambara. The questions were asked in Bambara by members of the research team which spoke Bambara as their native language. All answers were recorded in French. Before being applied in the study herds, the questionnaire was pre-tested with herdsmen of 2 herds that did not participate in the study. In addition, focus discussions with herdsmen about the sire selection strategy within their herds were conducted and herd management problems discussed with local private veterinarians (N=6) and the head of a local dairy unit.

Determination of causes of death

For each case, all information available from the postmortem examination, the reported history of death and the routinely collected information on parasite burden and live-weight were assembled to determine the cause of death. The information was handed over to two independent veterinarians who had not been involved in data collection to pose their diagnosis. If these two veterinarians made the same diagnosis for the primary cause of death, their diagnosis was registered as cause of death. If the two disagreed upon the cause of death, a third veterinarian was given the information and asked for his diagnosis. If his diagnosis matched the diagnosis of one of the two other veterinarians, this cause was registered. If all three veterinarians disagreed upon the cause of death, the cause was defined as unknown. The registered causes were the most likely causes of death based on the different amount of information available for each case. Case definitions of death categories are given in Table 5.3.

Statistical analysis

Calves born during the study could reach different ages. Only calves that died had absolute survival times, while survival times for all surviving calves were censored at the day the animals left the herd or the observations were terminated. SAS Version for Windows Release 8.2 was used to fit Kaplan-Meyer survival curves with the Proc Lifetest procedure and to compute Wilcoxon's signed-ranks tests for the determination of the effects of sex of calf, parity of dam, breed of calf and management system on calf mortality. Effect of management system on calf mortality was tested over all 3 management types and then pair wise comparisons between traditional and modernised and between traditional and station management were conducted. To test for the influence of breed of calf, management system and parity of dam on abortion rate, Chi-Square tests were used. Chi-Square tests were also used to test for an effect of management system on the occurrence of the most common causes of death and on frequency of herdsmen replacements.

5.4 Results

A total of 784 gestations, consisting of 22 abortions (3%), 6 stillbirths (1%) and 756 live-births (96%), were registered (Table 5.1). Management system and parity of dam had no effect on abortion rate, but breed had a significant effect with more European crossbreeds and less Zebu and N'Dama calves being aborted (Table 5.2). The reported average age of gestation at abortion was 6 ± 2 months. Seasonal distribution of abortions was 4 (18%) during the cold dry season, 5 (23%) during the hot dry season and 13 (59%) during the rainy season. Of 762 births, 6 (0.8%) were stillbirths (Table 5.1). Seasonal distribution of stillbirths was 5 during the cold dry season and 1 during the hot dry season. The frequency of total perinatal loss (TPL = abortions + stillbirths + perinatal mortality) was 5%.

Of the 756 live-births, 93 died during the course of the study (Table 5.1). Overall mortality rate during the first year of life was 16.7%. Mortality rate was significantly different for different management types (p=0.01), it was lowest for traditionally (9.9%), average for modernised (18.8%) and highest for station-managed calves (24.7%) (Figure 5.2). The differences between traditional and modernised management (P=0.02) and between traditional and station management (P=0.001) were significant. Neither breed, sex nor parity of dam had an effect on calf mortality rates (Table 5.2).

Table 5-1 Demographic data structure

Total number of observed gestations, losses due to abortions and stillbirths, number of observed live-births, number of deaths and number of postmortem examinations that could be performed per management system, breed of calf, parity of dam and sex of calf

	Total gestations	**Abortions**	**Stillbirths**	**Live-births**	**Deaths**	**Post-mortems**
Management						
Traditional	277	6	1	270	19	9
Modernised private	417	16	5	396	57	32
Modernised on station	90	0	0	90	17	10
Breed of calf						
Zebu	277	2	0	275	36	16
Zebu x N'Dama	46	1	1	44	6	6
European x Zebu	461	19	5	437	51	29
Parity of dam						
Primiparous	183	5	1	177	23	13
Multiparous	595	17	2	576	70	38
Unknown	6	0	3	3	0	0
Sex of calf						
Male	386	0	1	385	49	25
Female	369	0	2	367	43	26
Unknown	29	22	3	4	1	0
Total	784	22	6	756	93	51

Seasonal distribution of death cases was 44 (47%) during the rainy season (June to September), 29 (31%) during the cold dry season (October-February) and 20 (22%) during the hot dry season (February to May). Age distribution of cases was 21 (23%) aged less than 10 days, 30 (32%) aged 10 days to 3 months, 23 (25%) aged 3 to 6 months and 19 (20%) aged 6 to 15 months. In Table 5.3, the death categories, with case definitions and specific causes within that category, are listed. The most important causes of death were digestive tract disorders (28%), perinatal mortality (16%) and accidental losses (14%). The distribution of causes of death varied for different age classes and management systems (Table 5.4). Management system had a significant effect on the occurrence of losses due to digestive tract disorders (p=0.02), they were more common in modernised management (p=0.02) and on-station ($p<0.01$) than in traditional management. Management system had no significant effect on occurrence of perinatal losses or deaths due to malnutrition or accidents.

Table 5-2 Distribution of abortion rates and mortality rates (<12 months) in regard to management system, breed of calf, sex of calf and parity of dam

		Abortion rate*	Chi-Square Test	**Mortality rate**	Wilcoxon's signed rank test
			P-value		P-value
Management			0.22		0.01
	Traditional	2%		10%	
	Modernised private	4%		19%	
	Modernised on station	0%		25%	
Breed of calf			0.02		0.09
	Zebu	1%		18%	
	Zebu x N'Dama	2%		31%	
	European x Zebu	4%		16%	
Parity of dam			0.92		0.72
	Primiparous	3%		18%	
	Multiparous	3%		17%	
Sex of calf					0.80
	Male			18%	
	Female			16%	
Total		3%		17%	

*underestimated as early abortions are not reported by the herdsmen

In the interviews about the history of death, 48 animals were perceived by the herdsmen as having had a “disease” but only 25 of these calves had been treated. According to the herdsmen, the main reason preventing a treatment in 6 cases was the fact, that the owner had not visited the herd since the animal had fallen sick. In a further 9 cases the herdsmen reported, that the death had been to sudden. In focus discussions on sire selection with 15 herdsmen, 9 reported that in their herd the best male offspring of the last sire had been used as his replacement. In addition the same sire is used up to a decade. During the course of the study, one to two changes of the principal herdsman had been observed in 15 of the 38 participating herds. More herdsmen were replaced in traditionally managed herds than in modernised herds ($p=0.04$).

Table 5-3 Observed categories of death with case definitions and specific causes

N=93 dead calves aged 0-15 months	
Perinatal mortality	Live-births, that died during their first week of life without an obvious disease: 12 weak calves, 1 breech delivery, 1 suspected intra-uterine infection and 1 milk indigestibility
Accidental losses	1 road accident, 1 kill by dogs, 2 falls into a well, 1 reported snake bite, 2 suspected cases of botulism, 1 traumatization in a vaccination corridor, 1 horn blow, 1 broken leg, 2 losses on the pasture and 1 theft
Non-parasitic diarrhoea	9 calves with diarrhoea but a low number of gastrointestinal parasites or oocysts of coccidies
Starvation	Calves with a reported cause for malnutrition: 1 rejection by the dam, 2 deaths of the dam, 4 reduced lactations of the dam and 2 calves with a weak suckling instinct
Helminthosis	6 calves with diarrhoea, retarded growth, low hematocrit value and high numbers of gastrointestinal parasites *(Toxocara sp., Haemonchus sp., Oesophagostomum sp., Cooperia sp., Trichuris sp.*)
Ileus	5 calves with eaten plastics blocking the pylorus, 1 calf with a congenital intestinal malformation
Coccidiosis	5 calves with bloody diarrhoea and a high number of coccidian oocysts in their faeces
Sepsis	5 calves with fever and purulent arthritis in articulations of front and hind legs
Respiratory disorder	4 calves with cough and pathologies found on their lungs
Theileriosis	3 calves with positive blood smears for *Theileria sp*., nasal discharge, lacrimation, swelling of lymph nodes and emaciation
Nervous disorder	2 calves with coordination difficulties and trembling
Trypanosomiasis	1 calf with a positive blood smear for *Trypanosoma vivax,* anaemia and a progressive loss of condition
Unknown	15 deaths with an unclear ethiology

Table 5-4 Distribution of observed causes of death in different age classes and management systems

N = Number of dead calves per category, % = Proportion of all cases per category

Ranking	Death category	**Overall**		**Age category**								**Management system**					
				0-1 month		**1-3 months**		**3-6 months**		**6-15 months**		**Traditional**		**Modernised**		**Station**	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
2	Perinatal Mortality	15	*16.1*	15	*51.7*	0	*0.0*	0	*0.0*	0	*0.0*	2	*10.5*	10	*17.5*	3	*17.6*
3	Accidental losses	13	*14.0*	0	*0.0*	7	*31.8*	1	*4.3*	5	*26.3*	6	*31.6*	7	*12.3*	0	*0.0*
(1)	Non-parasitic diarrhoea *	9	*9.7*	3	*10.3*	2	*9.1*	4	*17.4*	0	*0.0*	1	*5.3*	6	*10.5*	2	*11.8*
4	Starvation	9	*9.7*	3	*10.3*	3	*13.6*	3	*13.0*	0	*0.0*	6	*31.6*	3	*5.3*	0	*0.0*
(1)	Helminthosis *	6	*6.5*	0	*0.0*	0	*0.0*	2	*8.7*	4	*21.1*	0	*0.0*	4	*7.0*	2	*11.8*
(1)	Ileus *	6	*6.5*	0	*0.0*	1	*4.5*	3	*13.0*	2	*10.5*	2	*10.5*	3	*5.3*	1	*5.9*
(1)	Coccidiosis *	5	*5.4*	1	*3.4*	2	*9.1*	2	*8.7*	0	*0.0*	0	*0.0*	4	*7.0*	1	*5.9*
5	Sepsis	5	*5.4*	3	*10.3*	1	*4.5*	0	*0.0*	1	*5.3*	0	*0.0*	1	*1.8*	4	*23.5*
6	Respiratory Disorder	4	*4.3*	0	*0.0*	1	*4.5*	2	*8.7*	1	*5.3*	1	*5.3*	3	*5.3*	0	*0.0*
7	Theileriosis	3	*3.2*	0	*0.0*	0	*0.0*	0	*0.0*	3	*15.8*	0	*0.0*	3	*5.3*	0	*0.0*
8	Nervous Disorder	2	*2.2*	0	*0.0*	1	*4.5*	1	*4.3*	0	*0.0*	1	*5.3*	1	*1.8*	0	*0.0*
9	Trypanosomiasis	1	*1.1*	0	*0.0*	0	*0.0*	1	*4.3*	0	*0.0*	0	*0.0*	0	*0.0*	1	*5.9*
	Unknown	15	*16.1*	4	*13.8*	4	*18.2*	4	*17.4*	3	*15.8*	0	*0.0*	12	*21.1*	3	*17.6*
	Total	**93**	***100.0***	**29**	***100.0***	**22**	***100.0***	**23**	***100.0***	**19**	***100.0***	**19**	***100.0***	**57**	***100.0***	**17**	***100.0***
1	Summarized as digestive disorder	26	*28.0*	4	*13.8*	5	*22.7*	11	*47.8*	6	*31.6*	3	*15.8*	17	*29.8*	6	*35.3*

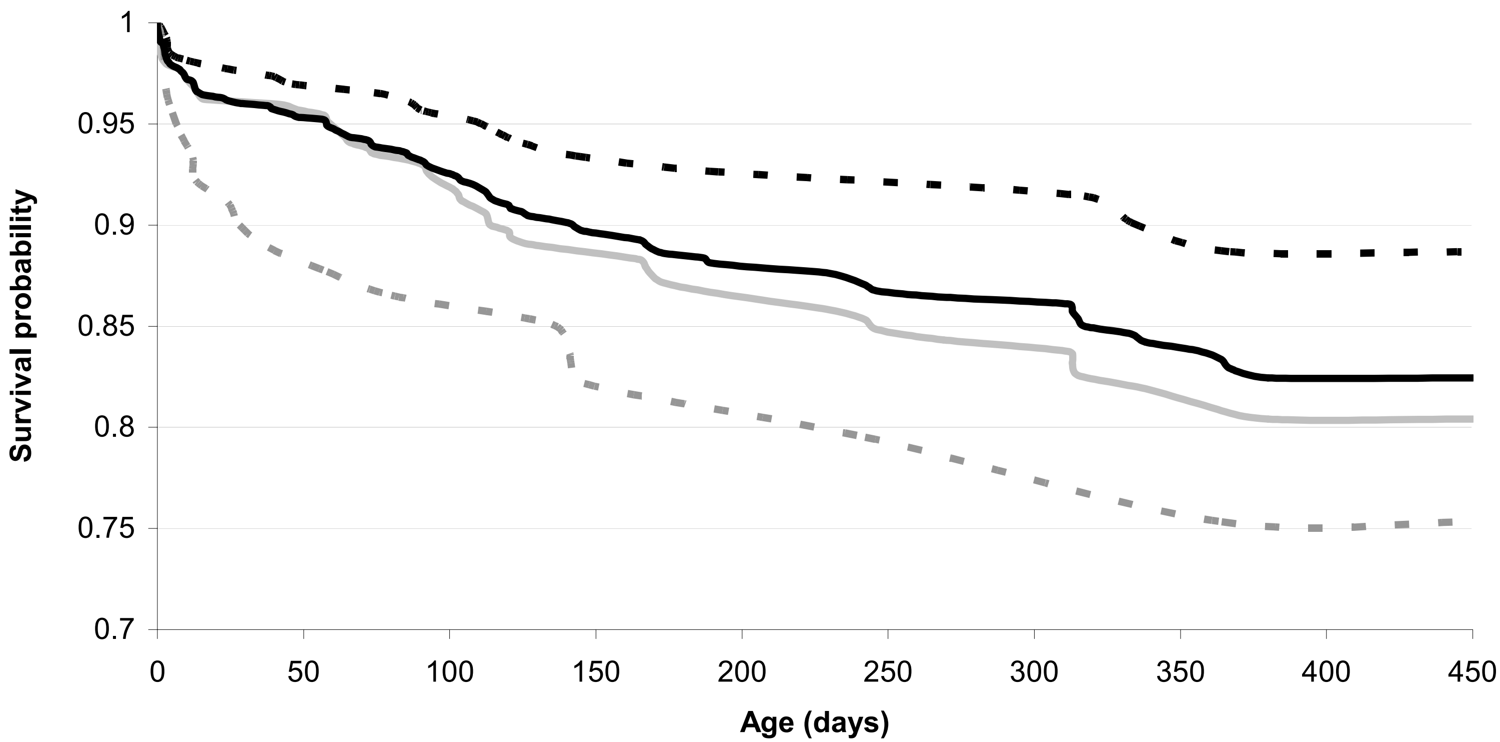

Figure 5-1 Kaplan Meier survival curves over all management systems (black) and for traditionally (dashed black), modernised (gray) and station (dashed grey) managed calves

5.5 Discussion

The aim of the study had been to determine calf mortality rates in different periurban livestock management systems as a baseline for the evaluation of the modernisation process and for the development of strategies to improve calf survival and thereby livestock productivity. Significant differences were found in mortality rates during the first year of life between management systems, with the lowest rate in traditional (10%), a medium rate in modernised (19%) and the highest rate in station (25%) managed herds. The mortality rate in traditionally managed herds was low compared to other recent West African studies which had found mortality rates of 6% (Ganaba et al. 2002) to 46% (Kudi et al. 1998) for traditionally managed calves. The mortality rate for station managed calves was very high in comparison to two recent West African studies that reported on-station calf mortality rates of 3% (Youssao et al. 2000) and 5-11% (Achard and Chanono 1997). The calf mortality rate found for modernised private periurban livestock production is the first reported for West Africa.

The willingness of the herd owners to participate in this study may reflect their interest in good herd management and the study itself may have increased awareness of calf health and as a consequence level of care given. Because herd owners are rarely present in their herd and difficult to reach, herds were not selected randomly but contacted through veterinarians. Veterinary care and the increased awareness of calf health may have lowered mortality rates in study herds in comparison to non-participating herds.

The higher mortality rates for modernised and station than for traditionally managed calves may be explained by the different holding systems, especially their impact on hygiene as discussed below under digestive tract disorders. Additionally European crossbreeds, the main breeds kept under modernised management, are reported to be more susceptible to diseases and parasites as the local Zebu breeds adapted to the environment (Kaufmann 1996), but an influence of breed was only found on abortion and not on mortality rate. A potential factor contributing to the high calf mortality rates is the relation between ownership and guardianship. In periurban livestock production, animals are normally not herded by their owners but by employed herdsmen. The lack of ownership of the guardian and small salaries are low incentives for a high commitment to animal care. Differences between management systems may be partially attributed to the relationship of herd owners to their animals and herdsmen and thus control of care given. Most of the traditional herds were visited regularly by their owners for which livestock production and agriculture are the main economic activities. Most of the modernised herds belonged to owners living in the capital Bamako, which invest in livestock production as a secondary economic activity and visit their animals on an irregular basis. On station, animals belong to the state and no personal economic interest in the health of the animals exists. But the personal contact of the owner to his animals may play an important role for the animals' welfare. Then the main reasons given for not treating sick animals were that the owner had not visited the herd since the animal had fallen sick and that the death had been to sudden, which sometimes may also include the above statement that the owner had had no time to see the sick calf. To reduce deaths due to delayed treatments, herdsmen should be authorized by the herd owners to call a veterinarian when animals become sick and no contact to the owner can be established.

Minor causes of death were sepsis, vector-borne diseases, respiratory and nervous disorders. All cases of sepsis occurred in modernised and station-managed calves kept in poor hygienic conditions. Vector-borne diseases, like trypanosomiasis and the tick-borne theileriosis, were not very frequent. Trypanosomiasis plays a much more important role in the more humid southern part of Mali, where it accounted for 38% of deaths in station-managed calves (Diall et al. 1992). Respiratory and nervous disorders occurred only in older calves but were rare.

Digestive tract disorders were the most important causes of death. Ileus occurred in all management types while all cases of helminthosis and coccidiosis occurred in modernised and station-managed calves and none in traditionally managed calves. The same is true for non-parasitic diarrhoea, for which only one case was found in traditional management and the remaining in modernised or station managed calves. In modernised and station management, calves are kept in stationary enclosures prone to problems with hygiene. The calf enclosures on the stations were rain-protected, but due to high stocking densities, hygiene was a problem all-year round. In modernised herds the main problems with hygiene occurred during the rainy season, when some of the enclosures were 10-20 cm deep filled with excrements and water. The proportion of animals dying of digestive tract disorders in our study was lower than either in Niger where this category accounted for 53% of deaths (Achard and Chanono 1997) or in Guinea where the category "Diarrhoea" caused 40% of deaths (Mourad and Magassouba 1996). No case of ileus due to plastics was reported in these studies. The 4 registered cases of deaths by plastics reflect the seasonal malnutrition and low milk yield which cause pica even in young calves and the problem of a poorly developed waste disposal system in Mali. In proximity to human settlements plastic bags can be found all over the place. In Bamako, herdsmen can even be seen herding their animals to rubbish piles for foraging. To reduce deaths due to digestive tract disorders, hygiene in modernised and station-managed herds should be ameliorated by regular cleaning out of the calf enclosures and structural modifications of the enclosures with drainage systems. Additionally, control strategies of gastrointestinal parasites in young calves kept under modernised management should be reconsidered.

Perinatal mortality accounted for 16% of losses, a proportion slightly lower than the 21% reported from Burkina Faso (Ganaba et al. 2002). Proportion of stillbirths found was similar to that in another study (Chassagne et al. 1999). Abortion and related to it, total perinatal loss, are underreported in this study as early abortions taking place during pasturing will pass unnoticed. A potential cause for stillbirths and especially for the reported abortions are infections with *Brucella abortus*. Brucellosis occurs frequently around Bamako, where a study on milk quality has found antibodies against *B. abortus* in 30% of raw milk samples at selling point (Bonfoh et al. 2003). The occurrence of a high number of weak calves that died may reflect a lack of immunity due to insufficient uptake of colostral milk or high levels of inbreeding in some herds. Questioned about sire selection, the majority of herdsmen reported to use the best male offspring of the last sire as his replacement. A significant relationship between level of inbreeding and calf mortality has been found by Uzmay and Akbas (2003). Free access of the newborn calf to its dam for colostral milk uptake during the first 48 hours after parturition, regular control for Brucellosis and avoidance of inbreeding may reduce perinatal losses.

The third most important cause of death were accidental losses due to management deficiencies. In herds with only one employed herdsman, calves are left unsupervised during the day while the herdsman pastures the herd. Young calves are kept in an enclosure or tethered. But especially in traditional herds, calves aged more than 2 months are let free to roam around on the surrounding pasture. This enables them to feed but increases the risk of accidental losses. Our result on the proportion of deaths due to accidental losses is in accordance with the reported proportion of 7-14% from Guinea (Mourad and Magassouba 1996) and 13% from Burkina Faso (Ganaba et al. 2002). To reduce losses due to accidents, calves should be better protected from dangers by securing hazardous spots in the vicinity of calves (e.g. open wells), by tethering them on the pasture or by assuring a better herding. But labour already accounts for 44% of production costs in periurban livestock production of Bamako (Sall 2002). Investments done in stationary enclosures are mainly aimed at improving security but lead to the observed problems with hygiene.

The fourth most important cause of death was starvation caused by a lack of milk. With the exception of the station-managed calves, nearly all calves suffer from malnutrition during the dry season. In traditional herds where animals receive few supplementary feed, starvation was the second most important cause of death. But starvation occurs also in modernised herds as supplementation is rarely given in a quantity large enough to cover alimentary needs. In modernised herds, amelioration of quality and quantity of feed may reduce direct and indirect losses due to malnutrition. If animals are not supplemented, the only possibility to control malnutrition is by controlling milk off-take. But to maximise quantity of milk off-take at the expense of the calf is favoured by the common remuneration payment of herdsmen in milk. Benefiting from more milk but not directly from calf health may entice herdsmen to milk too much. Another salary system with equal gains from milk production and calf health, e.g. cash salaries, may motivate herdsmen more to consider the needs of the calves and improve the relationship between herdsmen and owners. Then discussions with key informants (veterinarians, head of a local dairy unit) revealed, that the amount of milk off-take is the major cause for mistrust between cattle owners and their herdsmen. The strenuous relationship between the herdsmen and owners is reflected in the frequent replacement of herdsmen. This high turnover of herdsmen has lead to a loss of knowledge about the animals within the respective herds and may have contributed to high mortality rates.

5.6 Conclusions

Overall calf mortality rate found in the periurban zone of Bamako was 17% during the first year of life. This implies a reduced milk production of every 6th cow and losses of every 6th future dairy, slaughter and draught cattle. Higher mortality rates occurred in modernised private and on station systems than in traditional systems, reducing the benefits of modernising livestock production. The majority of deaths reported in this study are due to management problems, especially poor hygiene in modernised systems, lack of surveillance and milk deficiencies. With a better training of cattle breeders and herdsmen, an improved payment system for herdsmen, better hygiene, improved surveillance and supplementation, a high proportion of deaths could be prevented. All suggested management changes should be assessed for their cost-effectiveness in each management system, before being applied on a large scale.

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Chapter 6

Risk factors of calf mortality in periurban livestock production in Mali

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6 RISK FACTORS OF CALF MORTALITY IN PERIURBAN LIVESTOCK PRODUCTION IN MALI

6.1 Abstract

The survival of 756 calves in 38 herds in the periurban zone of Bamako, Mali, was observed from November 2002 to March 2004. To account for the heterogeneity within the population due to the clustering of individual calves in herds, herd was incorporated into the analysis, using a Cox frailty model. A two-step approach was used for the risk factor analysis. In a first step, demographic factors, management related factors and parasitic information were tested with a Cox proportional hazard model. All variables with a $p<0.1$ from the first step were then included in a second step into a Cox frailty analysis to correct for potential herd effects. Higher mortality rates in modernised in comparison to traditionally managed calves could be confirmed (Hazard ratio 2.2, CI 1.2-3.8, $p=0.01$). The risk factors found for the age class 0-1 month were birth complications (Hazard ratio 18.4, CI 4.4-75.9, $p<0.01$), season of birth with a higher risk of mortality for calves born during the rainy season (Hazard ratio 7.1, CI 2.9-17.8, $p<0.01$), parity of dam with calves of multiparous cows having a higher risk of mortality than calves of heifers (Hazard ratio 5.2, CI 1.2-22.1, $p=0.03$), chicken with calves being in no contact with chicken having a higher risk of mortality (Hazard ratio 8.9, CI 2.1-38.1, $p<0.01$) and herd size with calves born into larger herds having a higher mortality risk (Hazard ratio 3.4, CI 1.0-11.7, $p=0.05$). In the age class 1-6 months, calves managed by a single herdsman were at a higher risk of mortality than if several herdsmen were employed (Hazard ratio 3.5, CI 1.8-6.6, $p<0.01$). The only risk factor to occur more often in modernised management than in traditional management was low number of herdsmen.

6.2 Introduction

In Mali, although livestock is the third most important export commodity, local milk production does not cover the domestic demand for dairy products. Over 60% of the consumed milk products are imported but still consumption of dairy products is less than 12 kg/person/year (Debrah et al. 1995). To increase the genetic potential for growth and milk production, crossbreeding programs between local zebu breeds (*Bos taurus indicus*) and European breeds (*Bos taurus taurus*) have been implemented. In addition a modernisation of management practices has taken place in the periurban zones to overcome environmental constrains like seasonal malnutrition and losses due to parasites and infectious diseases. But the modernisation is only partial and the milking procedure is still with the calf at foot. As a consequence, calf mortality leads not only to losses in slaughter animals, future breeding stock and draught animals, but also to losses in milk yield, counteracting the Malian efforts to increase their domestic milk production. In a longitudinal cohort study conducted from 2002 to 2004 we found an overall mortality rate during the first year of life of 16.7%. Confirming previous findings (Anonymous 1978, Planchenault et al. 1981, Traore and Wilson 1988, Wagenaar et al. 1986) that calf mortality (< 1 year) is a real problem in Mali with mortality rates ranging from 10% to 47%. Of especial concern is our finding of higher mortality rates in modernised management (on-station 25%, private 19%) than in traditional management (10%) (Wymann et al. submitted), which counteracts the efforts to increase livestock productivity by modernisation of management practices. To reduce the losses due to calf mortality, above all in modernised management, information about the risk factors for calf mortality is necessary. Because all calves within a herd experience similar management practices and most share a similar genetic background (same sire or related dams), clustering in herds needs to be accounted for. The objectives of this study were to confirm the effect of management-type on calf mortality in regard to the clustering of calves in herds, to determine the risk factors for calf mortality and to test for associations between risk factors and management type.

6.3 Methods

Period and study zone

This study was conducted from January 2003 until March 2004 on animals born from November 2002 until March 2004. Animals originated from within a 40 km radius around Bamako, the capital of the Republic of Mali. Bamako lies within the Sahelian zone in West Africa, with a long dry season from November to May and a single rainy season from June to October. It is situated at the foothills of the Manding Mountains with an average elevation of 381 m.

Study herds

A total of 38 herds were recruited into the study. Because herd owners are rarely encountered in their herds, private veterinarians active in the study zone mediated the initial contacts. Herd selection criteria were a minimum herd size of 10 reproductive females, sedentary location within the periurban zone and the herd owners' consent to participate with their animals. Herd management practice was traditional in 15 private herds (374 reproductive females) and modernised in 23 herds (21 private herds with 465 reproductive females, 2 research stations with 115 reproductive females).

Study animals and data collection

All calves born alive (N=756 calves) into the participating study herds from November 2002 until March 2004 were individually ear tagged and followed-up monthly until the end of the study in March 2004. Information about date of birth, sex, breed, parity of dam and calving difficulties were reported for each newborn calf. Of each calf present at the age 0-1 month and 5-6 months, tick burden was assessed by counting all the ticks present on one side of the calf (Half body count). At the same time a faecal sample was collected from the rectum and processed according to a modified McMaster method (Boch et al. 1983) for quantitative determination of helminth egg and coccidian oocyst counts per gram of faeces (EPG and OPG). When one of the calves died, herdsmen were asked to inform the research team immediately about its death. In addition, during each monthly herd visit, the presence of all tagged calves was controlled and the herdsmen asked whether untagged newborn calves had already perished or if animals had left the herd. Calves died or were killed to reduce their agony and to salvage the meat for human consumption. No slaughter of healthy calves occurs, as the stimulus of the suckling calf is needed for milk letdown and the value of the calf increases with age. To gain information about herd management factors a structured interview was conducted with the herdsmen and herd owners at the onset of the cohort study. The interview was elaborated in French and forward-backward translated into the local languages Bambara and Peul. The interviews were conducted by native speakers in Bambara or Peul according to the mother tongue of the respondent. All answers were recorded in French. Before being applied in the study herds, the interview was pre-tested for its applicability with herdsmen of 2 non-participating herds.

Statistical analysis

Double data entry was carried out in Microsoft Access 2000 (Microsoft Corporation, USA) and in EpiData 2.1 (The EpiData Association, Denmark), which was used for the elaboration and processing of the interview. Stata 8.0 (Stata Corporation, USA) was used for statistical analysis. Survival times of all calves surviving until the end of the observation period or sold during the course of the study were right-censored at the day the study was finished or the day the calves were sold. Kaplan Meier method was used to estimate the survival function for each herd. Stata 8.0 allows to fit a Cox proportional hazard model with shared frailty. In this model the frailty is added to the basic proportional hazards model with hazard function

$h_k(t) = h_o(t) \exp(x_k, \beta)$

as Gamma distributed random effects with mean 1 and variance θ that enter multiplicatively on the hazard. The resulting hazard function for the *j*th calf in the *i*th herd at time t with shared frailty is

$h_{ij}(t) = \alpha_i h_o(t) \exp(x_{ij}, \beta)$

where t is the failure time, i the number of herds (in our example 1,..., 38 herds), j the 1,..., n_i calf in herd i, α_i the herd-level frailty, $h_o(t)$ the baseline hazard at time t, x_{ij} = row vector of covariates and β a parameter, whose estimates are obtained by maximizing the partial log-likelihood. The frailties are estimated as the coefficients of dummy variables added to the linear predictor (Gutierrez 2002, StataCorp 2003). The finite variance θ of the frailty is estimated by maximum profile log-likelihood from the data and given the standard error of θ, a likelihood-ratio test is performed to test for frailty effect (StataCorp 2003). Because the dummy variables for the frailty are added to the model, a sufficiently large sample is needed for analysis. In our study the sample was sufficient to perform a Cox frailty to test our previous finding of management effects on calf survival in regard to potential herd effects. But testing of a large set of explanatory variables could not be performed. To overcome this problem a two-step approach was chosen. In a first step a normal Cox proportional hazard model without frailty was conducted containing all the explanatory variables. Then in a second step all the variables which had a $p<0.1$ in the first step were tested in a Cox proportional hazard model with shared frailty to consider herd effects. The significance level was set at $p=0.1$ in the first step and $p=0.05$ in the second step. Because the level of exposure to the risk factors as well as the outcome to exposure may be age-dependent, separate analysis was done for the survival of newborn calves aged 0-1 month, for survival of young calves aged 1-6 months and for survival of older calves aged 6-12 months. Demographic and management factors were included in the model for calves aged 0-1 month (Table 6.2). Information about parasite burden collected at the age of 0-1 month respectively 5-6 months was added in the models for calves aged 1-6 months and 6-12 months (Table 6.3, Table 6.4). Demographic and management factors were available for all calves while parasite burden was limited to the calves present during herd visits. Calves with missing values were excluded from analysis. As a consequence, because most parasite variables were not included in the second step, the sample sizes for the age classes 1-6 months and 6-12 months were larger in the second than in the first step.

Table 6-1 Mortality rates (<1 year) for each herd and management type

Herd	Management type	Total	Dead	Time at risk (days)	Mortality rate
1	Modernised*	13	4	3204	0.49
2	Modernised*	77	13	14081	0.20
3	Modernised	21	2	4654	0.14
4	Modernised	13	3	3003	0.34
5	Modernised	28	3	6734	0.18
6	Modernised	17	3	3767	0.18
7	Modernised	12	0	2887	0.00
8	Modernised	15	1	3394	0.07
9	Traditional	26	3	4461	0.29
10	Modernised	10	0	3246	0.00
11	Modernised	31	4	7153	0.15
12	Traditional	12	1	2583	0.09
13	Traditional	11	0	1879	0.00
14	Traditional	23	1	5341	0.13
15	Modernised	38	2	8348	0.06
16	Modernised	8	2	1486	0.60
17	Modernised	10	3	2202	0.52
18	Modernised	13	5	2897	0.48
19	Modernised	25	4	5641	0.16
20	Modernised	18	1	3321	0.07
21	Traditional	18	1	3180	0.06
22	Traditional	15	1	2990	0.07
23	Modernised	15	8	2120	0.62
24	Traditional	21	0	4418	0.00
25	Modernised	31	2	7017	0.08
26	Traditional	29	2	5949	0.09
27	Traditional	24	3	5357	0.14
28	Traditional	11	0	2387	0.00
29	Modernised	25	1	5330	0.15
30	Modernised	11	2	2293	0.20
31	Modernised	24	2	5115	0.15
32	Traditional	13	1	2680	0.10
33	Modernised	18	5	3938	0.31
34	Traditional	11	0	2741	0.00
35	Traditional	22	4	5241	0.22
36	Traditional	6	0	1471	0.00
37	Modernised	14	3	2302	0.27
38	Traditional	27	1	2619	0.04
	Modernised	487	73	104133	0.20
	Traditional	269	18	53297	0.10
	Overall	756	91	157430	0.17

Kaplan Meier survival curves over the two strata levels were created for graphical presentation of significant risk factors. Management was not included in above multivariate models of risk factors, as some of the tested variables had been used for the categorization into management type. Chi-square tests were performed to test the association between the significant risk factors and management type (traditional, modernised). A two-sample t-test was performed to test for differences in the average number of cows per herdsman in small and large herds.

6.4 Results

Overall mortality rate during the first year of life was 17%, with some herds having no casualties while other herds loosing up to 62% of their calves (Table 6.1). With herd as random effect the higher calf mortality in modernised management in comparison to traditional management could be confirmed (Hazard ratio 2.2, CI 1.2-3.8, p=0.01). Calves in both modernised private (Hazard ratio 2.0, CI 1.1-3.7, p=0.02) and modernised on-station (Hazard ratio 3.1, CI 1.3-7.5, p=0.01) had a higher mortality than traditionally managed calves. The significant risk factors for the age class 0-1 month were birth complications, season of birth, parity of dam, no chicken and herd size (Table 6.2, Figure 6.1). The risk factor for calves aged 1-6 months was number of herdsmen (Table 6.3, Figure 6.2). No significant risk factor was found for the age class 6-12 months (Table 6.4). Occurrence of birth complications, season of birth and parity of dam did not depend on management type. Calves were more often kept with chicken in modernised management (49% with chicken) than in traditional management (29% with chicken) (p<0.01). Traditionally managed calves were born more often into large herds (68% into herds with more than 20 reproductive females) than calves under modernised management (56%) (p<0.01). Fewer herdsmen cared for calves in modernised management (36% with only 1 herdsman) than for calves under traditional management (23%) (p<0.01). Herdsmen in smaller herds were responsible for fewer cows per herdsman (Mean =11.2, CI = 8.6-13.7) than herdsmen in larger herds (Mean = 16.9, CI = 14.1-19.8; p<0.01).

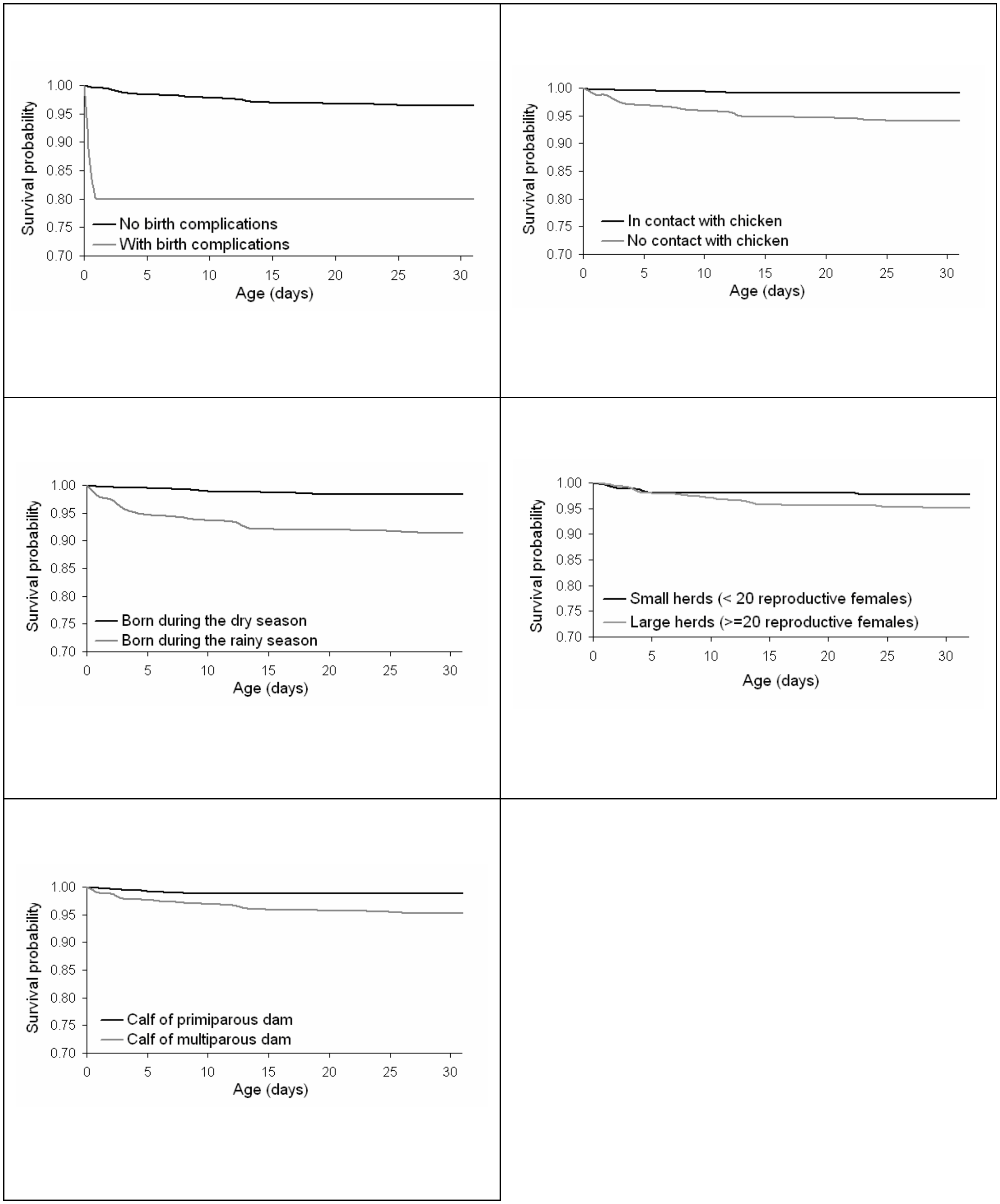

Figure 6-1 Kaplan Meier survival curves for the risk factors for calf mortality in the age class 0-1 month

Table 6-2 Results of the risk factor analysis for the age class 0-1 month

Results of the two-step risk factor analysis for calf survival from live-birth to 1 month: 1. step: Cox proportional hazard model, 2. step: Cox frailty model with herd as frailty effect and all variables with a p<0.1 from the Cox proportional hazard model

Variables			Cox proportional hazard model (n=753)				Cox frailty model with herd as frailty effect (n=753)			
			Hazard ratio	95% CI		p-value	Hazard ratio	95% CI		p-value
Birth complications	*no*	*yes*	11.9	2.9	48.1	**<0.01**	18.4	4.4	75.9	**<0.01**
Season of birth	*dry*	*rainy*	7.6	3.0	19.5	**<0.01**	7.1	2.9	17.8	**<0.01**
Sex	*male*	*female*	0.8	0.4	1.8	0.57	.	.	.	.
Parity of dam	*primiparous*	*multiparous*	5.1	1.2	22.2	**0.03**	5.2	1.2	22.1	**0.03**
Breed	*Zebu/N'Dama x Montbéliard/Holstein*	*Zebu/N'Dama*	0.8	0.3	2.3	0.74	.	.	.	.
Number of herdsmen	*several*	*only 1*	3.4	0.5	22.0	0.20	.	.	.	.
Experience of herdsmen	*>5 years*	*≤ 5 years*	0.2	0.1	1.0	**0.06**	0.5	0.2	1.5	0.20
Presence of chicken	*yes*	*no*	8.2	1.6	41.2	**0.01**	8.9	2.1	38.1	**<0.01**
Presence of sheep	*yes*	*no*	1.0	0.3	3.5	0.98	.	.	.	.
Night-holding place 0-1 month	*enclosure*	*rope*	2.0	0.3	13.3	0.46	.	.	.	.
Day-holding place 0-1 month	*pasture*	*rope/enclosure*	2.5	0.7	8.8	0.16	.	.	.	.
First separation from dam	*≤ 48 hours*	*> 48 hours*	0.3	0.0	2.9	0.30	.	.	.	.
First milking after parturition	*> 7 days*	*≤ 7 days*	2.9	0.6	14.4	0.18	.	.	.	.
Milking frequency	*2/day*	*1/day*	0.8	0.1	5.8	0.81	.	.	.	.
Access to water	*permanent*	*restricted*	2.5	0.6	9.3	0.19	.	.	.	.
Supplementation during rains	*no cotton residuals*	*with cotton residuals*	2.7	0.6	12.1	0.20	.	.	.	.
Supplementation in dry season	*no cotton residuals*	*with cotton residuals*	4.9	0.8	30.4	**0.09**	2.6	0.7	10.3	0.17
Herd size	*< 20 reproductive females*	*≥ 20 reproductive females*	6.5	1.1	36.5	**0.04**	3.4	1	11.7	**0.05**

Table 6-3 Results of the risk factor analysis for the age class 1-6 months

Results of the two-step risk factor analysis for calf survival from 1 month to 6 months: 1. step: Cox proportional hazard model, 2. step: Cox frailty model with herd as frailty effect and all variables with a p<0.1 from the Cox proportional hazard model

Variables			Cox proportional hazards model (n=267)				Cox frailty model with herd as frailty effect (n=702)			
			Hazard ratio	95% CI		p-value	Hazard ratio	95% CI		p-value
Season of birth	*dry*	*rainy*	2.3	0.6	8.1	0.20				
Sex	*male*	*female*	1.1	0.3	3.5	0.92				
Parity of dam	*primiparous*	*multiparous*	0.8	0.2	2.6	0.67				
Breed	*Zebu/N'Dama x Montbéliard/Holstein*	*Zebu/N'Dama*	1.5	0.2	9.6	0.69				
Number of herdsmen	*several*	*only 1*	67.6	4.1	1111.3	**<0.01**	**3.5**	**1.8**	**6.6**	**<0.01**
Experience of herdsmen	*>5 years*	*≤ 5 years*	0.2	0.0	1.1	**0.06**	0.8	0.4	1.5	0.49
Presence of chicken	*yes*	*no*	0.5	0.1	3.4	0.48				
Presence of sheep	*yes*	*no*	11.4	1.5	89.6	**0.02**	1.6	0.8	2.9	0.16
Night-holding place 1-6 months	*enclosure*	*rope*	0.1	0.0	2.0	0.13				
Day-holding place 1-6 months	*pasture*	*rope/enclosure*	9.7	0.8	121.3	**0.08**	0.8	0.5	1.5	0.56
Milking frequency	*2/day*	*1/day*	0.7	0.1	6.7	0.77				
Access to water	*permanent*	*restricted*	0.6	0.1	3.2	0.59				
Supplementation during rains	*no cotton residuals*	*with cotton residuals*	0.0	0.0	0.0	1.00				
Supplementation in dry season	*no cotton residuals*	*with cotton residuals*	0.6	0.1	3.2	0.57				
Herd size	*< 20 reproductive females*	*≥ 20 reproductive females*	6.0	0.6	56.6	0.12				
Strongyloides papillosus	*EPG<10'000*	*EPG ≥ 10'000*	0.0	0.0	0.0	1.00				
Strongyle-type parasites	*EPG<500*	*EPG ≥ 500*	0.0	0.0	0.0	1.00				
Eimeria sp.	*OPG<10'000*	*OPG ≥ 10'000*	6.6	0.6	74.0	0.13				
Toxocara vitulorum	*no*	*yes*	0.0	0.0	0.0	1.00				
Ticks	*half body count <5*	*Half body count ≥ 5*	1.7	0.1	25.0	0.70				

Table 6-4 Results of the risk factor analysis for the age class 6-12 months

Results of the two-step risk factor analysis for calf survival from 6 months to 12 months: 1. step: Cox proportional hazard model, 2. step: Cox frailty model with herd as frailty effect and all variables with a p<0.1 from the Cox proportional hazard model

Variables			Cox proportional hazards model (n=268)				Cox frailty model with herd as frailty effect (n=306)			
			Hazard ratio	95% CI		p-value	Hazard ratio	95% CI		p-value
Season of birth	*dry*	*rainy*	0.0	0.0	0.0	1.00				
Sex	*male*	*female*	1.2	0.3	4.5	0.77				
Parity of dam	*primiparous*	*multiparous*	1.4	0.3	7.5	0.72				
Breed	*Zebu/N'Dama x Montbéliard/Holstein*	*Zebu/N'Dama*	0.3	0.1	1.8	0.19				
Number of herdsmen	*several*	*only 1*	5.0	0.4	56.7	0.19				
Experience of herdsmen	*>5 years*	*≤ 5 years*	0.2	0.0	1.6	0.15				
Presence of chicken	*yes*	*no*	0.5	0.1	3.5	0.50				
Presence of sheep	*yes*	*no*	5.7	0.9	36.6	**0.07**	2.5	0.7	8.4	0.15
Night-holding place 6-12 months	*enclosure*	*rope*	0.1	0.0	13.1	0.37				
Day-holding place 6-12 months	*pasture*	*rope/enclosure*	2.7	0.5	16.0	0.27				
Milking frequency	*2/day*	*1/day*	2.0	0.0	182.0	0.77				
Access to water	*permanent*	*restricted*	1.5	0.2	12.6	0.70				
Supplementation during rains	*no cotton residuals*	*with cotton residuals*	1.2	0.1	21.3	0.91				
Supplementation in dry season	*no cotton residuals*	*with cotton residuals*	0.5	0.0	7.0	0.63				
Herd size	*< 20 reproductive females*	*≥ 20 reproductive females*	1.1	0.1	8.6	0.93				
Strongyles	*EPG<500*	EPG ≥ 500	2.0	0.2	20.5	0.58				
Ticks	*half body count <5*	*half body count ≥ 5*	4.4	1.0	18.8	**0.05**	2.5	0.7	8.8	0.14

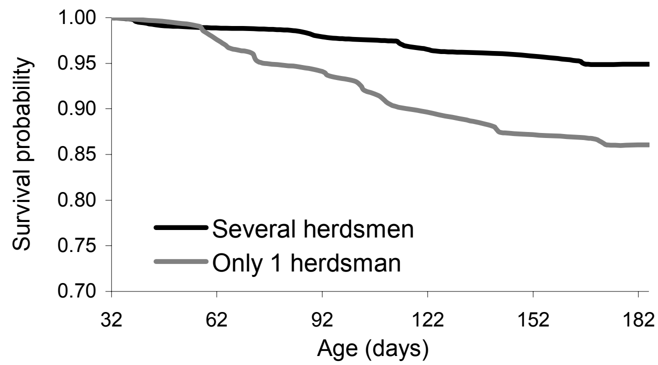

Figure 6-2 Kaplan Meier survival curves for the risk factor for calf mortality in the age class 1-6 months

6.5 Discussion

The usefulness of risk factor studies is limited to the scope of interventions available to counteract potential risks. In our study we have found that the risk factor with the highest hazard ratio in newborn calves are birth difficulties reported by the herdsmen. Normally cows are not assisted at calving in our study area and if complications are observed, most herdsmen do not have the decision power to call a veterinarian. To reduce the severity of calving complications, surveillance of pregnant animals should be increased and herdsmen should be empowered to call veterinarians and/or be trained in calving assistance. To reduce the occurrence of calving complications, herd owners should be advised on how to choose bulls and cows with good calving ease and at the same time be informed about the negative effects of the frequently conducted inbreeding on viability and productivity.

Calves born to multiparous cows had a higher mortality during their first month of life, contradicting the findings of other African studies (Mali: Traoré and Wilson 1988; Kenya: Bebe et al. 2001), that found higher mortality rates for calves of heifers. In our study multiparous cows were of different ages including old cows (>10 years) in poor body condition, which were often remarked by the herdsmen as having a very low milk yield. Further studies are needed to test whether old age is really the cause for the higher calf mortality of multiparous dams in our study area. If it is, culling of older animals and replacement by heifers could decrease overall calf mortality and increase the average milk production per cow.

Calves born during the rainy season had a higher risk of mortality during their first month of life than calves born during the dry season. Higher mortality rates of calves during the rainy season are also reported from other African countries (Senegal: Denis and Valenza 1972; The Gambia: Agyemang 1992; Guinea: Mourad and Magassouba 1996; Cameroun: Njoya et al. 1998; Kenya: Bebe et al. 2001). Because bulls are running with the herd, conceptions occur throughout the year, with a peak at the end of the rainy season when nutritional status of the cows is best (Zinsstag et al. 1997a). To counteract the adverse effects of the humid conditions, calves should be provided with dry, regularly cleaned or changed resting places.

Presence of chicken was protective, but a direct beneficial effect of chicken feeding on ticks (Hassan et al. 1991) upon calf survival is rather unlikely as young calves are not yet heavily infested with ticks. Chicken are more probably an indicator of surveillance, as chicken are normally kept in the vicinity of human housing. Another risk factor associated with surveillance is herd size. In small herds few animals occur per herdsman and as a consequence individual animals can be more easily observed and cared for. The same level of surveillance was not maintained in large herds, where more cows per herdsman occured. Although herd-size reflects an owner’s wealth, it is not a good indicator for the owner’s willingness to invest in individual animals, as in Mali large herds seem to be often kept more for prestige than for productivity.

Level of surveillance in terms of number of herdsmen employed was the risk factor associated with mortality in calves aged 1-6 months. In herds with only one herdsman the calves are unsupervised during the day when the herdsman leaves for pasturing the adult animals and weaned calves. In some herds, the wives and children of the herdsman may look after the calves, but care is only partial and depends on the amount of other household activities to be fulfilled. As a consequence, due to the lack of surveillance, sick calves are not remarked or attended to and accidental losses happen, which were the 3rd most important cause of death in our study (14%). To improve surveillance more herdsmen should be employed but labour already accounts for 44% of production costs in Malian periurban livestock production (Sall 2002)

Frailty models demand larger minimal samples than simple survival models, due to the creation of dummy variables for the frailty effect. This caused in our example a problem if larger sets of explanatory variables were to be tested. To reduce the number of variables a model can be build, using for example forward selection. A function available in Stata 8.0 for Cox proportional hazard models, but not if a frailty term is added. Another way is the two-step approach used in our example. It reduces the number of explanatory variables in the first step to only those that have a p-value below a given threshold (p=0.1) and then corrects for potential herd effects by doing a frailty analysis in the second step. This step-wise analysis is based on the assumption that the survival of a calf is positively correlated to the survival of other calves within the same herd, which is very likely as health hazards are similar for calves within a herd. If this assumption is true, the effects will be overestimated in the first step and no significant variables missed. A further possibility would have been to use a Bayesian approach in which frailty can be incorporated into the model as a function of covariates and estimated by Monte Carlo Markov Chain simulation (Chen et al. 2001). Whether a classical frequentist or a Bayesian approach is used, it is important to consider herd effects in on-farm survival studies as otherwise risk factors may be wrongly declared and scarce ressources of cattle breeders wasted. Even if the frailty effect turns out not to be significant, as in our example, incorporating it is the more accurate way to analyze data collected in on-farm studies.

Using herd as a random effect, the higher mortality in modernised than in traditional management could be confirmed. The only risk factor supporting the higher risk found in modernised management was that fewer herdsmen were employed in modernised compared to traditional management. But the two risk factors no chicken and large herds were both less frequent in modernised than in traditional management. The differences found in mortality rate between management types could therefore not be fully explained. The fact that all deaths caused by coccidiosis (5% of all deaths), helminthosis (7%) and the majority of deaths caused by non-parasitic diarrhoea (10%) had occurred in modernised management, indicates an important faecal sludge management problem. To test for the association between hygiene and higher mortality rates in modernised management, further studies establishing levels of hygiene are needed.

6.6 Conclusions

Cox frailty models offer the possibility to incorporate cluster effects into survival analysis, providing a more conservative assessment of risk factors. Considering herd effects, a higher calf mortality rate in modernised than in traditional management could be confirmed. But only one of the risk factors found, low number of herdsmen, did partially explain the higher mortality in modernised management. The other risk factors found were born during the rainy season, no chicken present, multiparous dam and large herd-size. The observed risks indicate the need for better surveillance, especially in modernised management. Employment of more herdsmen is costly, but could help to reduce accidental losses and provide better health care and calving assistance.

Acknowledgements

We would like to thank all herd owners for their permission to work with their animals. Thanks a lot to all herdsmen for their great efforts in handling the animals and informing the research team about mortalities. Laboratory work was carried out at the Central Veterinary Laboratory in Bamako, Mali. We would like to acknowledge N'Tio Samaké, Dicko Niafatoumata Ascofare, Lassine Zerbo, Bonfoh Viviane and Manuel Wymann for field and laboratory assistance. This study got financial support from the Jubilee Foundation of the Swiss Tropical Institute, the Mathieu-Stiftung Basel, the Syngenta Foundation, the Swiss Agency for Development and Cooperation (Capacity building programme "jeunes chercheurs"), the Swiss Tropical Institute, the Stiftung Emilia Guggenheim-Schnurr der naturforschenden Gesellschaft Basel and the Freiwillige Akademische Gesellschaft Basel.

Chapter 7

Species diversity and acquisition dynamics of gastrointestinal parasites in calves aged 0-13 months in Sahelian periurban livestock production

Monica N. WYMANN, Bassirou BONFOH, Koniba TRAORE, Saïdou TEMBELY and Jakob ZINSSTAG

7 SPECIES DIVERSITY AND ACQUISITION DYNAMICS OF GASTROINTESTINAL PARASITES IN CALVES AGED 0-13 MONTHS IN SAHELIAN PERIURBAN LIVESTOCK PRODUCTION

7.1 Abstract

We studied acquisition and spectrum of gastrointestinal parasites in young calves in periurban livestock production in Mali. Postmortem inspections on 51 calves that had died due to sickness or accidents were conducted. We used generalized linear models to test the influence of management, breed, age, season of birth and season of death on parasite number and parasite diversity. Number of parasite species and burden increased with age. In the age class 4-13 months animals carried already up to 8 parasite species. Parasite spectrum found included 11 nematodes, 3 cestodes and 1 protozoan parasite. The most frequent parasites found were *Haemonchus sp*. (Age class 0-1 month: 7%, 1-4 months: 38%, 4-13 months: 69%), *Cooperia pectinata* (0%, 33%, 44%), *Cooperia punctata* (0%, 33%, 38%) and *Moniezia sp.* (0%, 24%, 38%). Calves born during the rainy season had a higher parasite burden and diversity than calves born during the dry season. Calves acquired most of the parasites occurring in adult bovines within their first year of their life.

7.2 Introduction

Gastrointestinal parasite infections contribute to the low productivity of West African cattle production (Fabiyi 1987). To effectively control the parasites, choice and timing of the intervention strategy must be based on the age of the treated animals, the parasite species and environmental effects. To gain this baseline information, studies in West Africa have investigated gastrointestinal parasite burden and species diversity in bovines (Côte d'Ivoire: Achi et al. 2003; Komoin-Oka et al. 2000; Guinea: Ankers 1997; Mali: Tembely 1986; Senegal: Ndao et al. 1995; The Gambia: Kaufmann and Pfister 1990). Because species identification of gastrointestinal parasites can only be done by inspecting dead animals, nearly all studies have been conducted on adult slaughter-cattle in abattoirs. Young animals are seldom slaughtered, since local breeds need the stimulus of their suckling calf for milk letdown. As a consequence, data about suckling calves is very rare. Only one of above studies has looked at parasite burden in young calves that had died due to accidents or diseases

(Kaufmann and Pfister 1990). They stated that worm burden in suckling calves is very low but reported parasite spectrum and burden only for all “calves” with an average age of 27 months without further stratification into different age classes. The aim of this investigation was to collect information about species composition and acquisition dynamics of gastrointestinal parasites in calves aged less than a year to fill the information gap about the epidemiology of gastrointestinal parasites in very young bovines in West Africa.

7.3 Methods

Period and study zone

This work is part of a cohort study about causes and risk factors for calf mortality in the periurban zone of Bamako, Mali, and was conducted from January 2003 until March 2004. Animals originated from 4 zones in a 40 km radius around the capital. Bamako is situated at the foothills of the Manding Mountains with an average elevation of 381 m. It lies in the Sahelian zone with a long dry season from November to May and a single rainy season from June to October.

Study herds

To increase Malian milk production, a modernisation of periurban livestock management practices has taken place during the last decades, increasing daily milk yield from 0.5-2 litres/cow to more than 5 litres/cow (Debrah et al. 1995). Currently 2 main sedentary livestock management systems, traditional and modernised, can be distinguished. In traditional private management, local Zebu breeds and crossbreeds with N’Dama are kept on natural pastures with no or only few investments in supplementary feed or anti-parasitic treatments. In modernised private management, crossbreeding between local and European breeds has been done to increase the genetic potential for growth and milk production. The animals are supplemented to reduce the effects of seasonal malnutrition, parasite control is applied and calves are kept in enclosures for better protection. Modernised management is also encountered on state-owned research stations, where animals are bred for research purposes and production of breeding stock. Herd owners are rarely encountered in their herds and difficult to reach. To facilitate initial contacts, private veterinarians active in the 4 zones acted as intermediates for the study team. Herd selection criteria were a minimum herd size of 10 reproductive females, sedentary location within the periurban zone and herd owners that were willing to participate with their animals. We recruited 38 herds into our study for which management practice was traditional in 15 herds (374 reproductive females) and modernised in 23 herds (21 private herds with 465 reproductive females and 2 state-owned herds with 115 reproductive females).

Study animals

All calves born alive into the participating study herds from November 2002 until March 2004 were followed-up monthly (N=756 calves). When one of these calves died (N=93), we tried to access the carcass for an autopsy and for collection of the gastrointestinal tract (N=51). Some terminally ill or injured calves were killed by the owner to reduce their agony and to salvage the meat for human consumption. No slaughter of healthy calves occurs, because cows are milked with the calf at foot and need the stimulus of the suckling calf for milk production. Breed was either local like Zebu Maure, Zebu Peul and N'Dama or crossbreed of local breeds with European breeds like Montbéliard, Holstein or Rouge de Steppes.

Parasitic examinations

Whenever a study calf died, herdsmen were asked to inform the research team immediately about the calf's death. If the information was given within 24 hours after death we conducted a postmortem examination and bought the gastrointestinal tract for parasitological examinations. No viral or bacterial tests were conducted. We opened the carcass along the linea alba and inspected heart, lung and liver for parasites. We placed ligatures at the oesophagus and anus and double ligatures between each part of the gastrointestinal tract. In the field we opened the rumen, the reticulum and the omasum and examined them visually for pathologies, foreign bodies and parasites. We collected a faecal sample from the rectum and brought this sample, the abomasum, the small intestine and the large intestine to the laboratory. There we processed the faecal sample according to a modified McMaster technique for quantitative determination of egg and oocyst excretion (Boch et al. 1983). We inspected the mesenteric veins of the small intestine for *Schistosoma sp*. We then processed the abomasum, small and large intestine separately. We opened each part along its length and washed out its content. We passed the washing solution through a test sieve (200 µm), resuspended the sieve residual in 3 l of water and collected an aliquot of 200 ml. We counted and collected all parasites in this aliquot and identified their genus (females) and species (males) under a microscope after adding a drop of lacto-phenol. To account for the sampling of an aliquot of 200 ml of the total solution of 3 l, we multiplied parasite numbers by 15 to estimate the total burden. For detection of hypobiotic larvae we scratched off half of the abomasal mucosa and digested it in a pepsin solution. We then examined the sediment of the artificially digested mucosa for hypobiotic larvae and multiplied their number by 2 to estimate the total burden.

Statistical analysis

We used SAS 8.2 (Statistical Analysis System, Cary, USA) for statistical analysis. Because distributions of adult worm, egg and oocyst counts are highly skewed with the majority of animals having low counts and a minority having high counts, logarithmic transformations of worm, egg and oocyst counts were performed. The influence of environmental and demographic variables on EPG (number of eggs per gram of faeces) of *Strongyloides papillosus* and strongyles, OPG (number of oocysts per gram of faeces) of coccidies (*Eimeria sp*.), species diversity, number of *Haemonchus sp.*, number of *Cooperia sp*. and total number of parasites without *Haemonchus sp.* and *Cooperia sp*. were tested with generalized linear models with Poisson distribution and the variable herd included as a repeated effect to control for clustering (proc genmod). The variables considered were management (traditional, modernised), season of birth (dry, rainy), season of death (dry, rainy), breed (local breed including Zebu and crosses with N'Dama, crossbreed including all crosses between local and European breeds) and age in days (continuous variable).

7.4 Results

Of the 51 animals investigated, 10 (20%) had been born during the dry season and died during the rainy season, 12 (23.5%) had been born and died during the dry season, 12 (23.5%) had been born during the rainy season and died during the dry season and 17 (33%) had been born and died during the rainy season. Mean age at death was 121 days and age distribution was 14 (28%) calves aged 0-1 month, 21 (41%) aged 1-4 months and 16 (31%) aged 4-13 months. Of the 51 animals, 29 (57%) were European crossbreeds and 22 (43%) local breeds. Management practice was traditional for 7 (14%) cases and modernised for 44 (86%).

A total of 15 different parasites were found: 11 nematodes, 3 cestodes and 1 protozoa (Table 7.1). Of the 51 animals, 37 (73%) were infected with gastrointestinal parasites. Most of the parasite-free animals were calves aged 0-1 month. In this age class 9 (64%) had no parasites and 5 (36%) had 1 or 2 types of parasites. The 5 animals with parasites had all been born and died during the rainy season. The youngest calf in which a parasite was found was aged 3 days and had *Trichostrongylus axei*. In the age class 1-4 months, 3 (14%) animals were parasite free, 3 (14%) had one type of parasite and 15 (72%) had 2-5 parasite types. The 3 parasite-free animals had all been born and died during the dry season. In the older calves (4-13 months) only 1 (6%) animal was parasite-free, 3 (19%) had 1 type of parasite and 12 (75%) had 2-8 parasite types. The parasite free animal had been born during the dry and died at the onset of the rainy season. Number of different parasite species per animal increased with age ($p < 0.01$) (Figure 7.1) and animals born during the rainy season had more parasite species than animals born during the dry season ($p = 0.05$) (Figure 7.2).

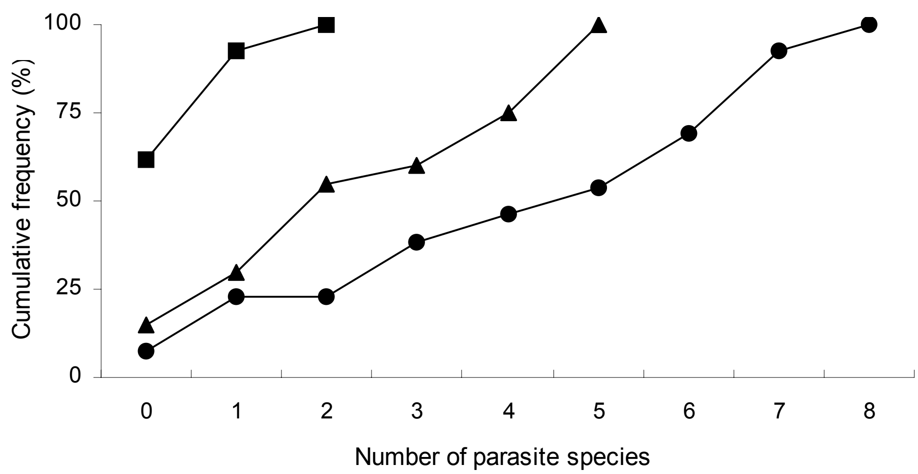

Figure 7-1 Cumulative frequency of gastrointestinal multiparasitism in calves aged 0-1 (squares), 1-4 (triangles) and 4-13 (circles) months

Born during the dry season (gray)
Born during the rainy season (black)

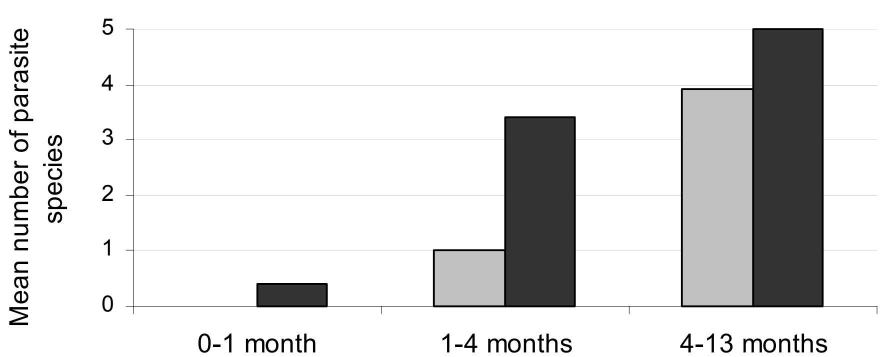

Figure 7-2 Mean number of gastrointestinal parasite species per age class and season of birth

Table 7-1 Inventory, prevalence and intensity of gastrointestinal parasite species found in postmortem examinations of calves aged 0-13 months

% = Prevalence, Mean = Geometric mean number of parasites in infected animals, Range = Minimum and maximum number of parasites

Parasites	**All age classes (N=51)**			**Age 0-1 month (N=14)**			**Age 1-4 months (N=21)**			**Age 4-13 months (N=16)**		
	%	Mean	Range	%	Mean	Range	%	Mean	Range	%	Mean	Range
Haemonchus sp.	41	166	15-3405	7	15		38	68	15-180	69	396	30-3405
Toxocara vitulorum	4	2	2-2	0			10	2	2-2	0		
Trichostrongylus axei	6	72	30-210	7	60		5	210		6	30	
Ostertagia sp.	10	38	15-60	0			5	45		25	37	15-60
Cooperia pectinata	27	650	45-14655	0			33	172	45-1005	44	2454	450-14655
Cooperia punctata	24	291	30-2910	0			33	170	30-780	38	543	75-2910
Cooperia curticei	4	1423	675-3000	0			5	675		6	3000	
Strongyloides papillosus	2	5145		0			5	5145		0		
Bunostomum phlebotonum	8	32	15-105	0			10	40	15-105	13	26	15-45
Moniezia sp.	24	3	1-12	0			24	3	1-12	38	2	1-3
Stilesia sp.	8	3	1-6	7	1		0			19	5	5-6
Avitellina sp.	2	6		0			5	6		0		
Trichuris sp.	2	405		0			0			6	405	
Oesophagostomum radiatum	6	37	15-75	0			0			19	37	15-75

Table 7-2 Inventory, prevalence and intensity of EPG and OPG of gastrointestinal parasites found in postmortem examinations of calves aged 0-13 months

EPG = number of eggs per gram of faeces, OPG = number of oocysts per gram of faeces, % = Prevalence, Mean = Geometric mean EPG or OPG in positive faecal samples, Range = Minimum and maximum EPG or OPG

	Parasites	**All age classes (N=48)**			**Age 0-1 month (N=14)**			**Age 1-4 months (N=18)**			**Age 4-13 months (N=16)**		
		%	Mean	Range	%	Mean	Range	%	Mean	Range	%	Mean	Range
EPG	*Strongyloides papillosus*	33	753	100-12000	0			50	560	100-4600	44	1237	300-12000
	Strongyle-type eggs	40	1455	50-14500	7	50		50	901	200-2850	56	3419	200-14500
	Moniezia sp	4	1269	700-2300	0			6	2300		6	700	
	Toxocara vitulorum	2	1700		0			6	1700		0		
OPG	*Eimeria sp.*	38	718	50-37500	14	250	50-1250	50	955	100-37500	44	702	50-29100

Spectrum, prevalence, average burden and minimum and maximum burden of parasites found in the gastrointestinal tract are summarized in Table 7.1. The parasite with the highest prevalence was *Haemonchus sp.* with 41% of all animals being infected. The youngest animal found to have *Haemonchus sp.* was aged 28 days. Besides *Haemonchus sp.* the most common parasites were *Cooperia pectinata, Cooperia punctata* and *Moniezia sp.* The youngest animal to have *Cooperia sp.* was aged 46 days and the youngest animal with *Moniezia sp*. aged 91 days. The youngest animal with *Oesophagostomum radiatum* was aged 270 days and the youngest animal with *Trichuris sp.* was aged 169 days. No infections with *Paraphistomatidae, Schistosoma sp., Fasciola sp., Dicrocoelium sp.* or *Echinococcus sp*. were found, but in faeces of live calves of the cohort aged 0-6 months eggs of *Paraphistomatidae* were identified. No hypobiotic larvae were found in the mucosa of the abomasum. Number of parasites increased with age (*Haemonchus sp.*: $p < 0.01$ (Figure 7.3); *Cooperia sp*.: $p < 0.01$ (Figure 7.4); total number of parasites without *Haemonchus sp.* and *Cooperia sp*.: $p = 0.01$ (Figure 7.5)). Number of *Cooperia sp*. was higher in animals born during the rainy than in animals born during the dry season ($p = 0.05$). Prevalence increased with age for most parasite species.

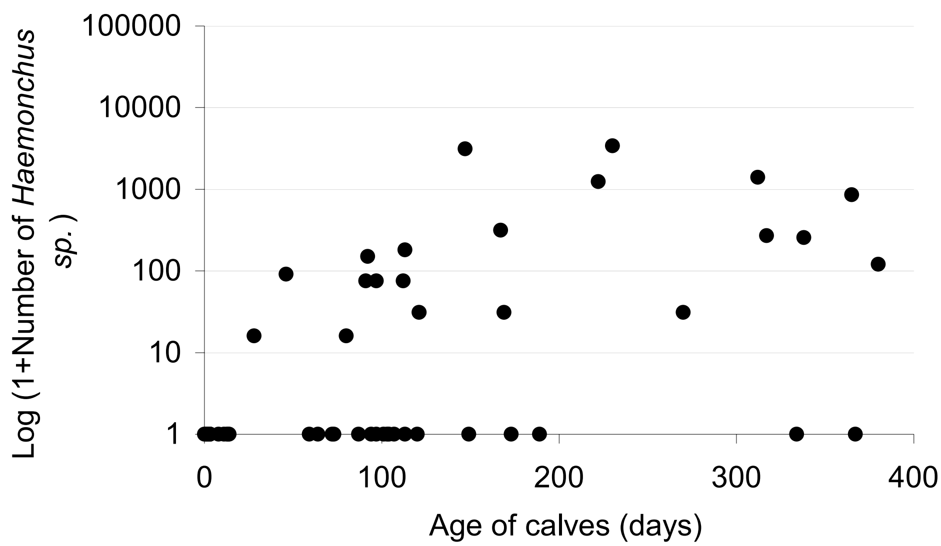

Figure 7-3 Parasite counts of Haemonchus sp. in postmortem examinations of calves

Spectrum, prevalence, average burden and range of eggs and cysts found in the coprological examinations are summarized in Table 7.2. Of the 51 animals, 3 had no stool in the rectum. Of the remaining 48, 33 (69%) had eggs and/or oocysts in their stool samples. Number of *S. papillosus* eggs excreted increased with age ($p < 0.01$). It was higher in animals kept under modernised management than under traditional management ($p < 0.01$) and animals born during the rainy season excreted more *S. papillosus* eggs than animals born during the dry season ($p < 0.01$). Number of coccidian oocysts excreted was higher in calves of local breeds than in crossbred cattle ($p = 0.03$).

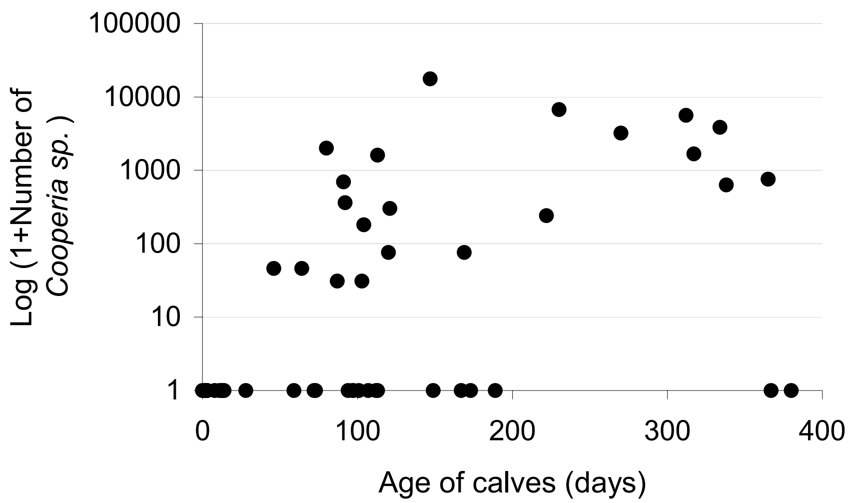

Figure 7-4 Parasite counts of Cooperia sp. in postmortem examinations of calves

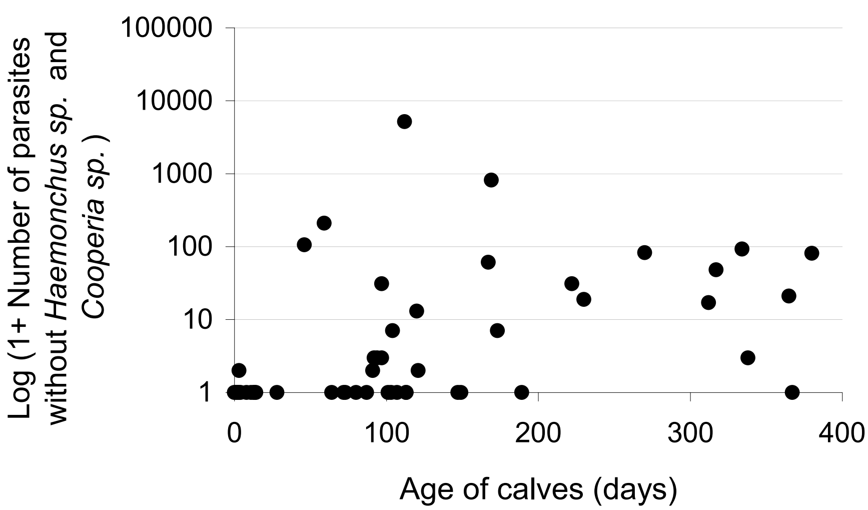

Figure 7-5 Parasite counts of gastrointestinal helminths without Haemonchus sp. and Cooperia sp. in postmortem examinations of calves

7.5 Discussion

Because healthy calves are normally not sold or slaughtered we worked with calves that died or were killed due to sickness or accidents. This had two main consequences. First, parasite burden of sick animals may differ from parasite burden of "healthy" calves, it may either be higher if immunity is suppressed or lower if sick animals were treated. Second, due to long distances between the location of the herds and the next telephone, herdsmen had to invest a lot of effort and time to inform the research team about mortalities. This resulted in a report rate of 55% of all cases and a time elapse between calf death and information of the team of up to 16 hours. The time elapse led to putrefaction and gave parasites the possibility to move within the carcass. This complicated species identification and potentially reduced parasite numbers found within the gastrointestinal tract.

Parasite spectrum encountered in this study with calves was similar to that found in other studies done on adult cattle in West Africa. As in adults, the most frequent parasites were *Haemonchus sp.* and *Cooperia sp.* The parasite *Haemonchus sp.* occurred in 69% of calves aged 4-12 months, a value which is already within the range of 67-88% found in studies on adult cattle in the Gambia (Zinsstag et al. 1998) and much higher than found in calves with an average age of 27 months in The Gambia (16-26%; Kaufmann and Pfister 1990). *Cooperia punctata* (24%) and *C. pectinata* (27%) occurred at a similar prevalence than in calves in The Gambia (17-32% and 14-24%; Kaufmann and Pfister, 1990) and were less frequent than in adult cattle in the Côte d'Ivoire (85% and 77%; Achi et al. 2003) or in Guinea (71% and 41%; Ankers et al. 1997). *Oesophagostomum radiatum* was only encountered in the oldest age class and at a lower prevalence (23%) than in adult cattle (38-85%; Zinsstag et al. 1998). *Toxocara vitulorum* occurred in one calf, confirming its presence in Mali. But prevalence of *T. vitulorum* was much lower than in Guinea, where a coprological study has shown a prevalence rate of 42% in calves aged 15-50 days (Ankers et al. 1997). Prevalence of *S. papillosus* eggs (33%) was also lower than found in calves in Guinea (46%; Ankers et al. 1997). Management type had an effect on *S. papillosus* egg excretion with higher EPGs in modernised than in traditional management. This is likely reflecting the hygienic problems created by keeping the calves in stationary enclosures in modernised management.

In West Africa, slaughterhouse and coprological studies performed on adult cattle have established that worm numbers and egg excretion are seasonal, with higher numbers during the rainy season (Ankers et al. 1994, Zinsstag et al. 1998). As a consequence, calves born during the rainy season are expected to be at a higher risk of infection with gastrointestinal parasites than calves born during the dry season. A hypothesis which we can confirm, as number of different parasite species, number of adult *Cooperia sp.* and *S. papillosus* egg excretion were all higher in calves born during the rainy season than in animals born during the dry season. In addition, all calves aged 0-1 month already harbouring parasites had been born during the rainy season and none during the dry season. And all parasite-free animals aged 1-4 months had been born and died during the dry season never experiencing a rainy season. Higher worm loads in calves born during the rainy season may influence their acquisition of immunity.

Some parasites are reported to be transmitted from dam to calf via the placenta or through the colostral milk (*T. vitulorum, S. papillosus*) (Kaufmann 1996). But most gastrointestinal parasites infect their host by active skin penetration or oral uptake from the environment. Infections start right after birth as underlined by our finding of *T. axei* in a calf aged only 4 days. With a longer time of exposure to infective parasite stages, diversity and number of parasites are expected to increase. We found that age of the calves, which corresponds to the time of exposure, had a significant effect on parasite acquisition and parasite burden. Proportion of animals with parasites, proportion of animals with multiple infections, *S. papillosus* egg excretion, number of *Cooperia sp.*, number of *Haemonchus sp.* and total number of adult parasites without *Cooperia sp.* and *Haemonchus sp.* all increased with age.

7.6 Conclusions

Parasite burden and diversity of gastrointestinal parasites in suckling calves increased with age and calves aged 4-13 months hosted already up to 8 different parasite species. At weaning, towards the end of the first year of life, calves had already acquired a parasite spectrum similar to that found in adult cattle, with the most common parasites being *Haemonchus sp., Cooperia sp.* and *Moniezia sp.* Risk of infection was higher for calves born during the rainy season than for calves born during the dry season, as shown by a higher number and diversity of parasites. The diverse parasite spectrum already encountered in older calves indicates a scope for parasite control in calves at weaning.

Acknowledgements

We would like to thank all herd owners and herdsmen for their participation and their efforts in informing the team about mortalities. We acknowledge N'Tio Samaké, Dicko Niafatoumata Ascofare, Viviane Bonfoh and Manuel Wymann for field and laboratory assistance, Lassine Zerbo for his great help in accessing dead calves and Sékouba Bengaly for logistic support. Laboratory work was carried out at the Central Veterinary Laboratory in Bamako, Mali. We would like to acknowledge its Animal Unit for logistic support. This study was financed by the Jubilee Foundation of the Swiss Tropical Institute, the Mathieu-Stiftung Basel, the Syngenta Foundation, the Swiss Agency for Development and Cooperation (Capacity building programme "jeunes chercheurs"), the Swiss Tropical Institute, the Stiftung Emilia Guggenheim-Schnurr der naturforschenden Gesellschaft Basel and the Freiwillige Akademische Gesellschaft Basel.

Chapter 8

Gastrointestinal parasite egg excretion in young calves in periurban livestock production in Mali

Monica Natalie WYMANN, Koniba TRAORE, Bassirou BONFOH, Saïdou TEMBELY and Jakob ZINSSTAG

8 GASTROINTESTINAL PARASITE EGG EXCRETION IN YOUNG CALVES IN PERIURBAN LIVESTOCK PRODUCTION IN MALI

8.1 Abstract

Coprological data of 694 calves born into 38 herds in the periurban zone of Bamako, Mali, was collected from January 2003 to March 2004. Repeated sampling of calves was done at calf age 0-1 month (N=437), 2-3 months (N=490) and 5-6 months (N=337). The effects of season, age, breed, management type, parasite control at herd level and presence of sheep on egg and oocyst counts were determined. A Bayesian model with a negative binomial distribution for parasite counts was used, with herd and individual effects to account for the clustering of calves in herds and the repeated sampling of individual calves. In addition, interviews were conducted with herdsmen and cattle owners to report the currently applied gastrointestinal parasite control strategies. We found at moderate to high prevalence eggs of *Strongyloides papillosus* (Age class 0-1 month: 39%, 2-3 months: 59%, 5-6 months: 42%) and strongyles (14%, 24%, 36%) and coccidian oocysts (37%, 68%, 64%) and at low prevalence eggs of *Toxocara vitulorum, Moniezia sp, Trichuris sp.* and *Paramphistomum sp*. Significant season and age effects were found on egg and oocyst counts. Transmission of gastrointestinal parasites occurred all year round but was lower during the dry than the rainy season. Egg counts of *S. papillosus* in calves aged 0-1 month were positively correlated to egg excretion of their dams, underlining the importance of vertical transmission for this parasite but also indicating a heritable component. Very early egg excretion in young calves showed a high infection pressure on newborn calves. Reported utilisation of gastrointestinal parasite control was high (92%), but actual recorded use during the observation period of 15 months was significantly lower (61%) ($p<0.01$), indicating a low priority given by cattle breeders to gastrointestinal parasite control.

8.2 Introduction

Malian livestock production does not cover the domestic demand for dairy products and, although consumption is only 12 kg/person/year, about 60% of consumed milk products are imported (Debrah et al. 1995). To increase Malian dairy productivity, a modernisation of management methods and crossbreeding of local Zebu with European breeds have taken place in the periurban zones during the last decades. This change from traditional to modernised management affects the environment in which the transmission of parasites and diseases takes place. This is important, as gastrointestinal parasite infections are one of the known constraints on livestock production in West Africa (Zinsstag et al. 1998). They reduce weight gain (Dwinger et al. 1994, N'Dao et al. 1995, Zinsstag et al. 1997a) and fertility (Zinsstag et al. 1997b) and may cause direct losses (Vassiliades 1984). In the periurban zone of Bamako, endo- and ectoparasites are reported to account for 50% of health problems of dams and calves (Coulibaly 2002). The negative impact of gastrointestinal parasites on calf-rearing has also been confirmed in our cohort study on calf survival in the periurban zone, in which 6% of death causes had been diagnosed as helminthosis and a further 5% as coccidiosis. All these deaths had occurred in modernised and none in traditional management systems. To plan effective control strategies, more information about gastrointestinal parasite acquisition in young calves kept in different management systems is necessary. The aim of this study was to determine the effect of environmental and demographic factors on egg excretion in young calves in traditional and modernised management. A second aim was to assess the current use of gastrointestinal control strategies in the periurban zone.

8.3 Methods

Study zone

This study was conducted in the periurban zone of Bamako, from January 2003 to March 2004. Bamako, the capital of the Republic of Mali, lies at the foothills of the Manding Mountains with an average altitude of 381m. It is within the Sahelian zone and can be climatically divided into a single rainy season from June to September, a cold dry season from October to January and a hot dry season from February to May. The study animals originated from 38 herds within the periurban zone of about 40 km around the capital.

Herd management systems

Two main sedentary management systems, traditional and modernised, can be distinguished in the periurban zone of Bamako. In the traditional system, local Zebu breeds and crosses with N'Dama are kept on unimproved pastures with few investments in supplementary feed, in vaccinations or in anti-parasitic treatments. The calves are kept tethered or in movable enclosures constructed of bushes, branches or wire-netting. During the rains, the surrounding of the calves is only temporary moistened and if the place gets too soiled, the rope or enclosure can be easily moved to another spot. Daily milk production of local breeds under traditional management is about 0.5-2 litres/cow (Debrah et al. 1995). In modernised private management, crossbreeding of local Zebu with European breeds has been conducted to increase genetic potential for milk and meat production. Additionally, more investments in supplementary feed, vaccinations (CBPP, anthrax, pasteurellosis, blackleg) and parasitic control are done to overcome the constraints of seasonal malnutrition and the detrimental effects of infectious and parasitic diseases. Calves are kept in enclosures build of brick or concrete with natural or concrete floors, without drainage systems. Often calves share the enclosure with sheep. During the rainy season, water mixes with excrements and stagnates within these enclosures for weeks. Daily milk production in modernised private management is above 5 litres/cow (Debrah et al. 1995). In modernised management on research stations, local breeds and European crossbreeds are kept for research purposes and production of breeding stock.

Herd selection and study animals

Thirty-eight herds were contacted with the aid of private veterinarians active in the periurban zone. The selection criteria were a minimum herd size of 10 reproductive females, a sedentary location within the study zone and the herd owner's willingness to participate. Management system in the study herds was traditional for 15 herds (374 reproductive females) and modernised for 23 herds (21 private herds and 2 research stations with a total of 580 reproductive females). All calves born alive into the participating herds from November 2002 to March 2004 (N=756) were individually ear-tagged and followed up monthly.

Sampling method

Of 694 calves 1 to 3 faecal samples per animal were collected during the course of the study, depending on the date of birth, the presence of calves during herd visits and study exit of calves due to death or sale. Faecal sampling was conducted at the age of 0-1 month (N=437), 2-3 months (N=490) and 5-6 months (N=338). In addition a faecal sample was collected each of the dams of newborn calves (N=156) and of sheep kept in the same enclosure as calves (8 herds, 78 sheep, faecal collection in September and October 2003). The samples were directly collected from the rectum into a plastic bag and transported in a cooler-box to the Central Veterinary Laboratory. They were processed and examined according to a modified

McMaster technique (Boch et al. 1983) for quantitative determination of number of eggs per gram of faeces (EPG) and number of oocysts per gram of faeces (OPG).

Reported and recorded parasite control

A structured interview was conducted with the herdsmen and/or herd owners about their applied parasite control strategies and perceived importance of gastrointestinal parasites as a cause of calf losses within their herd. The interview consisted of open and closed questions. For some questions probes were included after spontaneous answers. The interview was elaborated in French and forward-backward translated into the local languages Bambara and Peul. The questions were asked in Bambara or Peul according to the mother tongue of the respondent. The interviews were conducted by native speakers of the respective languages. All answers were recorded in French. Before being applied in the study herds, the interview was pre-tested for its applicability with herdsmen of 2 non-participating herds. In addition, during each monthly follow-up visit we asked the herdsmen about treatments conducted since our last visit to compare the in the interviews reported use to the actual recorded use of gastrointestinal control during the course of the study.

Statistical analysis

Frequentist data analysis was conducted in STATA v. 8.0 (Stata Corporation, College Station, Texas, USA) and Bayesian modelling in WinBUGS v. 1.4 (Imperial College & Medical Research Council, London, UK). Separate regression analysis was done to test the effect of covariates on EPG of *Strongyloides papillosus*, strongyles, *Toxocara vitulorum* and on OPG of coccidies. The covariates considered in our models were management type (traditional, modernised), season (cold dry, hot dry, rainy), age category (0-40 days, 50-100 days, 140-190 days), breed (local breed including Zebu and crosses with N'Dama, crossbreed including all crosses between local and European breeds like Montbéliard, Holstein and Rouge de Steppes), recorded use of gastrointestinal parasite control at herd level during the 15 months of the study (yes, no) and contact of calves with sheep as a potential host reservoir for gastrointestinal parasites (no, yes). The two random factors considered were herd (38 herds) and calf (694 calves). Because egg and oocyst counts were overdispersed, with most animals having no or few eggs or oocysts and only a few having a high number of eggs or oocysts, negative binomial regression models were applied. In these models, the egg and oocyst counts y have a negative binomial distribution

$y_1, y_2, y_3, ..y_n \sim$ NB (p_i, r)

The mean (μ_i) of the egg and oocyst counts depend on the individual's covariates X_i

$\mu_i = \exp(X_{i.}\ \beta)$

$\log(\mu_i) = b1 + b2*X_{1i} + b3*X_{2i} + b4*X_{3i} + ... + b_k*X_{ni}$

and the variance (Var) is based on the mean (μ_i) and r, the aggregation parameter of the negative binomial distribution which quantifies the amount of extra Poisson variation

$Var = \mu_i + \mu_i^2/r$

The covariates are modelled on the log (μ_i), where

$p_i = r / (r + \mu_i)$.

Clustering of calves in herds (H) and repeated sampling of individual calves (C) was incorporated into the model by adding two random effects to the linear predictor of log (μ_i)

$\log(\mu_i) = b1 + b2*X_{1i} + b3*X_{2i} + b4*X_{3i} + ... + b_k*X_{ni} + a1*H_i + a2*C_i$

A first Bayesian model was run without random effects and its results compared to the outcome of a negative binomial regression model calculated in STATA v. 8.0. In a second step, the two random effects were added to the model. We used a Gamma (0.1, 0.1) distribution for the prior of the aggregation parameter r. For the regression parameters b_k non-informative Normal (0, 0.01) prior distributions were chosen. For the random effect parameters a1 and a2, Normal (0, tau1) and Normal (0, tau2) prior distributions were selected, with Gamma (0.01, 0.01) hyper-prior distributions for tau1 and tau2. In the model without random effects, zeros were chosen as initial values for b_k. In the second model with random effects, the estimated means for b_k from the first model were used as initial values for b_k and zeros as initial values for the dummy variables of the random effects. Monte Carlo Markov Chain (MCMC) simulation was applied to fit the models. A single chain was run for each model with an initial burning in of 5000 iterations. Assessment of convergence was done by inspecting the means of covariates. To assess whether the model with random effects or the model without random effects had a better fit, the deviance information criterion (DIC) was used (Spiegelhalter et al. 2002). For presentation of results, the estimated coefficients b were transformed to incidence rate ratios e^b.

A Chi-Square Test was applied to test for a difference in use of parasite control between herds that had reported to have lost calves due to gastrointestinal parasites in the year preceding the study and those that had not. A Chi-Square Test was used to test for a difference between reported and actually conducted gastrointestinal parasite control. A t-Test was used to compare mean number of gastrointestinal parasite controls in herds with modernised and with traditional management. A simple linear regression was applied to assess the association between egg and oocyst excretion of calves (0-1 month) with egg and oocyst excretion of their respective dams (N=95).

8.4 Results

A total of 6 types of eggs and different oocysts of coccidia were found. The inventory and prevalence of parasite eggs and coccidian oocysts for the 3 age classes of calves, the adult cows and sheep are presented in Table 8.1 and Table 8.2.

Table 8-1 Inventory, prevalence and intensity of EPG and OPG of gastrointestinal parasites in live sheep and cows

EPG = number of eggs per gram of faeces, OPG = number of oocysts per gram of faeces, Prev = prevalence, Mean = geometric mean EPG and OPG of animals with positive faecal samples, Range = Minimum and maximum EPG and OPG

Parasites		**Sheep (N=78)**			**Cows > 3 years (N=156)**		
		Prev	Mean	Range	Prev	Mean	Range
EPG	*Strongyloides papillosus*	55.1	384	0-10300	13.5	229	0-5505
	Strongyle-type eggs	80.8	1076	0-32900	28.2	111	0-800
	Moniezia sp	7.7	222	0-2400	0	0	0
	Trichuris sp.	0	0	0	0	0	0
	Paramphistomum sp.	0	0	0	0	0	0
	Toxocara vitulorum	0	0	0	0	0	0
OPG	*Eimeria sp.*	88.5	1059	0-19650	25.6	189	0-18900

For monthly prevalence of *S. papillosus*, strongyle and *T. vitulorum* eggs and coccidian oocysts see Figure 8.1 and Figure 8.2. A significant positive correlation between EPG of *Strongyloides papillosus* of calves and of their dams was found (p=0.002) (Figure 8.3). No significant correlations between strongyle-type egg and coccidian oocyst counts of dams and calves were found. Age and season had significant effects on egg and oocyst excretion in the models with random effects, but sheep had only an effect in models without random effects but not if the models were corrected for random effects (Table 8.3-8.6) (Figure 8.4). Herd and individual calf effects were significant in all 4 models with random effects. With the exception of the model for strongyle-type eggs, the deviance information criterion (DIC) in models with random effects was lower than in the models without random effects, indicating a better fit of models with random effects.

Herdsmen/owners of 35 (92%) of the 38 participating herds reported in interviews to routinely use 1 to 2 different anthelmintic drugs. The utilised products were Vermitan® (Albendazole) (54%), Albendazole® (40%), Synanthic® (Ofendazole) (14%), Ivomec® (Ivermectin) (9%), Exhelm® (6%), Typersan® (3%) and Eclosan® (3%). Asked about the causes of calf deaths within their herds in 2002, 8 herdsmen/owners reported spontaneously that deaths had been caused by gastrointestinal parasites and a further 3 affirmed them as a cause when probed for it. Eight herdsmen/owners reported spontaneously diarrhoea, which may include parasitic and non-parasitic diarrhoea, as a cause of death and a further 7 affirmed diarrhoea when probed for it. To improve calf health, 3 herdsmen/owners stated to use gastrointestinal parasite control, 3 to assure a good hygiene and 3 to provide a general good prophylaxis including gastrointestinal parasite control. The recorded frequency of actual treatments was significantly lower than the reported use ($p<0.01$). Only 23 herds (61%) had been actually treated during the 15 months of observation, of which 11 (48%) once, 8 (35%) twice, 3 (13%) thrice and 1 (4%) herd more than 3 times. In both modernised and traditionally managed herds parasite control was applied, but mean number of treatments was higher in modernised managed herds (1.4 treatments/15 months) than in traditional herds (0.7 treatments/15 months) ($p=0.05$). Of the recorded 45 treatments, 40 had been done in 2003, of which 28 (70%) during the rainy season and 12 (30%) during the dry seasons. Herds that had reported to have lost calves due to gastrointestinal parasites had a tendency to treat more than herds that had no losses reported, but the difference was not significant.

Table 8-2 Inventory, prevalence and intensity of EPG and OPG of gastrointestinal parasites in faecal samples of live calves aged 0-1, 2-3 and 5-6 months

EPG = Number of eggs per gram of faeces, OPG = Number of oocysts per gram of faeces, Prev = prevalence, Mean = geometric mean EPG and OPG of animals with positive faecal samples, Range = Minimum and maximum EPG and OPG

Parasites		**Age class 0-1 month (N=437)**			**Age class 2-3 months (N=490)**			**Age class 5-6 months (N=338)**		
		Prev	Mean	Range	Prev	Mean	Range	Prev	Mean	Range
EPG	*Strongyloides papillosus*	39.4	503	0-46900	59.4	343	0-9800	41.8	274	0-9150
	Strongyle-type eggs	14.0	145	0-4650	23.9	251	0-11000	36.2	260	0-10400
	Moniezia sp	0.2	50	0-50	0.8	21.3	0-10100	1.8	270	0-5200
	Trichuris sp.	0.2	1000	0-1000	2.5	89	0-300	0.3	50	0-50
	Paramphistomum sp.	0.2	50	0-50	0.2	50	0-50	0.3	250	0-250
	Toxocara vitulorum	2.7	841	0-19100	7.6	716	0-72300	0.9	324	0-4550
OPG	*Eimeria sp.*	37.3	570	0-65800	68.0	452	0-95500	63.5	293	0-62300

Table 8-3 Results of the negative binomial regression models for strongyle egg counts of calves (0-6 months)

Negative binomial regression without and with calf and herd effects to account for associations between strongyle-type egg excretion (EPG) and season, age, breed, management type, presence of sheep and parasite control

	Model without random effects			**Model with random effects**		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**0.06**	**0.03**	**0.13**	**0.06**	**0.03**	**0.12**
June-September	1.35	0.65	2.90	1.35	0.64	2.94
Age						
0-40 days	1.00			1.00		
50-100 days	**2.80**	**1.37**	**5.60**	**2.89**	**1.39**	**5.98**
140-190 days	**5.63**	**2.61**	**12.19**	**6.03**	**2.76**	**13.41**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	1.08	0.56	2.04	1.12	0.57	2.18
Management type						
Traditional	1.00			1.00		
Modernised	0.60	0.30	1.15	0.59	0.28	1.20
Parasite control at herd level						
No	1.00			1.00		
Yes	1.33	0.72	2.43	1.30	0.67	2.46
Sheep						
No sheep in calf enclosure	1.00			1.00		
Sheep in calf enclosure	**0.51**	**0.29**	**0.90**	0.54	0.29	1.02
				Mean	95% CI	
Herd effect: 1/tau1				0.09	0.00	0.42
Calf effect: 1/tau2				0.06	0.01	0.26
DIC	5887.21		<	5889.83		

Table 8-4 Results of the negative binomial regression models for Strongyloides papillosus egg counts of calves (0-6 months)

Negative binomial regression without and with calf and herd effects to account for associations between *Strongyloides papillosus* egg excretion (EPG) and season, age, breed, management type, presence of sheep and parasite control

	Model without random effects			**Model with random effects**		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	0.81	0.51	1.27	0.87	0.54	1.40
June-September	1.08	0.65	1.81	1.04	0.61	1.78
Age						
0-40 days	1.00			1.00		
50-100 days	0.72	0.46	1.14	0.77	0.48	1.24
140-190 days	**0.39**	**0.24**	**0.66**	**0.44**	**0.26**	**0.77**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	0.77	0.48	1.21	0.74	0.45	1.22
Management type						
Traditional	1.00			1.00		
Modernised	0.70	0.43	1.12	0.73	0.40	1.31
Parasite control at herd level						
No	1.00			1.00		
Yes	1.28	0.84	1.93	1.28	0.75	2.20
Sheep						
No sheep in calf enclosure	1.00			1.00		
Sheep in calf enclosure	0.95	0.62	1.45	0.94	1.00	0.94
				Mean	95% CI	
Herd effect: 1/tau1				0.21	0.02	0.60
Calf effect: 1/tau2				0.05	0.00	0.03
DIC	11526.4		>	11521.40		

Table 8-5 Results of the negative binomial regression models for Toxocara vitulorum egg counts of calves (0-6 months)

Negative binomial regression without and with calf and herd effects to account for associations between *Toxocara vitulorum* egg excretion (EPG) and season, age, breed, management type, presence of sheep and parasite control

	Model without random effects			**Model with random effects**		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	4.62	0.35	62.68	4.43	0.33	57.17
June-September	2.30	0.07	80.00	2.12	0.06	72.31
Age						
0-40 days	1.00			1.00		
50-100 days	3.04	0.15	95.30	3.11	0.15	105.64
140-190 days	**0.01**	**0.00**	**0.75**	**0.01**	**0.00**	**0.78**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	0.46	0.01	8.30	0.45	0.01	8.36
Management type						
Traditional	1.00			1.00		
Modernised	0.11	0.00	6.17	0.11	0.00	6.10
Parasite control at herd level						
No	1.00			1.00		
Yes	0.22	0.01	7.47	0.20	0.01	6.40
Sheep						
No sheep in calf enclosure	1.00			1.00		
Sheep in calf enclosure	5.42	0.13	310.44	5.67	0.14	330.96
				Mean	95% CI	
Herd effect: 1/tau1				37.22	5.71	107.20
Calf effect: 1/tau2				3.16	0.01	27.95
DIC	1378.15		>	1345.09		

Table 8-6 Results of the negative binomial regression models for coccidian oocyst counts of calves (0-6 months)

Negative binomial regression without and with calf and herd effects to account for associations between *Eimeria sp*. oocyst excretion (OPG) and season, age, breed, management type, presence of sheep and parasite control

	Model without random effects			**Model with random effects**		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**1.69**	**1.07**	**2.64**	**1.88**	**1.16**	**3.06**
June-September	**1.90**	**1.17**	**3.11**	**1.89**	**1.11**	**3.22**
Age						
0-40 days	1.00			1.00		
50-100 days	0.92	0.59	1.44	1.11	0.67	1.87
140-190 days	**0.37**	**0.23**	**0.61**	**0.53**	**0.31**	**0.94**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	0.75	0.51	1.11	0.91	0.52	1.59
Management type						
Traditional	1.00			1.00		
Modernised	0.91	0.62	1.32	0.98	0.61	1.58
Parasite control at herd level						
No	1.00			1.00		
Yes	1.37	0.94	1.97	1.37	0.82	2.29
Sheep						
No sheep in calf enclosure	1.00			1.00		
Sheep in calf enclosure	**1.54**	**1.05**	**2.22**	1.21	0.73	2.01
				Mean	95% CI	
Herd effect: 1/tau1				0.15	0.01	0.53
Calf effect: 1/tau2				0.47	0.09	0.91
DIC	13501.40		>	13463.40		

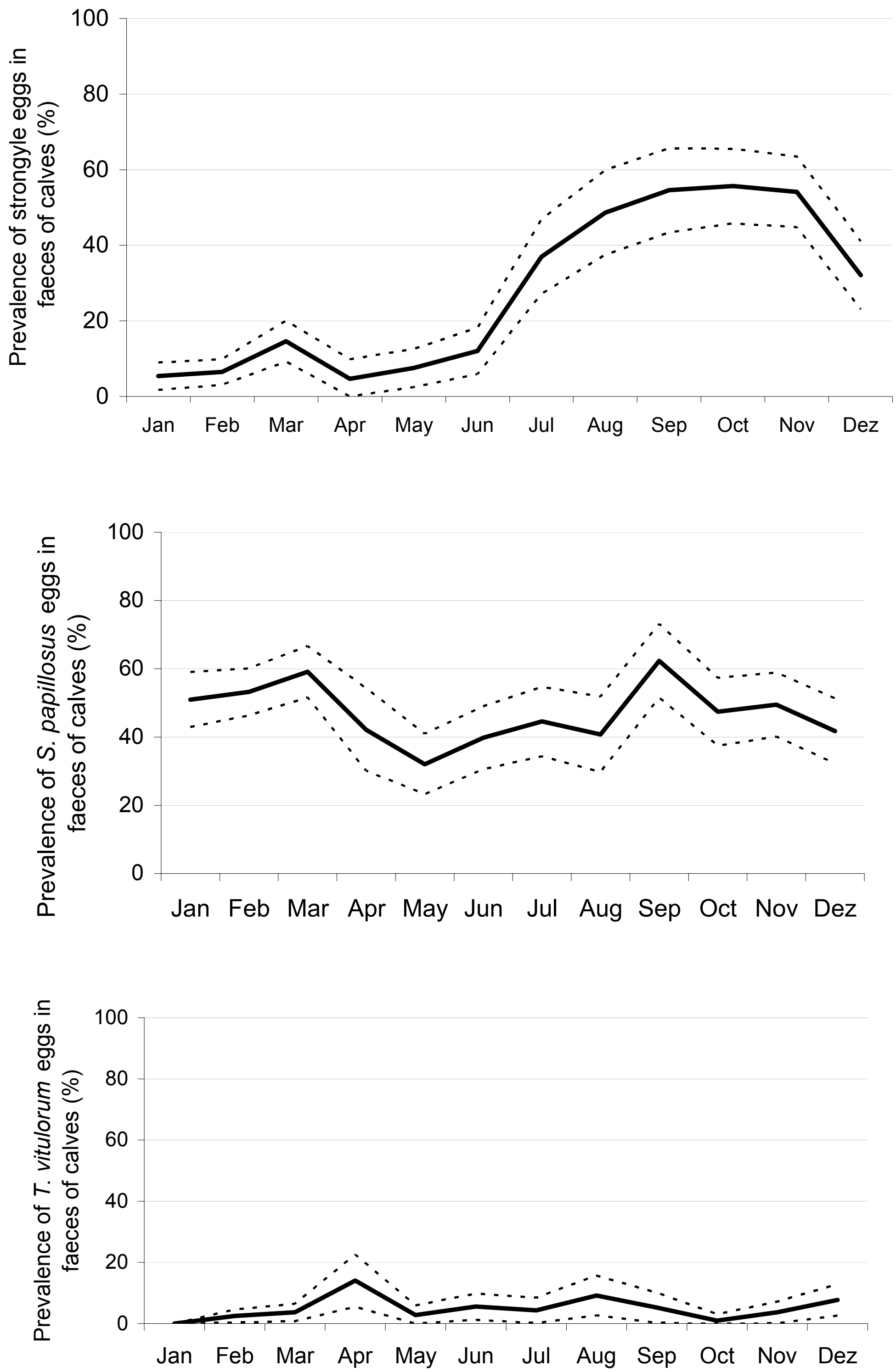

Figure 8-1 Monthly prevalence of strongyle, Strongyloides papillosus and Toxocarum vitulorum eggs in faeces of calves aged 0-6 months

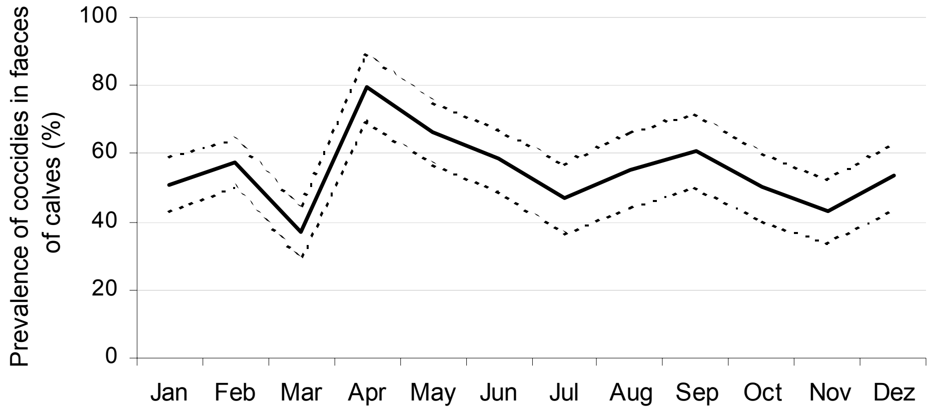

Figure 8-2 Monthly prevalence of coccidian oocysts in faeces of calves aged 0-6 months

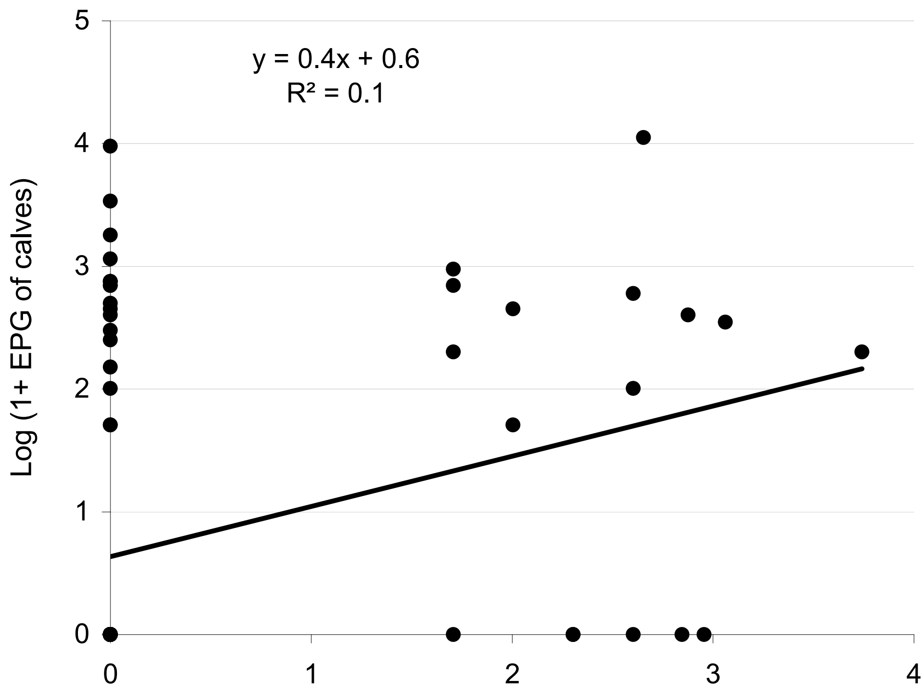

Figure 8-3 Linear regression of Strongyloides papillosus egg counts of calves and dams (N=95)

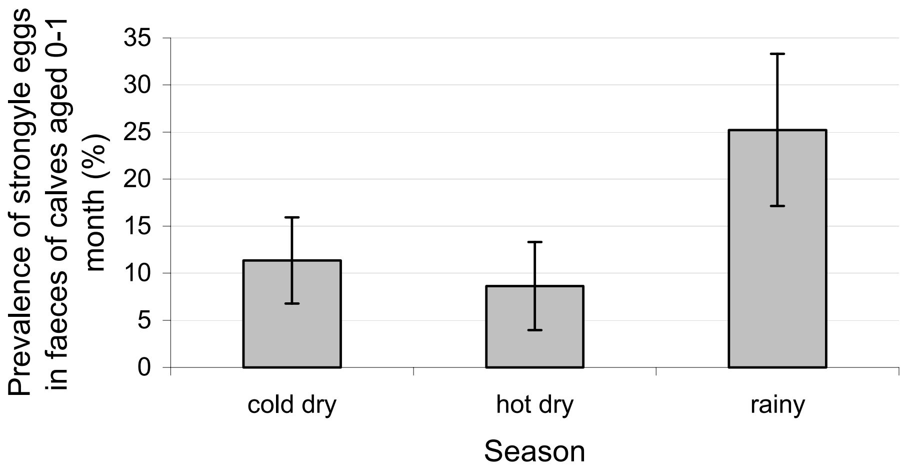

Figure 8-4 Seasonal prevalence of strongyle eggs in faeces of calves (0-1 month)

8.5 Discussion

Herd management, including anti-parasitic treatments, was practiced by the owners as normal with no interference by the study team. The results presented are therefore the spectrum and prevalence of parasite eggs and oocysts found in faecal samples under the currently applied management practices. Under these conditions, eggs of strongyles and *S. papillosus* and coccidian oocysts occurred in calves at moderate to high prevalence and eggs of *Moniezia sp*., *T. vitulorum, Trichuris sp*. and *Paramphistomum sp.* at low prevalence. The prevalence of cestode eggs was within the range of 0-24% found in adult cattle in Mali (Traoré and Wilson 1988). The prevalence of *Trichuris sp.* was within the range found in adult cattle in Côte d'Ivoire (Komoin-Oka et al. 2003) or in Guinea (Ankers et al. 1997). The prevalence of *Paramphistomum sp*. eggs was very low. Frequency of *T. vitulorum* eggs was lower than in Guinea with 42% in calves aged 15-50 days (Ankers et al. 1997) and Côte d'Ivoire with 12% in calves aged 0-12 months (Knopf et al. 2000). Coccidies were frequent and prevalence in calves higher than in adult cows in our study or another Malian study with 0-5% (Traoré and Wilson 1988). Prevalence of *S. papillosus* eggs was similar to the prevalence of 46% found in calves aged 15-50 days in Guinea (Ankers et al. 1997). Prevalence of strongyle eggs was similar to the prevalence found in calves aged 0-3 months (22%) and 3-6 months (21%) in an older study from Côte d'Ivoire (Mishra et al. 1979).

Age dependent increase and decrease of egg counts followed expectations based on the different parasite transmission strategies. The partially maternally transmitted parasites *S.*

papillosus and *T. vitulorum* were most common in young calves and already less frequent in calves aged 5-6 months. Coccidies were also more frequent in young calves, indicating development of immunity in older animals. Strongyle eggs increased with age and were most frequent in older calves with increased feed intake and thus increased risk of ingestion of infective paraite stages. Frequency of strongyle eggs is expected to increase further after weaning, as highest infection rates with strongyles are reported to occur in animals aged 1.5-3 years (Kaufmann and Pfister 1990). Very early occurrence of *S. papillosus*, strongyle and *T. vitulorum* eggs in faeces of calves aged less than 10 days were observed. These eggs were most likely taken up from the environment and passed out with faeces, as prepatence periods are longer. The occurrence of eggs in faeces of very young calves indicated a strong early infection pressure on newborn calves.

Seasonal egg excretion has been widely documented for adult cattle in West Africa (Ankers et al. 1997, Zinsstag et al. 1994). It is explained by the occurrence of harsh climatic conditions during the long dry season, which are unfavourable to most larval development (Kaufmann 1996). As a consequence, nematode transmission is very low on communal pastures during the dry season (Zinsstag et al. 1994). Strongyle egg counts of calves aged 0-6 months followed this seasonal pattern of adult egg excretion and were lowest during the hot dry season. Transmission in holding places was lowered but still present during the hot dry season as shown by the occurrence of strongyle eggs in faeces of calves born and sampled during the hot dry season. Egg excretion of partially maternally transmitted *S. papillosus* and *T. vitulorum* showed no seasonality.

A small pilot study on sheep, kept together with calves in the same enclosures, showed, that sheep shed high numbers of parasite eggs and could serve as an important source of infection for young calves. But in our analysis sheep effects were only found in models without random effects and could not be confirmed when results were corrected for clustering. Nevertheless, treating sheep is economically justified (Ankers et al. 1998) and it may therefore be recommended to treat sheep kept together with calves to reduce their potential role as a host reservoir.

Heritability of faecal egg counts is reported for N'Dama cattle in West Africa with a fraction of 0.18 of the faecal egg excretion being accounted for by a genetic component (Zinsstag et al. 2000). Heritability is difficult to asses as correlations found between dams and their offspring or half sibs are not only caused by heritable genetic resistance but are also due to a similar environment or direct transmission from dam to calf. All three factors may have been responsible for the positive correlation found between egg excretion of *S. papillosus* in dams and calves (0-1 month), as this parasite can be both horizontally and vertically transmitted (Kaufmann 1996). No correlation was found for coccidian oocyst counts or for strongyle egg counts in dams and calves, but prevalence of strongyle eggs was low in calves aged 0-1 month. Deworming of gestating females is an option to reduce dam to calf transmission. But neither an effect of herd treatments on occurrence of maternally transmitted parasites was found, nor an effect on strongyle egg excretion, although older calves were commonly included in gastrointestinal parasite control conducted by herd owners. Effectiveness and profitability of currently applied parasite control strategies in the periurban zone should be assessed. Then treating suckling calves in West Africa is often not economically justified, because live weight does not improve with strategic anthelmintic treatments in animals aged less than 1-2 years (Dwinger et al. 1994; N'Dao et al. 1995; Zinsstag et al. 1997). A low perceived economic benefit of gastrointestinal parasite control is indicated by the low priority given to it by herd owners. The discrepancy between the high reported use of gastrointestinal parasite control during the interviews and the lower actual frequency of applied controls recorded during the course of the study shows that although herd owners had the intention to treat, priorities were set different when the actual treatments should have been applied. Control treatments were conducted both in modernised and in traditionally managed herds but mean number of treatments was higher in modernised management. So although hygienic conditions were worse in modernised than in traditional management and all cases of fatal acute coccidiosis and helminthosis in our cohort study had occurred in modernised management, no effect of management system on egg and oocyst counts were found.

8.6 Conclusions

Under the current management strategies gastrointestinal parasite egg and oocyst excretion was moderate in calves in the periurban zone of Bamako. Transmission occurred all year round but was lower during the dry than the rainy season. Occurrence of eggs in faeces of very young calves indicated a very early infection risk for newborn calves. A correlation between *S. papillosus* egg counts of calves and their dams was observed, underlining the importance of vertical transmission for this parasite but also indicating a heritable component. No effect of management system on egg and oocyst counts was found. Routinely investigated egg and oocyst excretion did therefore not reflect the excess mortalities caused by gastrointestinal parasites in modernised in comparison to traditional management systems.

Profitability of currently applied parasite control strategies needs to be assessed and the potential role of sheep as a host reservoir for strongyles infecting newborn calves further examined.

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Chapter 9

Ticks, tick control and trypanosomes in young calves in periurban livestock production systems in Mali

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9 TICKS, TICK CONTROL AND TRYPANOSOMES IN YOUNG CALVES (0-6 MONTHS) IN PERIURBAN LIVESTOCK PRODUCTION SYSTEMS IN MALI

9.1 Abstract

A survey on ticks (N=667 calves) and of trypanosomes (N=705 calves) in 38 herds in the periurban zone of Bamako, Mali, was done from January 2003 to March 2004. Repeated assessment of tick burden was conducted at calf age 0-1 month, 2-3 months and 5-6 months. The effects of season, age, calf breed, herd management, tick control at herd level and presence of chicken on tick counts were determined. A Bayesian model with a negative binomial distribution for parasite counts was used, with herd and individual effects to account for the clustering of calves in herds and the repeated sampling of individual calves. In addition interviews were conducted with herdsmen and cattle owners to report the currently applied tick control strategies. The most common ticks found were *Amblyomma sp*. (71%), followed by *Hyalomma sp*. (23%), *Boophilus sp*. (4%) and *Rhipicephalus sp*. (1%). Mean geometric half-body tick count was 3.1 (range 0-65) with most calves being tick free (76%). Significant season, age and management effects on tick counts were found, with *A. variegatum* being less frequent in modernised than in traditional management (Incidence rate ratio 0.4, Confidence interval 0.2-0.9). Livestock owners and herdsmen reported trypanosomes to be an important cause of calf mortality in their herds. But their perception was not supported by the actual low *Trypanosoma sp.* prevalence of 1% in calves aged 0-6 months. The profitability of applied tick control should be assessed to optimise the use of scarce resources.

9.2 Introduction

With 7 Mio cattle, 18 Mio small ruminants and 230’000 camels, Mali is an important producer of livestock in West Africa. Live cattle for slaughter are the 3rd most important export commodity of the country and play an important role in its economy (DNS 2000). But in contrast to the beef sector, the dairy sector is not very productive and about 60% of consumed dairy products for about 15.5 Mia CFA (28.5 Mio USD) per year have to be imported (DNS 1999). To strengthen the dairy production, crossbreeding and a modernisation of management practices are taking place in the periurban areas. This modernisation affects calf mortality which is higher in modernised than in traditional management (Wymann et al, submitted) and also changes the environment in which parasites occur. Ticks, tick-borne diseases and tsetse fly transmitted trypanosomes are all known factors contributing to livestock production losses in West Africa (Mattioli et al. 2000; d'Ieteren and Kimani 2002). Parasite control is widely used in the periurban zone of Bamako, but ecto- and endoparasites are still reported to account for 50% of health problems of dams and their calves in this area (Coulibaly 2002). To improve parasite control strategies in calves, information on parasite dynamics in young calves kept in different herd management systems is needed. The aim of this study was to investigate the age-dependent seasonal occurrence of trypanosomes and ticks and to determine the effects of herd management system, occurrence of tick control at herd level, breed and the presence of chicken as a potential biological tick control tool (Hassan et al. 1991) on tick numbers. The second aim was to test a rapid tick assessment method developed by Knopf et al. (2002) for its applicability on calves.

9.3 Methods

This study was conducted from January 2003 to March 2004 as part of a longitudinal cohort study about calf mortality in the periurban zone of Bamako, Mali. Bamako lies within the Sahelian zone characterised by one annual rainy season from June to September, a cold dry season from October to January and a hot dry season from February to May. Mean annual precipitation is 1037 mm and mean annual temperature lies between 26°C to 35°C. Study animals originated from 38 herds, which were distributed over 4 zones in a 40 km radius around the capital. Herd selection criteria were the willingness of the owner to participate, a minimum herd size of 10 reproductive females and a sedentary location within the study zone. Initial contacts with cattle breeders were mediated by local veterinarians active in the periurban zone. Management system of the 38 participating herds was traditional in 15 private herds (374 reproductive females) and modernised in 21 private herds (465 reproductive females) and 2 research stations (115 reproductive females). All calves born alive from November 2002 until March 2004 were individually ear-tagged and followed-up monthly (N=756 calves). From March 2003 until March 2004, tick burden of 667 calves was assessed by examining one side of a calf's body surface (half body count) visually and in a tactile way for ticks. All ticks were counted and their genera, sex and development stage determined, if possible without removing the ticks from the calf. Tick burden assessment was conducted at the age of 0-1 month (N=438 calves), 2-3 months (N=417 calves) and 5-6 months (N=352 calves), resulting in 1 to 3 samples per calf depending on its date of birth, its presence during herd visits and its drop out of the study due to death, gift or sale. A further 36 tick counts were conducted on calves of other age categories (1-2 and 3-5 months), resulting in a total of 1244 half body counts. In addition from January 2003 until March 2004, a semi-quantitative rapid assessment method for ticks proposed by Knopf et al. (2002) was tested for its applicability in calves. In this rapid assessment only ticks present in a square of 7 cm-side length on the mid-dew lap were counted (Square count) (N=705 calves, N=1607 samples). Of all calves that died during the course of the cohort study, the study team tried to access the brain for production of squash smears of cerebral grey matter (N=46 samples). The smears were coloured in a Giemsa solution and the cytoplasm of the capillary endothelial cells investigated for colonies of tick-borne *Ehrlichia ruminantium* (formerly *Cowdria ruminantium*) (CIRDES 1998). For determination of trypanosome infections, a blood sample was collected from the jugular vein of calves (N=705 calves) aged 0-1 month (N=579 samples), 2-3 months (N=553 samples) and 5-6 months (N=369 samples). A phase-contrast buffy coat method was used for assessment of trypanosome infections and Giemsa stained thin blood smears produced for species confirmation (Kaufmann 1996). To gain information about tick control and the perceived importance of ticks and trypanosomes, a semi-structured interview with herdsmen and herd owners was conducted. The interview was elaborated in French and forward-backward translated into the local languages Bambara and Peul. Questions were asked in the mother-tongue of the respondent and answers recorded in French. For some questions probes were added after spontaneous answers. Before being applied to the study herds, the interview was pre-tested for its applicability with herdsmen of two non-participating herds. In addition during each monthly herd visit, tick control measures applied since the last visit were recorded.

Statistical analysis

Tick counts were overdispersed with most animals having no or few ticks and only a few having lots of ticks. As a consequence negative binomial models were used to test the effect of covariates on tick counts. In these models, the tick counts (Y) have a negative binomial distribution

$Y_1, Y_2, Y_3, ..Y_n \sim NB(p_i, r)$

The mean (μ_i) of the tick counts depends on the individual's covariates X_i

$\mu_i = \exp(X_i \beta)$

$\log(\mu_i) = b1 + b2{*}X_{1i} + b3{*}X_{2i} + b4{*}X_{3i} + \ldots\ldots.. + b_k{*}X_{ni}$

and the variance (Var) is based on the mean (μ_i) and the aggregation parameter (r) of the negative binomial distribution which quantifies the amount of extra Poisson variation

$Var = \mu_i + \mu_i^2 / r$

The covariates are modelled on the log (μ_i), where

$p_i = r / (r + \mu_i)$.

Because calves occur in herds, in which they share similar environments, similar management and often similar genetic background (same sire or related dams), analysis of data collected on different farms must consider clustering at herd level. In addition, in our longitudinal cohort design, repeated sampling was conducted on individual calves, demanding for a second random effect to account for individual calf effects. This clustering at herd (H) and at calf (C) level was incorporated into the model by adding two random effects to the linear predictor of log (μ_i)

$\log(\mu_i) = b1 + b2{*}X_{1i} + b3{*}X_{2i} + b4{*}X_{3i} + \ldots\ldots.. + b_k{*}X_{ni} + a1{*}H_i + a2{*}C_i$

(Gelman et al. 1995; Congdon 2001)

The covariates considered in the models were breed (local Zebu breeds or rare N'Dama and their crosses, crossbreeds of local breeds with European breeds like Montbéliard, Holstein or Rouge de Steppes), contact with chicken as a potential biological control tool (yes, no), season (rainy season, cold dry season, hot dry season), age (0-1 months, 2-3 months, 5-6 months), herd management (traditional, modernised) and tick control at herd level (1-2 treatments, > 2 treatments). The two random factors were herd (N=38) and calf (N=667). Analysis was done separately for the three different development stages of *Amblyomma variegatum* (adults, nymphs, larvae), and for adult *Hyalomma sp*. and adult *Boophilus sp*. *Rhipicephalus sp*. and other development stages of *Hyalomma sp*. and of *Boophilus sp.* occurred at too low a prevalence for in-depth analysis. Additionally the impact of the reported use of the acaricide Bayticol® (not used, used) on adult *A. variegatum* tick burden was examined with a negative binomial model, stratified for management type and corrected for season and age effects. Bayesian modelling was done in WinBUGS v. 1.4 (Imperial College & Medical Research Council, London, UK). In a first step a Bayesian model was run without random effects. In a second step, the two random effects were added to the model. A Gamma (0.1, 0.1) distribution for the prior of the aggregation parameter r was used. For the regression parameters b_k non-informative Normal (0, 0.01) prior distributions were chosen. For the random effect parameters a1 and a2, Normal (0, tau1) and Normal (0, tau2) prior distributions were selected, with Gamma (0.01, 0.01) prior distributions for tau1 and tau2. In the first model without random effects, zeros were chosen as initial values for b_k. In the second model with random effects, the estimated means for b_k from the first model were used as initial values for b_k and zeros as initial values for the dummy variables of the random effects. The estimated b were transformed to incidence rate ratios e^b for presentation of results. Monte Carlo Markov Chain (MCMC) simulation was applied to fit the models. A single chain was run for each model with an initial burning in of 5000 iterations. Assessment of convergence was done by inspecting the means of covariates. To assess the goodness of fit of models with random effects in comparison to the models without random effects, the deviance information criterion (DIC) was used (Spiegelhalter et al. 2002). To test the rapid tick assessment method on its applicability in calves, a simple linear regression as done by Knopf et al. (2002) was applied to compare dewlap counts with half body tick counts (N=1145). Pearson Chi-Square Tests were applied to compare between herd management types the use of tick control methods and the access of calves to pasture during the first week of life. T-tests were used to compare mean number of tick controls between herd management types and between herds using and not using the acaricide Bayticol®. Frequentist data analysis was conducted in STATA v. 8.0 (Stata Corporation, College Station, Texas, USA).

9.4 Results

In 1244 half-body counts a total of 1631 ticks were counted, belonging to 4 tick genera. *Amblyomma sp.* was the most common genus encountered (71%), followed by *Hyalomma sp*. (23%), *Boophilus sp*. (4%) and *Rhipicephalus sp*. (1%) (Table 9.1). The geometric mean half-body tick count was 3.1 (range 0-65) with most calves being tick free (76%). In 1607 square-counts the geometric mean was 1.8 ticks (range: 0-26), most animals had no ticks in the square on the dewlap (91%). Regression of half body counts for square-counts (Figure 9.1) resulted in an adjusted R^2=0.42 and a slope of 3.8 (95% CI: 3.5-4.1) ticks per square-counted tick for the half body tick burden. No evidence of tick-borne *E. ruminantium* was found in 46 brain smears of dead calves. Age, season and management type had significant effects on tick counts (Tables 9.2-9.6). Prevalence of ticks increased with age (Figure 9.2 and Figure 9.3). *Amblyomma variegatum* adults were most frequent in the hot dry and at the beginning of the rainy season, while *A. variegatum* juvenile stages and adult *Boophilus sp*. had a peak in the cold dry season (Figure 9.4 and Figure 9.5). Frequency of *A. variegatum* was lower in modernised than in traditional management (Figure 9.6). Herd and individual calf effects were significant in all models with random effects and based on the deviance information criterion (DIC) goodness of fit was better for all models with random effects.

Table 9-1 Number of ticks per genus and development stage found in half body counts (N=1244) on calves aged 0-6 months

	Total	Males	Females	Nymphs	Larvae
Amblyomma sp.	1157	426	114	266	351
Hyalomma sp.	381	306	72	2	1
Boophilus sp.	71	6	49	13	3
Rhipicephalus sp.	22	21	0	0	1

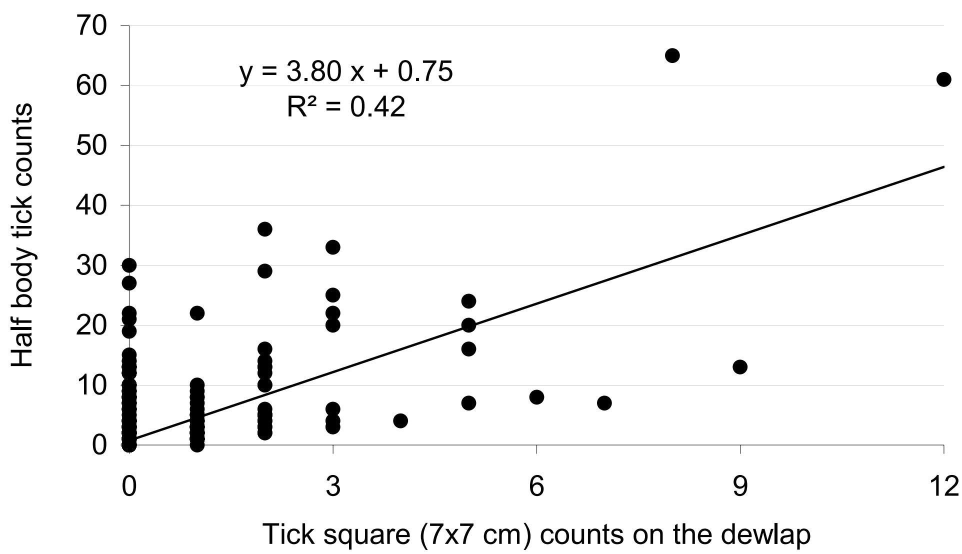

Figure 9-1 Linear regression of tick square counts on tick half body counts

Table 9-2 Results of the negative binomial regression models on half body counts of Amblyomma variegatum adults on calves (0-6 months)

	Model without calf and herd effects			*Model with calf and herd effects*		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**14.98**	**8.35**	**26.98**	**14.40**	**7.76**	**27.33**
June-September	1.74	0.98	1.74	1.50	0.72	3.15
Age						
0-40 days	1.00			1.00		
50-100 days	1.52	0.85	1.51	1.57	0.88	2.85
140-190-days	**2.85**	**1.53**	**2.87**	**3.25**	**1.76**	**6.04**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	1.21	0.60	2.38	1.24	0.61	2.42
Herd management						
Traditional	1.00			1.00		
Modernised	**0.40**	**0.17**	**0.90**	**0.40**	**0.16**	**0.91**
Parasite control at herd level						
Rare	1.00			1.00		
Frequent	1.00	0.45	2.15	0.99	0.45	2.13
Chicken						
In contact with chicken	1.00			1.00		
No contact with chicken	0.57	0.26	1.25	0.57	0.26	1.29
				Mean	95% CI	
Herd effect: sigma1=1/tau1				0.22	0.01	0.95
Calf effect: sigma2=1/tau2				0.62	0.02	1.77
DIC	1357.61	>		1340.01		

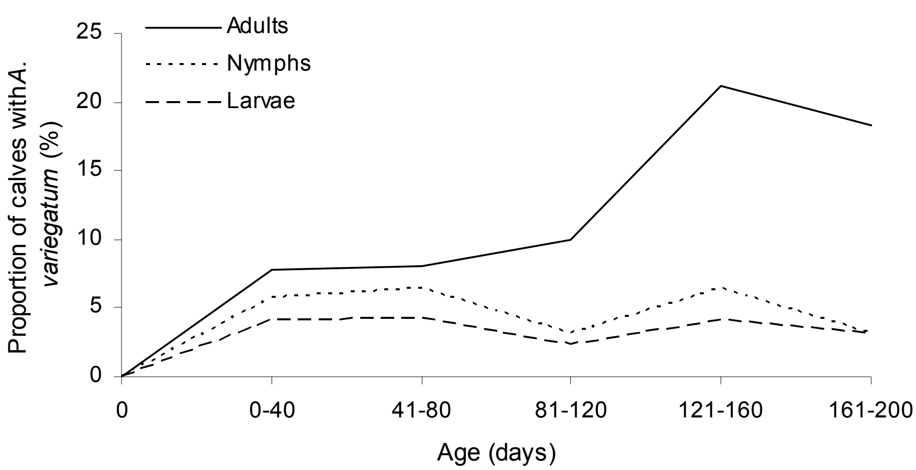

Figure 9-2 Prevalence of A. variegatum adults, nymphs and larvae in different age classes of calves

Table 9-3 Results of the negative binomial regression models on half body counts of Amblyomma variegatum nymphs on calves (0-6 months)

	Model without calf and herd effects			*Model with calf and herd effects*		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**0.02**	**0.01**	**0.07**	**0.02**	**0.00**	**0.08**
June-September	0.59	0.24	1.38	0.74	0.28	1.93
Age						
0-40 days	1.00			1.00		
50-100 days	**23.52**	**7.43**	**82.93**	**21.16**	**6.28**	**82.19**
140-190-days	**49.11**	**15.01**	**180.73**	**54.54**	**15.67**	**219.64**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	1.07	0.46	2.48	1.29	0.48	3.59
Herd management						
Traditional	1.00			1.00		
Modernised	**0.35**	**0.13**	**0.86**	0.34	0.09	1.15
Parasite control at herd level						
Rare	1.00			1.00		
Frequent	0.45	0.19	1.00	0.51	0.16	1.85
Chicken						
In contact with chicken	1.00			1.00		
No contact with chicken	0.78	0.35	1.74	0.69	0.21	2.26
				Mean	95% CI	
Herd effect: sigma1=1/tau1				1.14	0.01	3.99
Calf effect: sigma2=1/tau2				0.30	0.01	1.57
DIC	707.64	>		702.11		

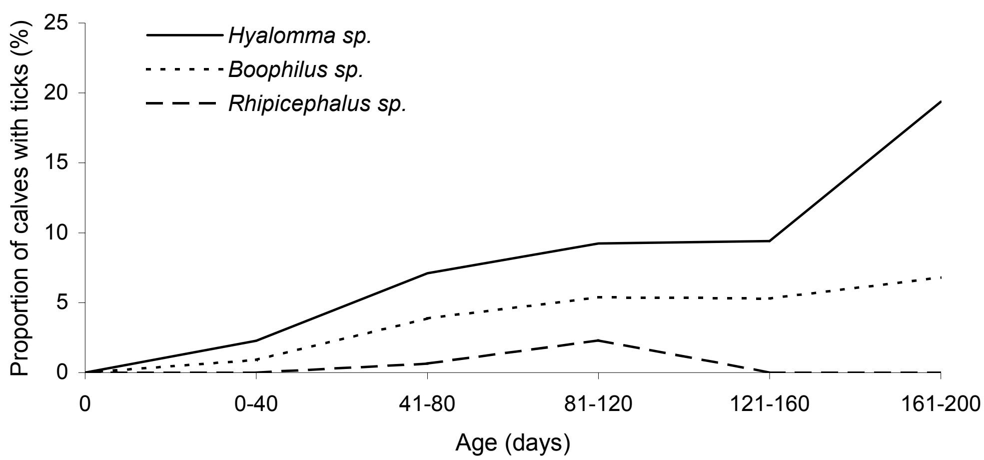

Figure 9-3 Prevalence of Boophilus sp., Hyalomma sp. and Rhipicephalus sp. in different age classes of calves

Table 9-4 Results of the negative binomial regression models on half body counts of Amblyomma variegatum larvae on calves (0-6 months)

	Model without calf and herd effects			*Model with calf and herd effects*		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**0.00**	**0.00**	**0.03**	**0.00**	**0.00**	**0.04**
June-September	**0.11**	**0.03**	**0.43**	**0.20**	**0.05**	**0.78**
Age						
0-40 days	1.00			1.00		
50-100 days	**13.46**	**3.04**	**70.39**	**14.84**	**2.72**	**98.99**
140-190-days	**37.75**	**8.53**	**197.95**	**66.09**	**11.55**	**465.91**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	1.69	0.53	5.23	3.02	0.60	16.30
Herd management						
Traditional	1.00			1.00		
Modernised	**0.25**	**0.07**	**0.83**	0.23	0.02	2.27
Parasite control at herd level						
Rare	1.00			1.00		
Frequent	1.04	0.35	3.12	1.78	0.16	24.88
Chicken						
In contact with chicken	1.00			1.00		
No contact with chicken	1.25	0.39	4.45	0.53	0.04	5.26
				Mean	95% CI	
Herd effect: sigma1=1/tau1				5.98	0.03	19.07
Calf effect: sigma2=1/tau2				1.33	0.01	7.89
DIC	586.62	>		560.77		

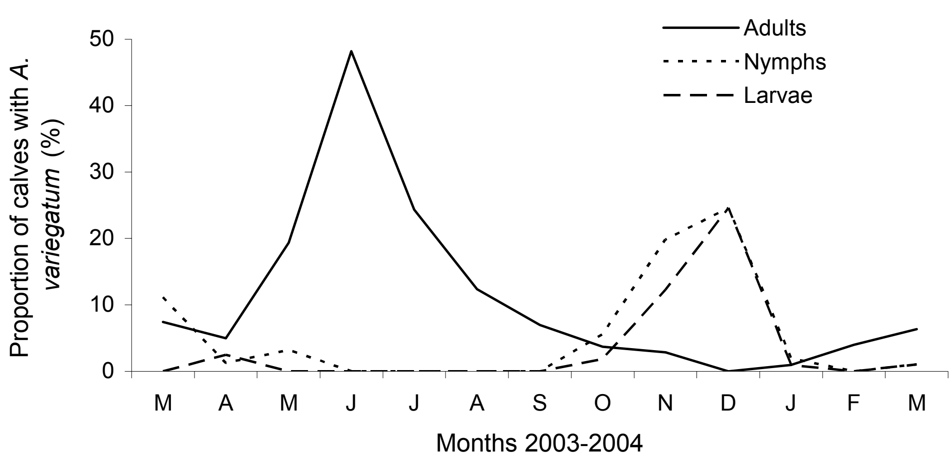

Figure 9-4 Mean monthly prevalence of A. variegatum adults, nymphs and larvae on calves aged 0-6 months

Table 9-5 Results of the negative binomial regression models on half body counts of Boophilus sp. adults on calves (0-6 months)

	Model without calf and herd effects			*Model with calf and herd effects*		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	**0.24**	**0.08**	**0.71**	**0.24**	**0.08**	**0.71**
June-September	0.74	0.26	2.08	0.77	0.28	2.05
Age						
0-40 days	1.00			1.00		
50-100 days	**13.30**	**3.72**	**55.70**	**11.98**	**3.26**	**56.60**
140-190-days	**14.67**	**4.06**	**65.56**	**13.37**	**3.49**	**65.30**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	0.82	0.33	1.87	0.70	0.23	1.95
Herd management						
Traditional	1.00			1.00		
Modernised	1.14	0.44	2.98	1.18	0.34	4.25
Parasite control at herd level						
Rare	1.00			1.00		
Frequent	0.83	0.34	1.99	0.87	0.26	2.88
Chicken						
In contact with chicken	1.00			1.00		
No contact with chicken	0.98	0.42	2.37	1.09	0.36	3.61
				Mean	95% CI	
Herd effect: sigma1=1/tau1				0.30	0.01	1.68
Calf effect: sigma2=1/tau2				0.88	0.01	3.63
DIC	396.79	>		345.04		

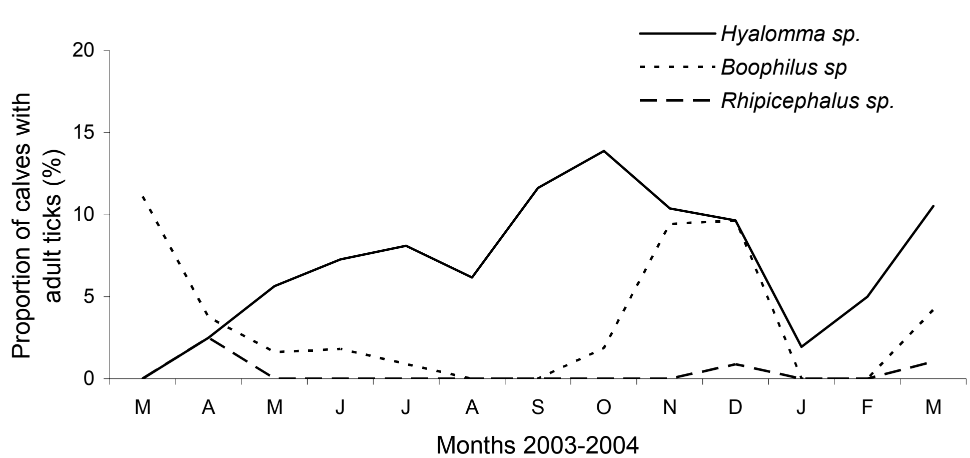

Figure 9-5 Mean monthly prevalence of adult Boophilus sp., Hyalomma sp. and Rhipicephalus sp. on calves aged 0-6 months

Table 9-6 Results of the negative binomial regression models on half body counts of Hyalomma sp. adults on calves (0-6 months)

	Model without calf and herd effects			*Model with calf and herd effects*		
	Incidence rate ratio	95% CI		Incidence rate ratio	95% CI	
Season						
October-January	1.00			1.00		
February-May	0.74	0.30	1.85	0.78	0.31	1.97
June-September	1.27	0.52	3.03	2.12	0.86	5.24
Age						
0-40 days	1.00			1.00		
50-100 days	**4.14**	**1.78**	**10.01**	**5.51**	**2.17**	**15.49**
140-190-days	**9.15**	**3.84**	**22.74**	**21.71**	**8.35**	**64.01**
Breed						
European x Zebu/N'Dama	1.00			1.00		
Zebu/N'Dama	1.49	0.70	3.18	1.46	0.58	3.68
Herd management						
Traditional	1.00			1.00		
Modernised	1.63	0.73	3.55	0.89	0.24	3.03
Parasite control at herd level						
Rare	1.00			1.00		
Frequent	0.51	0.23	1.07	0.80	0.23	2.97
Chicken						
In contact with chicken	1.00			1.00		
No contact with chicken	0.81	0.41	1.64	1.04	0.30	3.59
				Mean	95% CI	
Herd effect: sigma1=1/tau1				1.92	0.62	4.21
Calf effect: sigma2=1/tau2				1.45	0.02	4.70
DIC	1021.32	>		974.27		

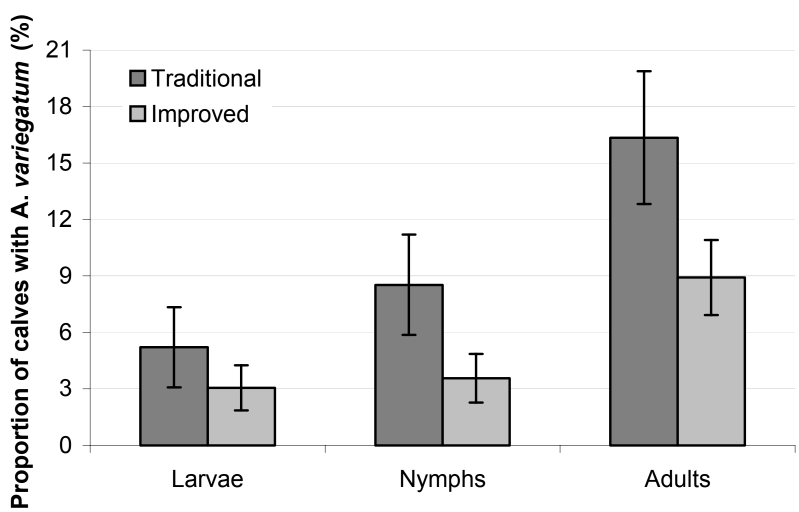

Figure 9-6 Prevalence of A. variegatum adults, nymphs and larvae on calves aged 0-6 months in different management systems

Tick control was recorded throughout the year with all herds being treated at least once during the rainy season (Figure 9.7). The majority of herds was treated 2-4 times (81%), 5% used only 1 control and 13% applied 5-7 controls during the 15 months of observation. No difference in the mean number of treatments per herd between traditional and modernised management was found. Of the 37 herds that had initially reported to use tick control, 24 stated to use one acaricide and 13 to use to 2 different acaricides. The acaricides used were Bayticol® in 21 (55%) herds, Taktic® in 25 (66%) herds, Amitix® in 3 (8%) herds and Milbitraz® in 1 herd (3%). In addition 26 of 38 herdsmen reported to pick off ticks manually. Bayticol® was used more often in modernised than in traditional management (p=0.03), while manual picking off and the use of Taktic® did not differ between the two management systems. No difference between mean number of treatments and use of Bayticol® was found. In modernised management no significant effect of the reported use of Bayticol® on *A. variegatum* adult tick burden was found (Model without random effects: IRR ratio 0.75, CI 0.35-1.52; Model with random effects: IRR 0.64, CI 0.23-1.73). In traditional management a significant effect of the reported use of Bayticol® on *A. variegatum* adult tick burden was found in the model without random effects (IRR 2.51, CI 1.21-5.09) but not if the model was corrected for clustering (IRR 1.92, CI 0.49-6.16) (Figure 9.8). Besides the recorded herd treatments, herdsmen were observed to individually treat animals prominently carrying ticks. Calves in traditional management had significantly earlier access to pasture than calves in modernised management (p=0.05).

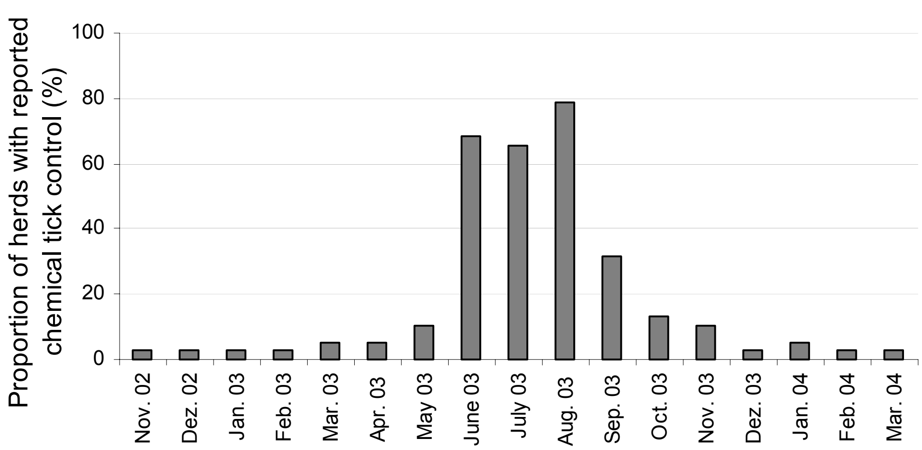

Figure 9-7 Monthly proportion of herds (N=38) with tick control

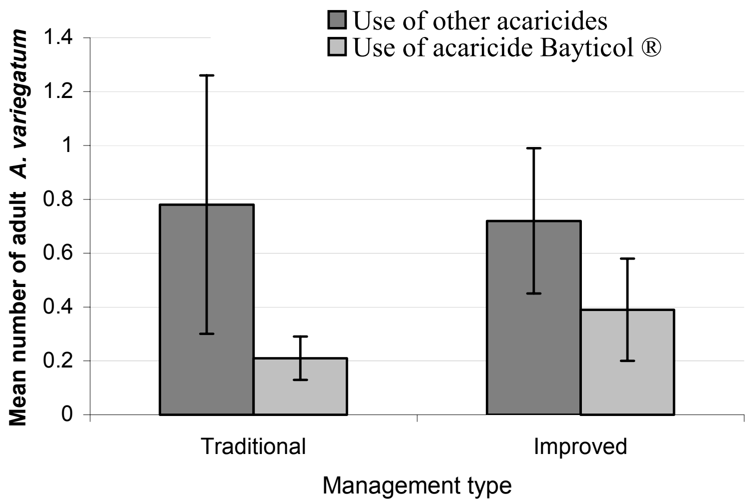

Figure 9-8 Effect of the reported use at herd level of the acaricide Bayticol® on A. variegatum burden on calves

Asked about the causes of death of calves within their herds during the year 2002, 2 herdsmen/owners reported spontaneously that deaths had been caused by ticks and a further 7 affirmed ticks as a cause when probed for it, adding up to 9 (24%) herds with reported losses due to ticks. Four herdsmen had reported to have lost calves due to trypanosomes and a further 9 affirmed trypanosomes as a cause when probed for it, adding up to 13 (34%) herds with reported losses due to trypanosomes. Only 7 (1%) out of 705 investigated calves had trypanosomes in one of their blood samples. Six calves were infected with *Trypanosoma vivax* (1 calf aged 0-1 month, 3 calves aged 2-3 months and 2 calves aged 5-6 months) and 1 calf aged 0-1 month was infected with *T. congolense.* All calves with trypanosomes occurred in the same study zone in proximity to the River Niger.

9.5 Discussion

Tick and trypanosome control were practiced by the livestock owners without any interference by the study team. The results presented are therefore the spectrum and prevalence of ticks and trypanosomes found on respectively in calves (0-6 months) under the currently applied management practices. Under these conditions, occurrence of trypanosomes in calves aged 0-6 months was low and only one older calf (5 months) had died due to trypanosomes. Five of the 7 infections were recorded during the rainy season, one during the cold dry season and one during the hot dry season, which is in line with a finding that on the left side of the River Niger prevalence of the vector *Glossina palpalis gambiensis* is highest in the rainy season (Djiteye et al. 1997a). The low prevalence of trypanosomes is the result of vector control programs (Djiteye et al. 1997a), frequently used tick control and herd treatments with trypanocides (2 herds). The in our cohort study recorded results for 2003-2004 did not reflect the by the herdsmen and owners reported importance of calf losses due to trypanosomes in 2002. Yearly fluctuations in trypanosome numbers due to climatic variations or control programs are possible but unlikely to account for this large discrepancy. Either cattle breeder questioned on calf deaths had also reported death causes of older "calves" (some animals suckle up to 15 months) or the awareness of trypanosome control programs may have led to over reporting of the disease. Trypanosome infections were less frequent in calves in the periurban zone of Bamako than in the southern part of Mali, where 38% of calf losses are caused by trypanosomes (Diall et al. 1992) and 49% of newborn calves born in the rainy season get infected with trypanosomes during the first 8 weeks of life (Diarra 1983).

The absence of tick-borne *E. ruminantium* in young calves indicates a low importance of cowdriosis in the periurban zone of Bamako but it is also in line with findings that calves born in endemic areas receive protective antibodies with the colostrum and are relatively resistant during their first weeks of life (Norval et al. 1995, Deem et al. 1996). In addition, rapid decomposition of calves at temperatures of 45°C during the dry season may have destroyed parasite colonies, potentially lowering the sensitivity of the method used.

Tick burden was low with the majority of animals having no ticks at all. Prevalence was much lower but geometric mean square count higher than in the Ivorian study on cattle of all ages in which the rapid tick assessment method had been developed. As a consequence the slope of 3.8 of the regression line in our analysis was smaller than the slope of 14.9 given by Knopf et al. (2002). Hence this method seems to be more useful for tick assessment on adult cattle in settings with higher tick burden. Tick genera found were the same as in the nation-wide Malian survey of Teel et al (1988) and in a small study done in Bamako (N'diaye 1989), but frequencies differed. In our study *Amblyomma sp*. was the most common tick genus, while in Teel et al (1988) *Hyalomma sp.* was more common (45.6%) than *Amblyomma sp*. (25.7%) and *Boophilus sp.* (22.4%). The observed age effects followed the expected pattern with more ticks on older calves with larger body surface and access to pasture. Seasonal occurrence of ticks was as described in Teel et al. (1988) with the exception of adult *A. variegatum,* which peaked already in the late dry season and not in the late rainy season. Although chicken kept together with calves were observed to forage within calf enclosures, their role as a biological control tool for ticks could not be confirmed.

Herd management system had an effect on *A. variegatum* ticks, with lower tick counts in modernised than in traditional management. The observed difference cannot be simply explained by more investments in tick control. Then no differences occurred in number of treatments between herd management systems nor was an effect of number of treatments on tick burden found. And the higher investments in the pour-on Bayticol® in modernised management did not lead to a significant lower tick burden if clustering was considered. The lower tick burden in modernised management must therefore be caused by other management practices like later onset of pasturing of calves.

In all herds an awareness of ticks was present as indicated by the widespread reported and recorded acaricide use. In informal discussions livestock owners of both management types remarked Bayticol® pour-on to be their acaricide of choice. The only reasons mentioned to use other products were their better availability on some local markets and their lower price, which may account for the less frequent use of Bayticol® pour-on in traditionally managed herds. Tick control had an effect on tick burden as shown by the drop of adult *A. variegatum* during the rainy season, when adults of this species normally have their peak (Teel et al. 1988). But better compliance with the manufacturer's recommendation could further increase effectiveness of used acaricides. Personal observations were that herdsmen applied pour-on's generously on restricted spots with visible ticks without considering time interval since last application or the by the manufacturer recommended dose and application along the animal's dorsal midline from the head to the base of the tail. Inappropriate application will raise cost-benefit ratios, are a health hazard for treated animals and may lead to more rapid development of resistance to the used drugs.

9.6 Conclusions

With the current management strategies, trypanosome infections were rare and tick burden low in calves aged 0-6 months in the periurban zone of Bamako. No evidence of cowdriosis in calves aged less than a year was found. Tick counts of the most frequent genus *Amblyomma* were lower in modernised management than in traditional management, but no effect of treatment frequency on tick burden nor of management system on treatment frequency was found. Neither could a better efficacy of the in modernised management more frequently used acaricide Bayticol® pour-on be affirmed if corrected for cluster effects. The role of chicken as a potential biological control tool for ticks was examined but could not be confirmed. Profitability of currently applied tick control strategies need to be assessed and awareness of the appropriate use of drugs increased.

Acknowledgements

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Chapter 10

General Discussion

10 GENERAL DISCUSSION

Local demand for dairy products in Mali can currently not be covered by domestic production. Demand for dairy products will further increase with ongoing population growth and result in a large market opportunity for Malian livestock producers. To increase milk production, livestock keeping in periurban areas has undergone big changes in the last decades from traditional to modernised management with crossbreeding and more investments in housing, nutrition and health care. This modernisation has increased milk production per cow and has changed the environment in which calves are raised. This is of high importance, as cows are still milked with the calf at foot and calf survival is therefore essential for milk production and for overall productivity of periurban livestock production. Although modernised management gains more and more weight in periurban areas, no published information had been available on calf mortality and importance of ecto- and endoparasites on calf mortality in modernised periurban livestock production in West Africa. Neither had calf mortality in traditional management been compared to calf mortality in modernised management in periurban areas. However this is essential baseline information needed for economical evaluation of the ongoing modernisation and improvement of livestock productivity.

In the preceding chapters, calf mortality rate (Chapter 5, 6) and causes of calf mortality (Chapter 5) in periurban modernised and traditional livestock production were presented and risk factors for calf mortality examined (Chapter 6). To further evaluate the importance of endo- and ectoparasites on calf health and mortality under currently applied management practices in the periurban areas, in depth studies examined age-dependent acquisition of gastrointestinal parasites in young calves (Chapter 7), seasonal and age-dependent gastro-intestinal parasite egg excretion (Chapter 8) and seasonal and age-dependent tick and trypanosome burden and the occurrence of tick-borne cowdriosis in young calves (Chapter 9). The key findings of the whole study where a high calf mortality rate of 17% with higher mortality rates in modernised than in traditional management. Main causes of mortality were management related problems (accidents, losses, malnutrition), digestive disorders and perinatal mortality. Digestive disorders were more frequent in modernised than in traditional management. Risk factors of calf mortality were parity of dam, birth complications, season of birth and factors related to supervision (low number of herdsmen, absence of chicken, large herdsize). Tick burden was low, trypanosomes rare and gastrointestinal egg excretion moderate. Spectrum of gastrointestinal parasites of calves was already similar to that found in adult cattle and multi-parasitism was frequent. A high turn-over of herdsmen was observed.

The general discussion will follow the following structure

- The methodologies used will be discussed and benefits to participants and some ethical issues outlined.
- The importance of the observed calf mortality rates will be discussed in regard to the profitability of livestock production and ongoing modernisation.
- Observed causes of death will be discussed in relation to livestock management, risk factors for calf mortality and parasitic data found.
- An outlook on the future of periurban livestock production and modernised management systems will be provided.
- A general conclusion will be drawn and recommendations for future research, for national authorities and for livestock producers outlined (Chapter 11).

10.1 Methodologies

10.1.1 Study design

Because the majority of herds did not keep a herd book, demographic information collected with a cross-sectional study would not have been precise. As a consequence, a longitudinal cohort approach was chosen, which, although time and cost-intensive, allowed for more accurate estimation of mortality rates within the first year of life. The cohort approach allowed for repeated sampling of parasitic data on individually marked calves and provided the basis for the access to dead calves for postmortem examinations. During the whole course of the study, calf management, including parasite control and treatment of sick animals, was done by the herd owners according to their own management strategy, without interference by the study team. The observed mortality rates, causes of death and parasite burden are therefore the actual “real world” rates, causes and burden occurring in periurban livestock production.

10.1.2 Herd selection

In general small herds produce milk for subsistence, without selling much to village communities or Bamako. This study was therefore focusing on herds with a minimum herd size of 10 reproductive females to capture the importance of calf mortality in herds with the potential for provisioning domestic markets with locally produced dairy products. Sedentary location within the study zone was the second selection criteria, as transhumant movements change the exposure to parasites and make follow-up difficult. The third mandatory criterion was informed consent of herd owners. Which may potentially introduce a bias, as herd owners willing to participate may have had a special interest in the issues of calf mortality and parasites.

Herd owners of village herds were encountered within their villages, but herd owners of rural compounds living in Bamako were difficult to reach. To access also herds with modernised management, initial herd contacts based on the 3 selection criteria were mediated by private veterinarians. Herd selection was therefore not a random but rather a convenience sampling, with the bias that only herds with an existing relationship to the contact veterinarians were included into the study. Veterinarians were motivated to contact as many herds fitting the selection criteria as possible for collaboration. Herds included into the study were therefore not only those in which the veterinarians conducted regular follow-ups, but also herds in which they were only called in emergencies. Cooperation with all participating herds was very good. Of 38 herds, only 1 herd dropped out of the study when it left the study zone for an unpredicted opportunity to feed upon harvest residuals.

10.1.3 Data collection

Standard sampling, laboratory and questionnaire methods were used for determination of parasite burden and conducting of interviews. Data collection was complicated by several factors.

- Due to poor condition of tracks some herds could not be accessed during the peak of the rainy season.
- Animals missing at the time of herd visits reduced the amount of samples that could be collected. Herdsmen knew that the team would arrive once a month, but no fixed appointments were made to prevent scheduling of parasite control treatments in regard to herd visits.

- A big problem for the autopsies were the hot temperatures of up to 45°C and the time elapse between death and receive of information. Rapid putrefaction may have affected the detection of *E. ruminantium* in brain tissue and the identification of gastrointestinal parasites.
- Report rate of dead calves was lowered by the frequent change of herdsmen and their difficulties to reach a telephone. Of 93 dead calves, 5 had totally vanished (eaten by dogs, stolen or disappeared) and of the remaining 88 cases, the study team was informed within 24 hours on 54 cases (3 of those were too decomposed for a postmortem), leading to a report rate of 61%.
- Deaths and mortalities followed a seasonal pattern. As a consequence, fewer data is available for the late dry season than for the rainy and early dry season.
- Definition of causes of deaths was based on the available information present, whose quantity and quality varied from case to case.
- The scientific interest in calf mortality and parasites may have altered the herd owners' awareness of calf health and thus augmented the level of care provided to the calves, potentially reducing calf mortality rates and parasite burden.

10.1.4 Statistical analysis

Within a herd, calves share a similar environment, management system and genetic background. As a consequence, variance of samples collected on calves within herds is lower than variance of samples collected between herds. The same is true for repeated sampling on individual calves, as the variance of samples collected on the same individual is lower than the variance of samples collected of different individuals. Hence, estimates of overall variance of our clustered data based on formulas for homogenous populations would have been too small and may have lead to overestimating effects using normal ANOVAs. To prevent potential misinterpretations, clustering of data at herd and calf level had to be taken into account in data analysis. Risk factor analysis was done with a frailty model to account for herd effects (Chapter 6). And the effect of management systems on calf mortality rate found in a first analysis without herd effects (Chapter 5) was confirmed with a frailty analysis (Chapter 6). After logarithmic transformation, the parasitic data of the post-mortem examinations were analysed with generalized linear models with Poisson distribution and the variable herd included as a repeated effect (Chapter 7). Bayesian models with two random effects (herd, calf) and a negative binomial distribution to account for the overdispersion of parasite counts were utilised for the analysis of tick and coprological data (Chapter 8, Chapter 9).

10.1.5 Some ethical considerations

- Handling of animals was done with great care. But sampling may have stressed the calves, potentially negatively affecting their condition.
- Coprological sampling of dams of newborn calves was stopped because the more ferocious ones had to be thrown to the ground at the risk of injuries to both the herdsmen and the cow. The potential value of the gained data was considered not to justify the incurred risks, which were high enough, working in cow-calf herds with free running bulls.
- Meat of slaughtered ill calves is normaly used for human consumption. General recommendations given to herdsmen and owners were to discard the meat of animals with a suspicion of poisoning or which had just been treated with antibiotics, and to cook the meat well if an infectious disease was suspected.
- To prevent creating an incentive for premature slaughtering of calves, an equal amount was paid for the heads and intestines of dead and slaughtered calves, although the meat of the former is normally not consumed.
- When several calves in a herd died with symptoms similar to those caused by the notifiable Foot and Mouth Disease, the L.C.V. was informed.

10.1.6 Benefits to participants and dissemination of results

- Herdsmen were financially compensated for their work and in addition (on a private basis) received each a pair of boots for working in the waterlogged enclosures during the rainy season.
- Veterinarians were remunerated for their role as intermediaries between the study team and herd owners and for their participation in data collection during the first herd visits.
- Herd owners received several benefits. First, all participating calves were ear tagged for individual identification. In 2005, this has already served as a proof of ownership of stolen animals to the police. Second, of each calf that was autopsied, the intestines

and the head were purchased. Third, after the study was finished, all participating calves were treated against gastrointestinal parasites. Fourth, at the end of the study each herd owner received the results concerning his herd, containing causes of deaths, parasitic information and recommendations on how to improve management within his herd. A herd owner meeting was organised in the milk cooperative of Kasséla for feeding back the results and counselling.

- The main overall results were presented in Bamako to the scientific community of the L.C.V., the I.E.R., representatives of local livestock cooperatives and veterinarians in an oral presentation at the L.C.V., which was followed by a question and discussion round.

10.2 Importance of calf mortality

A high overall calf mortality rate during the first year of life of 17% was found in periurban livestock production of Bamako. This implicates a partial loss of lactation of every 6th cow and a loss of one sixth of all potential slaughter cattle, draught oxen and future dairy and breeding stock. Much higher calf mortality rates occurred in modernised management (19% in modernised private and 25% in modernised on station) than in traditional management (10%). The mortality rate of 10% in traditional management was similar to calf mortality rates in traditional management in central Mali (13%, Traoré and Wilson 1988), Senegal (12%, Fall et al. 1999) and within the range of calf mortality rates in The Gambia (8-21%, Zinsstag et al. 1997a). Slightly lower mortality rates for traditionally managed calves are recorded from Burkina Faso (6%, Ganaba et al. 2002) and Cameroon (7%, Njaya et al. 1998) while higher calf mortality rates were found in traditional management in Côte d'Ivoire (19%, Knopf et al. 2000), Nigeria (46%, Kudi et al. 1998), Benin (23%, Youssao et al. 2000) or Guinea (>38%, Mourad and Magassouba 1996) or for traditionally managed nomadic calves in Mali (19-47%, Wagenaar et al. 1986). The mortality rates for modernised private and station managed calves of 19% and 25% were much higher than in recent studies on station managed calves from the Niger (5-11%, Achard and Chanono 1997) or Benin (3%, Youssao et al. 2000) but within the range found in older studies on station-managed cattle in Mali (20%, Anonymous 1978; 30%, Planchenault et al. 1981). In comparison with these West African studies we can therefore conclude that mortality rates in Malian periurban livestock production are low to moderate in traditional management and high in modernised management. This is a very alarming finding

in view of the ongoing modernisation of management practices in the periurban zones. If this trend persists, overall calf mortality rate will further increase.
Modernisation is mainly done to increase milk production. But if it is accompanied by the observed double losses of calves in comparison to traditional management, its benefits may be drastically reduced. An in depth economic analysis is needed to evaluate the benefits of modernised management in terms of increased milk production with the costs incurred by the higher investments in infrastructure, feeding and health care and the higher calf mortality rate in comparison to traditional management. One of the existing studies on profitability of periurban milk production based on direct production costs has already found very low gross profits of only 2-31 CFA/litre (Ouattara 2001). If the costs incurred by the higher calf mortality in modernised management are added to the overall production costs, modernised periurban milk production may not be very profitable.

10.2.1 General management factors with a potential effect on calf mortality

Three general factors affecting calf mortality shall be considered, before discussing in detail the implications of death causes, risk factors and parasitic data found.

10.2.1.1 Ownership and guardianship

Animals are commonly not herded by the owner but by employed herdsmen. This lack of ownership of the guardian and the performance independent small salary received by the herdsmen are a low incentive for a high commitment to animal care. Differences in calf mortality rates between traditional and modernised management may be partially due to the relation between the owners and their herdsmen and thus control and motivation of the care-givers. Most owners of traditional herds live within the same village as their herds and have daily contact with their animals and herdsmen. For these agro-pastoralists, animals are an important part of their overall income and possession. Wealthy owners of modernised private herds live mainly in Bamako and most of them visit their animals and herdsmen on an irregular basis. Animals in modernised on-station management belong to the state and no personal economic interest in the health of the animals exists. But the personal closeness between the owner and the animal may play an important role for the animal's welfare, for example in regard to control of milk off-take from the dam and veterinary care for sick calves. To reduce deaths due to delayed treatments, herdsmen should be authorized by absent herd owners to call a veterinarian when animals become sick and no immediate contact for advice with the owner can be established.

10.2.1.2 Malnutrition and milk off-take

Malnutrition has played a role in several cases of death by weakening the animals. Nearly all calves suffered at least during the dry season from malnutrition, when pasture was poor, milk production low and feed supplements rarely given in quantities large enough to cover the nutritional needs. In addition, calves suffered from malnutrition if herdsmen took too much milk from the dam. To maximise quantity of milk off-take at the expense of the calf was favoured by the common remuneration payment of herdsmen in milk. Benefiting from more milk but not directly from calf health may entice herdsmen to milk too much. Key informants reported that the amount of milk off-take was the major cause of mistrust between herd owners and their employed herdsmen. For control of milk off-take another salary system should be developed in which herdsmen gain equally from milk production and calf health, e.g. cash salaries. Higher quantity and quality of supplementation provided to calves may improve calf nutrition and health status. But an economic analysis of supplementation of young calves in periurban livestock production is needed, comparing costs of supplementation with increased growth, fertility and survival. Then live weight gain of young village calves through supplementation is too small to generally recommend feed supplementation of calves below a live weight of 100 kg (Little et al. 1994).

10.2.1.3 High turnover of herdsmen

A high observed turnover of herdsmen indicated a strenuous relationship between herd owners and herdsmen. During the 15 months of observation, in 15 out of 38 herds the principal herdsman was replaced one to two times. Changes of herdsmen were more common in traditional management than in modernised management, where contact between owners and herdsmen are less frequent. This high turnover of herdsmen led each time to a loss of experience on management of individual animals and may have contributed to high mortality rates.

10.2.2 Higher mortality rate in modernised than traditional management

The higher mortality rate in modernised management was mainly due to a higher occurrence of gastrointestinal tract disorders in modernised in comparison to traditional management.

This was a consequence of different management strategies in regard to housing and hygiene, as discussed in the following section about causes and risk factors for calf mortality. In addition, European crossbreeds, the main breed kept under modernised management, are reported to be more susceptible to local diseases and parasites than local Zebu breeds, the main breeds kept in traditional management (Kaufmann 1996). However, in our study we have found no effect of breed on mortality, gastrointestinal egg excretion or tick burden. But complex interactions between breed, management system, feeding, parasite control and parasite burden may have obscured an impact of breed on calf mortality.

10.3 Causes and risk factors for calf mortality

In the following sections, observed causes of death are discussed in relation to risk factors found and parasitic data obtained. Recommendations on reduction of losses due to specific causes will be outlined. The causes of death will be related in order of their observed frequencies: management deficiencies (29%), consisting of accidental losses (14%), starvation (10%) and sepsis (5%); digestive disorders (28%), consisting of gastrointestinal parasites (12%), non-parasitic diarrhoea (10%) and ileus (7%); perinatal mortality (16%); vector-borne diseases (4%); respiratory disorders (4%).

10.3.1 <u>Losses incurred by management deficiencies</u>

10.3.1.1 Accidental losses and lack of supervision

Accidental losses (accidents, thefts, intoxications, disappearances) were the third most important category of death. Our result is in accordance with reported proportions of accidental losses of 13% from Burkina Faso (Ganaba et al. 2002) and 7-14% from Guinea (Mourad and Magassouba 1996). Accidental losses were less prevalent with 5-6% in Niger (Achard and Chanono 1997) or Nigeria (Kudi et al. 1998). Most accidental losses were clearly caused by a lack of supervision.

*The calves were playing around the well ...... In the afternoon I've realised that one of the calves was missing. I was looking for it everywhere until I found his body at the bottom of the well. (*Death history of a calf aged 2 weeks, told by the herdsman)

A low number of herdsmen employed represented a risk factor for calf mortality in older calves. In herds with only one herdsman, common practice was to leave the calves unsupervised during the day, while the herdsman herded the adult animals and weaned calves. Newborn calves were normally kept restrained, but older calves were often let on pasture unsupervised. In some herds, the wives and children of the herdsman looked after the youngest calves while the herdsman was away, but care was only partial and depended on the amount of other household activities to be fulfilled. Supervision of calves by other family members was only possible if calves were kept in close proximity to human housing. The importance of proximity is reflected in the protective effect of chicken holding on mortality of newborn calves. Chicken are normally found around the house and may serve as an indicator for proximity to human housing. Theoretically, chicken could also have had a direct effect on calf mortality by reducing tick burden through feeding upon ticks (Hassan et al. 1991). However, in our setting, tick burden in young calves was very low and no effect of chicken on tick burden was found. Large herd size was another risk factor for calf mortality associated with supervision. In large herds, individual animals are easily overseen and if few herdsmen have to care for a large number of animals, calves are more likely to suffer from neglect. To improve care provided to calves, more herdsmen should be employed. But labour costs already account for 44% of production costs in Malian periurban livestock production (Sall 2002). A part of the higher investments in modernised management are done in building stationary enclosures for better protection of livestock. But stationary housing was prone to problems with hygiene and did not always meet the objective of improved security.

*Last night, a thief entered the calf enclosure. He took one of the calves and butchered it behind the enclosure. He cut the calf in two and took away the front part with the tights and left the other part....... (*Death history of a calf aged 10 months, told by the herdsman*)*

10.3.1.2 Starvation

The cases of starvation reported in this section are those which had been caused by a direct lack of milk, e.g. due to the death of the dam, due to a reduced milk production of the dam or suckling problems. Fewer losses (5%) due to starvation are reported from Nigeria (Kudi et al. 1998), but no details on the causes for malnutrition are provided. A common problem in our study was the loss of teats by tick infestation reducing milk production of the cow. In addition, pain caused by the attachment of ticks to the udder and secondary infections may cause the cow to reject suckling attempts of the calf (Norval et al. 1997b). If calves lack milk, for example due to the death of their mother, herdsmen try to give the calf to another cow for adoption (37% of herds) or feed the calf with milk (87% of herds). But as the calves are in direct competition with milk off-take for human consumption, milk is rarely given in sufficient quantity.

The dam of the calf had an udder infection leading to a low milk yield......... I have fed the newborn calf with milk in a bottle, but when it reached the age of two months, I've decided to stop giving it the bottle. I think it was due to that reason, the calf weakened.... (Death history of a calf aged 3 months, told by the herdsman)

10.3.1.3 Sepsis

A minor cause of death related to management problems was sepsis. Sepsis was also recorded from the Niger (Achard and Chanono 1997) and caused 15% of all calf deaths in Nigeria (Kudi et al 1998). In our study, several cases of sepsis had occurred in one herd with poor hygiene. Ameliorated faecal sludge management as described in the following section about gastrointestinal problems may have improved hygienic conditions and lowered the occurrence of sepsis. In adition, insufficient colostral milk uptake may favor losses incurred by bacterial and viral infections due to a lack of immunity.

10.3.2 Digestive disorders

10.3.2.1 Gastrointestinal parasites and non-parasitic diarrhoea

Observed proportion of animals dying due to gastrointestinal problems was high but still lower than in other West African studies which reported 41% to 59% of calf losses due to gastrointestinal problems (Niger 53%: Achard and Chanono 1997, Nigeria 47%: Kudi et al. 1998, Guinea 41%-59%: Mourad and Magassouba 1996). The proportion of herds with losses of calves due to non-parasitic diarrhoea and gastrointestinal parasites (11 of 38 herds) was similar to the occurrence reported by the herdsmen and owners in 2004 (15 of 38 herds). In our study, all mortalities due to gastrointestinal parasites, and with one exception, all cases of fatal non-parasitic diarrhoea had occurred in modernised management, indicating a serious sludge disposal problem in modernised management. Differentiation into management type was based on the kind of holding place in which calves were kept. In traditional management, calves were held either attached to a rope or in mobile enclosures build of bushes, branches or wire netting. Calf holding places were therefore mobile and had been displaced in more than half of the traditionally managed herds (9 of 15) between planting seasons, when the whole herd including calves was moved forth and back between harvested fields and communal pasture. In modernised management calves were kept in stationary enclosures, built of concrete or bricks with natural or concrete floors, and only moved to other places when the enclosure was flooded during the rainy season (4 of 23 herds). Most enclosures were unroofed and all lacked a drainage system, so that rain water stagnated within the enclosures for weeks during the rainy season. The stagnating water mixed with excrements accumulating in the enclosures, which were only cleaned once a year before the planting season for collection of manure as field fertilizer. The hazard of poor hygienic conditions and high humidity during the rainy season was reflected in the higher risk of mortality in newborn calves born in the rainy season in comparison to those born during the dry season. Higher mortality rates for calves born into the rainy season are also reported from other African countries (Senegal: Denis and Valenza 1972; The Gambia: Agyemang 1992; Guinea: Mourad and Magassouba 1996; Cameroon: Njoya et al. 1998; Kenya: Bebe et al. 2001).

Gastrointestinal egg excretion was moderate and routinely collected data on egg excretion was not a significant risk factor for calf mortality. In addition management system had no effect on egg or oocyst counts in faeces of live calves. This is not a discrepancy with the observed causes of death under modernised management, as gastrointestinal control was more frequently applied in modernised than in traditional management. With the poor hygiene present in stationary enclosures, parasites may have rapidly accumulated in animals missed during treatments, leading to the observed losses, as indicated by the higer *S. papillosus* egg counts in dead animals kept under modernised management than under traditional management. Transmission occurred all year round but was lowest during the hot dry season. The occurrence of eggs in faeces of very young calves showed an early infection risk for newborn calves. A positive correlation between *S. papillosus* counts of dams and calves was found, underlining the importance of vertical transmission for this parasite species and indicating the potential for heritable resistance.

As shown for the first time by this thesis, young calves in West Africa acquire during their first year of life a nematode spectrum already similar to that found in adult cattle. In addition some parasite species like *Haemonchus sp*. were much more frequent in calves in our study than in young cattle with a mean age of 27 months in The Gambia (16-26%) (Kaufmann and Pfister 1990) and already occurred in older calves at a prevalence (69%) similar to that found in adult cattle in the Gambia (67-88%: Zinsstag et al. 1998). These findings contrast the statement by Kaufmann and Pfister (1990) that worm burden in suckling calves is low.

Awareness of gastrointestinal parasites was present but control of these parasites was not conceived as a priority by herd owners, as shown by the discrepancy between the high reported use of anthelmintic drugs with the actual lower recorded use. In addition both reported and recorded use of anthelmintic drugs was lower than that of acaricides. West African studies on gastrointestinal parasite control in calves aged less than a year in traditional management have found that neither live weight gain of young calves nor calf survival is improved with strategic anthelmintic control (Dwinger et al. 1994, Zinsstag et al. 1997a, Zinsstag et al. 1997b). They conclude that control of gastrointestinal parasites is not economically justified for young calves. This conclusion may be reflected in the low priority given by herd owners to gastrointestinal parasite control. Treating animals aged more than 1 year, which have acquired already a large spectrum of parasites, can be recommended as it improves live weight (Zinsstag et al. 1997b). The enclosures should also be cleaned when animals are treated, to delay re-infection. As the complementary small study on sheep kept together with calves has shown, sheep shed high number of eggs and may therefore serve as an important source of infection for newborn calves. Treating sheep is economically justified (Ankers et al. 1998) and it is therefore recommended to treat sheep kept together with calves to reduce their potential role as a host reservoir.

To control gastrointestinal parasites in young calves and to prevent losses due to non-parasitic diarrhoea, improvement of the hygienic conditions is essential. For traditionally managed calves, regular change of the holding place to reduce transmission of gastrointestinal parasites has been recommended by Kaufmann et al. (1995). For modernised managed calves kept in stationary enclosures, simple modifications of the enclosure like elevating part of the ground and covering it with a roof may already provide the calves with a dry resting place and improve their overall comfort. Further modifications like a drainage system to drain the rain water out of the enclosure would further reduce humidity. Faeces must be regularly cleaned away. Calf enclosures are commonly small so that the effort needed for better hygiene and structural modifications are visible. Collected faeces can be stored away from the calves and still be used as manure during the planting season.

10.3.2.2 Deaths due to eaten plastics

The registered cases of deaths caused by plastics reflect the seasonal malnutrition and low milk yield which cause pica even in young calves and the problem of a poorly developed waste disposal system in Mali. No case of ileus due to ingestion of waste had been specifically reported from other West African studies which listed gastrointestinal problems (Niger: Achard and Chanono 1997, Nigeria: Kudi et al. 1998, Guinea: Mourad and Magassouba 1996). A lack of awareness about the dangers of plastic bags was observed. Animals that had died due to plastics were reported to have been "sick" and "unthrifty" due to an unknown disease or to have died suddenly without having been sick before. When assisting at the postmortem examination, herdsmen were surprised to see the amount of plastic taken up by their calves.

"*The calf was very sick. Since a week, it had eaten nothing and became very weak and skinny. I have given it some pills from the veterinarian, but they did not help.....* (Death history of an orphaned calf aged 4 months, weighting only 25 kg, whose rumen was filled with 2 kg of plastic bags and other waste. Story told by the owner)

In vicinity to human settlements plastic bags can be found all over the place. In Bamako, herdsmen can even be seen herding their animals to rubbish piles for foraging without being aware of the risks. Cattle owners and herdsmen should therefore be informed about the danger of plastic bags and motivated to reduce the exposure of calves to waste contaminated pasture and remove plastics from within the enclosures and around thethering places. Improved nutrition will also help to reduce the tendency of calves to feed upon waste. Another potential problem for human and animal health, which is associated with waste disposal, is the current practice of disposing animal carcasses and slaughter remnants on communal pastures where they are eaten by stray dogs and wildlife. In proximity of Bamako, where settlement density is higher, personal observation was that cadavers were deposited under some bushes within 10 m of human housing, incurring the risks of transmission of zoonotic diseases like *Echinococcus granulosus (*Kaufmann 1996*)*.

10.3.3 <u>Perinatal mortality</u>

A high number of losses of newborn calves occurred. Proportion of deaths caused by perinatal losses was slightly lower than the proportion of 21% recorded from Burkina Faso (Ganaba et al. 2002). Total perinatal losses, consisting of perinatal mortality, abortions and stillbirths, led to a minimum loss of 5% of all gestations. This value is underestimated, as early abortions are difficult to observe and therefore not reported by the herdsmen. Various causes may have led to the observed perinatal losses but further studies are needed to investigate them in detail. Potential causes based on the information collected in this study are obstetric complications, which was the most important risk factor for calf mortality of newborn calves. Poor body condition of the dam due to malnutrition and old age may be another cause, as indicated by the higher risk of mortality of calves born to multiparous dams than of calves born to heifers. But this finding is in contrast to the reported lower mortality risk for calves born to multiparous dams in another study from Mali (Traoré and Wilson 1988) and a Kenyan study (Bebe et al. 2001). Malnutrition of the dam may also play a role, as most stillbirths and abortions occurred during the dry season when pasture is poor. Frequent inbreeding may have been an important cause for weak born calves, as discussions about sire selection revealed that commonly bulls are used for up to a decade before being replaced by their own best male offspring. A reason for abortions may have been infections with *Brucella abortus*, of which antibodies can be found in 30% of milk samples at selling point (Bonfoh et al. 2003b). In addition, early separation of newborn calves from their dams may prevent a sufficient colostral milk uptake and result in low calf immunity. Improvement of calving assistance, culling of older cows in weak body condition, culling of cows with confirmed brucellosis, enhanced colostral milk uptake and sire selection strategies with a focus on avoidance of inbreeding and calving ease, may help to reduce perinatal losses.

The cow had had a normal calving. The calf was in a good condition, was standing up and the herdsman told me that it suckled its dam. But yesterday afternoon, when the herdsman returned from the pasture, the calf was dead. This was now already the fourth newborn calf in a row that had died. I really do not know what to do, it must be some sort of a disease (Death history of a newborn calf, told by its owner)

10.3.4 <u>Vector and vector-borne diseases</u>

Trypanosomes occurred at a low frequency of 1% in calves aged 0-6 months and only in herds kept near the River Niger. One single calf loss was diagnosed as being caused by trypanosomes. Trypanosome infections were much less frequent than in the more humid Southern part of Mali, where 49% of newborn calves became infected with trypanosomes during the first 8 weeks of their life (Diarra 1983) and trypanosome infections accounted for 38% of all calf losses (Diall et al. 1992). Low occurrence of trypanosomes in the periurban area of Bamako is partially due to the climate and its influence on the distribution of the tsetse flies along the river, but also the consequence of control programs (Djiteye et al. 1997a) and the frequent use of tick control. Two livestock owners also reported to treat all their animals on a regular basis with trypanocides. This is an expensive option which is not recommended for calves kept away from the River Niger and its tributaries. Our finding of the low impact of trypanosomes on calf mortality was in contrast to the reported importance of trypanosomes by herdsmen and owners as a cause of calf mortality in the year preciding the study. Yearly fluctuations in trypanosome numbers due to climatic variations or control programs are possible, but are unlikely to account for this large discrepancy. Either cattle breeder had also reported causes of death of older calves aged more than 12 months (some animals suckle up to 15 months) or the awareness of trypanosome control programs may have led to over-reporting of the disease.

Under the currently widely applied acaricide use in both management types, tick burden of calves was low and most calves had no ticks at all. The tick spectrum found was in line with the findings of the nation-wide tick survey by Teel et al. (1988). Three calves had died due to presumptive theileriosis. Another two animals had nervous disorders but no sign of cowdriosis was found in any of the autopsied calves. With the observed low tick density and the low number of losses, no further intensification of tick control is recommended. The currently used control strategies should be tested for their cost-effectiveness, as strategic tick control did not improve weight gain in young calves in Central and Southern Africa (Pegram and Chizyuka 1990, Meltzer et al. 1995). In addition, a delay in acaricide application on young animals is recommended by Chema (1990) to allow for development of premunition against tick-borne diseases like the observed theileriosis. Herd owners treating their animals should be aware of the recommended application of products as proposed by the manufacturer, to save their resources, prevent development of resistance against used drugs and assure safety of treated animals. Care should be given to the removal of ticks from the udder of cows to prevent losses of teats and painful suckling.

10.3.5 Respiratory disorders and infectious diseases

Respiratory disorders were of low importance in young calves. Of four calves with respiratory disorders, two were suspected to have been caused by bovine tuberculosis based on their history of death and postmortem findings, but no confirmation could be made. Deaths due to infectious diseases were also rare in calves in Guinea (4-6%) (Mourad and Magassouba 1996). To prevent infectious disease outbreaks, which may lead to serious losses as reported from central Mali (Troaré and Wilson 1988), vaccination coverage must be increased. Currently vaccination coverage is reported to be very poor (Coulibaly 2002). Of our 38 study herds, only animals in 4 herds were vaccinated against the 4 infectious diseases, pasteurellosis, contagious bovine pleuropneumonia, anthrax and blackleg. Animals in 21 herds were vaccinated against 3 of these diseases, animals in 11 herds only against 2 and in 4 herds no vaccinations were done. Herd owners further away from Bamako with poorer access to vaccination services are likely to vaccinate even less.

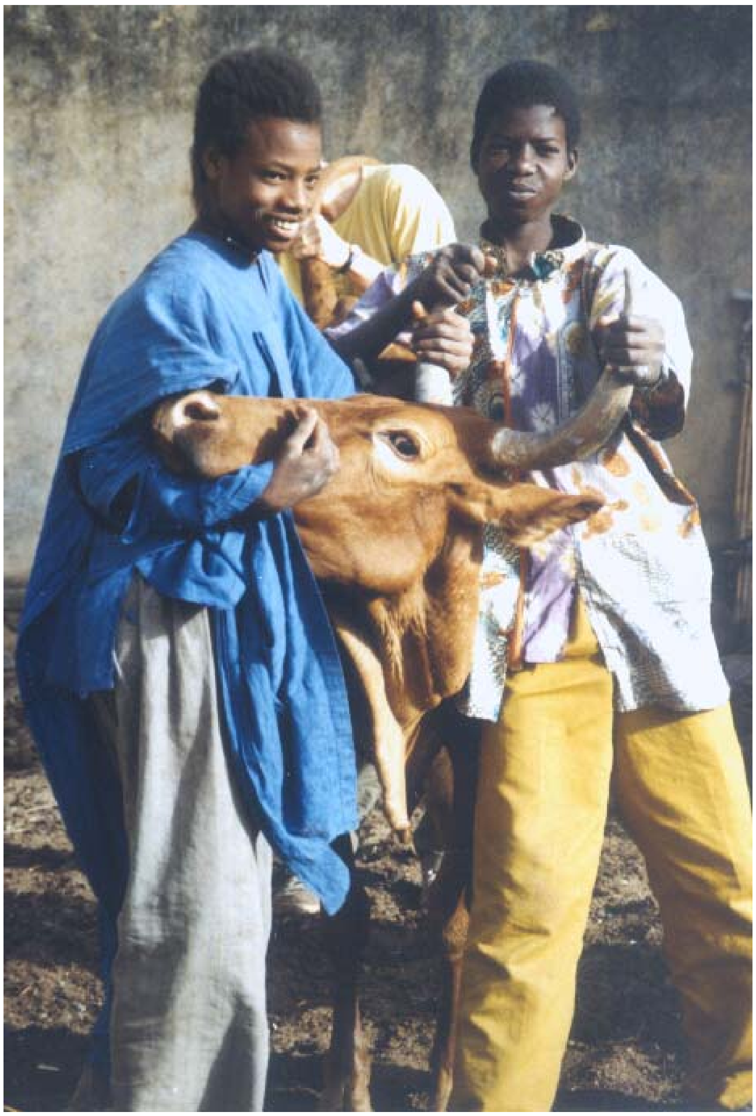
10.4 Outlook on the future of periurban livestock production in Mali

Rapid growth of Bamako will further increase the demand for dairy products. To what extend periurban livestock production can cover this demand in the future will strongly depend on the quantity that can be potentially produced and the profitability based on production costs and import-dependent market prices. The latter will be affected by the lowering of import taxes on agricultural goods, which will increase pressure on local producers to lower the production costs and to improve the quality of their products. Traditional management systems have the competitive advantage of low production costs. But livestock producers face relatively high transport costs of delivering small quantities of surplus milk to the urban centre and a partial loss of their production through lack of a cooling chain and fluctuating market demand. One way to overcome these obstacles is the formation of milk co-operatives to reduce transport and purchase costs and to collectively transform and market the milk. An example is the milk co-operative of Kasséla, whose dairy unit was installed and extended by the “Healthy Milk for the Sahel” project. It provides motivating financial security to local milk producers by being a guaranteed buyer of fresh milk for a fixed price and, being on place, facilitates milk collection. But even if transport and sale problems are alleviated, the fact remains that local breeds have a low genetic potential for milk production. Milk yield of station-managed Zebu cows in Mali is only 2.7 litres/day (Coulibaly 2002) and may be as low as 0.5 litres/day under private traditional management (Debrah et al. 1995). With this low daily production per cow, total quantity produced in traditional systems is relatively low. Hence an improvement of genetic resources through crossbreeding of local Zebu with more productive European breeds has been targeted during the last few decades. Achieved on-station milk production of Zebu x European breeds of 4.3 litres/day is nearly twice as high as milk production of pure Zebu breeds (Coulibaly 2002). Milk yield can also be raised with supplementary feeding and strategic parasite control. Preliminary results of the Kasséla co-operative have shown, that with few investments in supplementary feed, milk production can be significantly increased, paying off the costs of supplementation (Bonfoh pers. comm.). This trend towards modernisation of traditional systems for an increase in milk quantity produced will be accelerated by the loss of communal pastures due to ongoing human population growth. Depletion of natural feed sources will necessitate an intensified husbandry system which will be the most important management system in periurban areas in the future. Our findings of the higher calf mortality rate in modernised management and the observed causes of death need to be considered in this modernisation process of livestock management to optimise the benefits gained by the higher investments.

The modernisation of the livestock sector may help to generate more income and to reduce poverty. Furthermore, larger milk quantities produced in modernised systems will stabilise local prices in regard to fluctuating global market prices. Intensification of livestock keeping will thereby lead to the desired increase of domestic milk production for satisfaction of human needs in urban centres and improved food security. But costs of intensification of livestock production should not be neglected by national authorities and considered in advance in policy making. Not only in view of the higher calf mortality rate found in our study but also in regard to the overall effects of intensive livestock production on the environment and society. Intensified animal production leads to a risk of environmental degradation trough overgrazing and animal manure disposal, an increased demand for animal feed which competes with crop production for human consumption, a risk of emerging diseases, a risk of increasing inequity and marginalisation of smallholder farmers and a reduction in animal welfare (Hursey and Slingenbergh 1998). Moreover, Malian livestock and agricultural production is at the risk of droughts and locust swarms. The two big drought periods in 1972/73 and 1984/85 killed 32% respectively 35% of all Malian bovines due to lack of water and food (Anonymous 1995). Periurban livestock producers may escape such massive losses by supplementation with imported feed, but in situations of famine, usage of water and feed in animal production instead of human alimentation may be economically but not ethically justified. Nevertheless, periurban food production plays a role in food security and poverty alleviation in developing countries in general (Ellis and Sumberg 1998) and in Mali with its large livestock population in particular. And any attempts at reducing calf mortality and thereby increasing profitability of existing management systems are justified.

Chapter 11

Conclusions and recommendations



11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

- Under the current calf management strategies practiced in the periurban zone of Bamako, overall calf mortality rate was 17% during the first year of life. This implies a reduced milk production of every 6^{th} lactation and losses of every 6^{th} future dairy, slaughter and draught cattle.
- Calf mortality rate was lower in traditional livestock management (10%) than in modernised management (19%-25%). This is a serious finding with regard to the ongoing modernisation process. Strategies aimed at modernising livestock production must consider the risk of increasing calf mortality as otherwise profitability is lowered.
- Main causes of calf death were management-related problems, digestive disorders and perinatal mortality
- Risk factors of calf mortality were mainly management-related, such as low number of herdsmen, large herd size and obstetric complications. Two further risk factors were birth during the rainy season and multiparous dam.
- Tick burden was low and tick-borne diseases and trypanosome infections were rare. Vector and vector-borne diseases had a low impact on calf mortality.
- Gastrointestinal parasite spectrum and prevalence of some species in calves aged less than one year was similar to those found in adult cattle. Nematode egg excretion under the currently applied control strategies was moderate. Gastrointestinal parasites were important causes for calf mortality in modernised management.
- Overall calf survival may be increased with better calf management regarding hygiene, herding and nutrition.

11.2 Recommendations for livestock owners, national authorities and future research

The high calf mortality rate in periurban livestock production and the causes and risk factors of calf mortality pointed out key issues which need to be considered by livestock owners and by national authorities for improvement of calf survival and thereby livestock productivity. In addition the results raised new research questions and implications for future studies to improve calf survival.

11.2.1 ***Recommendations for future research***

- Causes of the non-parasitic diarrhoea in calves should be identified, i.e. the role of viral and bacterial infections.
- Causes for abortion, stillbirths and perinatal mortality should be investigated in detail, with a focus on inbreeding, malnutrition during gestation, obstetric complications, lack of antenatal care and brucellosis.
- The higher mortality of calves of multiparous cows needs to be researched to elucidate its causes.
- Access of newborn calves to the colostral milk and level of acquired colostral immunity, as an important factor influencing calf health, should be determined.
- Effects of feed supplementation on calf survival should be tested, and, if a positive effect is found, its cost-effectiveness assessed.
- Profitability of tick, nematode and trypanosome control strategies currently used by the livestock owners should be assessed and strategies improved to save scarce resources.
- An in-depth economic analysis of different livestock management systems is needed. Evaluating the benefits of modernised livestock production in comparison to traditional management, in terms of higher milk quantities produced and the increase in production costs and calf mortality rates.

11.2.2 ***Recommendations for national authorities***

- Because most modernised herds within the periurban zone belong to rich merchants and civil servants without an in-depth background in livestock keeping, training in livestock management, including lessons on feeding, health, breeding and housing should be made available to livestock owners and herdsmen. Either by regular workshops or lectures open to the public in existing facilities or by founding a school for agriculture and livestock production. With improved knowledge about livestock management and market economy, local livestock producers may increase their production and competitive capacity.
- National livestock research stations should evaluate their calf management strategies for improvement of calf survival.

- Accomplishment of mandatory vaccinations should be controlled for improvement of vaccination coverage.
- Policy makers need to consider both the positive and negative effects of intensifying periurban livestock production for sustainable agricultural, urban and periurban development.

11.2.3 Recommendations for livestock producers

- Contact of calves with faeces should be reduced. Either by a regular change of the holding place in traditional management or by better hygiene and improved holding systems in modernised management. Livestock owners planning to invest in housing of animals should consider the increased problems with hygiene in stationary enclosures and plan in advance an efficient faecal sludge management strategy.
- Supervision of calves should be increased to prevent accidental losses and to improve health care provided to calves.
- To prevent a delay in treatment of sick or injured animals, herdsmen should be empowered to call a veterinarian in the absence of herd owners.
- To reduce malnutrition in calves, milk off-take and quantity of milk left to the calves should be controlled and another salary system for herdsmen developed.
- Adherence to the manufacturer's recommendation concerning usage and dosage of drugs is recommended to save scarce resources, prevent toxic effects and delay development of resistance.
- Sire selection strategy should include a focus on avoidance of inbreeding and calving ease.
- To maximise immunity and thereby resistance of calves towards bacterial and viral infections, newborn calves should have unrestricted access to the colostral milk of their dam during the first 48 hours after parturition.

Epilogue

This work has provided baseline information and recommendations for improvement of calf survival in periurban livestock production, as a scientific complement to the strategy for improvement of calf health described by one of the herdsmen.

"*On behalf of my (entrusted) calves I went to the Marabout. He has slaughtered a chicken to ensure good health of my calves and since then, I have had no further losses*".

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Appendix

13 APPENDIX

13.1 Interview about calf management

Interview sur l'élevage bovin dans la zone périurbaine de Bamako

" Dans le cadre de notre étude sur l'élevage des veaux nous avons besoin de l'information générale sur l'élevage bovin pour déterminer l'environnement. Nous vous prions de partager avec nous vos connaissances sur la gestion de votre troupeau. Toutes les informations seront traitées de façon confidentielle. Nous vous remercions de votre aide."

N° d'interview 5-_______

A Identification

A1. N° de troupeau ______ **A2.** Date _______ _______ __________ *(jj,mm,aaaa)*

A3. Langue utilisée pour faire l'enquête *Marquez les catégories justes*

Français	Peul	Bambara

A4. Enquêtés(s) *Marquez les catégories justes*

Propriétaire	Berger (s)	Vétérinaire

B Démographie

B1. Combien de bergers travaillent-ils avec ce troupeau? ________ personnes *Donnez le chiffre*

B2. Combien d'années travaille le berger le plus ancien? ________ ans *Donnez le chiffre*

C Gestion du troupeau

C1. Y a-t-il d'autres animaux dans l'enclos? *Marquez non ou tous les catégories justes*

Non □

Moutons	Chèvres	Anes	Chevaux	Poules	Chiens	Chats	Autres__________________________

Questionnaire Gestion du troupeau N° d'interview 5- ______ Page___

C2. Quelle est la distance minimale entre l'enclos et l'habitation la plus proche du berger ou du propriétaire? *Marquez seulement une catégorie*

Intérieur du parc	< 20 m	20-100 m	>100 m

C3. Où sont gardés les animaux des différentes catégories d'âge pendant la nuit?

Marquez seulement une catégorie de lieu par catégorie d'âge

Lieu/ Age	< 1 semaine	1 semaine - 3 mois	3 mois à 1 an	>1 an
Enclos général				
Enclos des veaux couvert				
Enclos des veaux non couvert				
Pâturage				
Attaché à une corde				
Autres *(spécifiez)*				

C4. Où sont les animaux de différentes catégories d'âge dans la journée?

Marquez seulement une catégorie de lieu par catégorie d'âge

Lieu/ Age	< 1 semaine	1 semaine - 3 mois	3 mois à 1 an	>1 an
Enclos général				
Enclos des veaux couvert				
Enclos des veaux non couvert				
Pâturage				
Attaché à une corde				
Autres *(spécifiez)*				

C5. A la naissance, à quel âge les veaux sont-ils séparés de leur mères?

Donnez la chiffre ou marquez jamais

________ jours	jamais

Questionnaire Gestion du troupeau N° d'interview 5- ______ Page___

D Abreuvement

D1. Quelle est la source d'abreuvement principale pour les vaches ?

pendant l'hivernage? ______ *Spécifiez le code pour chaque saison*

pendant la saison sèche? ______

1 Mares	2 Niger	3 Affluent du Niger	4 Puisards	5 EDM	6 Forage	7 Puits
*8 Autres (spécifiez)*________________________________						

D2. Combien de fois les vaches ont-elles accès à la source d'abreuvement?

pendant l'hivernage? ______ *Spécifiez le code pour chaque saison*

pendant la saison sèche? ______

1 Toujours	*2 2 fois/jour*	*3 1 fois/jour*	*4 1 fois/2 jours*

D3. Les veaux s'abreuvent-ils ?

Toujours	Souvent	Rarement	Jamais

Si jamais, continuez avec E1, si toujours, souvent ou rarement continuez avec D4

D4. Quelle est la source d'abreuvement principale pour les veaux ?

Spécifiez le code pour chaque saison

pendant l'hivernage? ______

pendant la saison sèche? ______

1 Mares	2 Niger	3 Affluent du Niger	4 Puisards	5 EDM	6 Forage	7 Puits
*8 Autres (spécifiez)*________________________________						

D5. Comment est le rythme d'accès à la source d'abreuvement pour les veaux ?

Spécifiez le code pour chaque saison

pendant l'hivernage? ______

pendant la saison sèche? ______

1 Toujours	*2 2 fois/jour*	*3 1 fois/jour*	*4 1 fois/2 jours*

E. Alimentation

E1. Quelle est la source de nourriture principale pour les vaches? *Spécifiez pour chaque saison*

Pendant l'hivernage ? ____________________

pendant la saison sèche?____________________

E2. Quelles sont les sources de nourriture secondaires (compléments) pour les vaches?

Spécifiez pour chaque saison

pendant l'hivernage?____________________

pendant la saison sèche?____________________

E3. Donnez-vous de la nourriture supplémentaire aux veaux?

Non ☐ *Marquez non ou spécifiez pour chaque saison*

pendant l'hivernage? ____________________

pendant la saison sèche?____________________

E4. Donnez-vous du sel aux vaches? *Marquez seulement une catégorie*

Toujours	Souvent	Rarement	Jamais

E5. Donnez-vous du sel aux veaux? *Marquez seulement une catégorie*

Toujours	Souvent	Rarement	Jamais

E6. Que faites-vous avec un veau si la vache n'a pas assez de lait ou est morte?

Marquez tous les catégories justes

Laisser au pâturage	Abattre	Don du lait	Don du compléments	Adoption par une autre vache
Autres (*spécifiez)*____________________				

F. Production laitière

F1. Combien de traites faites-vous par jour ? *Marquez seulement une catégorie*

0	1	2

Si 0 fois (lait laissé au veau), continuez avec question G1

F2. Combien de jours après la mise bas utilisez-vous pour la première fois le lait pour la consommation humaine? *Donnez le chiffre ou marquez jamais*

________ jours	Jamais

F3. Que faites-vous si un veau meurt pour assurer la production laitière de la vache?

Marquez tous les catégories justes

Rien, vache tombe sèche	Attribuer un autre veau à cette vache	Traite sans veau
Autres, *(spécifiez)*____________________		

F4. Quelles sont les raisons pour vous de ne pas traire une vache?

Marquez pas de raison ou tous les catégories justes

Pas de raison	Vache en gestation avancée	Lait laissé au veau	Vache malade	Vache sauvage
Veau malade	Veau jeune	Mauvaise laitière	Vache maigre	Infection du pis
Autres *(spécifiez)*____________________				

G Reproduction

G1. Quel est l'âge moyen d'une génisse au premier vêlage dans votre parc? _____ mois

Donnez le chiffre

G2. Quel est l'intervalle moyen entre deux vêlages d'une vache dans votre parc? _____ mois

Donnez le chiffre

G3. Quelles races et métissages sont présents dans votre parc ? *Donnez les noms de races*

____

____

____

H Santé du bétail

H1. Faites-vous une lutte contre les parasites gastro-intestinaux? *Marquez non ou spécifiez*

Non ☐

	Combien de fois par an	Quels animaux *1=tous, 2= adultes, 3=veaux, 4= métis exotiques, 5=races locales, 6=malades, 7=maigres*
Vermifuge 1 *(Spécifiez)* ________________		
Vermifuge 2 *(Spécifiez)* ________________		
Autres *(Spécifiez)*________________ ________________		

H2. Faites-vous une lutte contre les tiques? *Marquez non ou spécifiez*

Non ☐

Quoi	Combien de fois par an	Quels animaux *1= tous, 2=adultes, 3=veaux, 4=métis exotique, 5=races locales, 6=malades, 7=maigres, 8= visiblement parasité*
Acaricides *(Spécifiez)* ________________		
Elimination manuelle ________________		
Pharmacopée *(Spécifiez)* ________________		
Autres *(Spécifiez)*________________ ________________ ________________		

H3. Les animaux du troupeau sont-ils vaccinés? *Marquez non ou spécifiez*

Non ☐

Nom de la maladie	Date de la dernière vaccination *(mm.aaaa)*	Quels animaux *1 = tous 2=adultes, 3= jeunes, 4=métis exotique, 5=races locales*

H4. Quels sont les soins donnés aux veaux et à la mère après la mise bas?

Marquez rien ou toutes les catégories justes

Rien	Don de la nourriture supplémentaire à la vache	Abreuvement de la vache
Désinfection du cordon ombilical	Autres (*spécifiez*)____	

I. Mortalité de veaux

I1. Il y a eu combien des mises bas pendant les 12 derniers mois dans ce parc? ____ *Donnez le chiffre*

I2. Il y a eu combien des veaux morts pendant les 12 derniers mois dans ce parc? ____

Donnez le chiffre

I3. Il y a eu combien des avortements pendant les 12 derniers mois dans ce parc? ____

Donnez le chiffre

I4. Avez-vous des problèmes avec la mortalité de veaux dans ce parc? *Marquez seulement une catégorie*

Toujours	Souvent	Rarement	Jamais

Questionnaire Gestion du troupeau N° d'interview 5- ______ Page___

I5. Quels sont les causes de mort de veaux dans votre parc?

Marquez toutes les causes spécifiés spontanément (Spontané) et puis toutes les causes à la demande (Demande)

Code	Spontané	Demande
1. Accident		
2. Mort de faim		
3. Empoisonnement		
4. Faiblesse générale		
5. Diarrhée		
6. Nématodes et autres endoparasites		
7. Tiques et autres ectoparasites		
8. Maladies infectieuses		
9. Pneumonie		
10. Obstruction intestinale causée par des objets étrangers consommés		
11. Trypanosomiase		
12. Mise bas difficile		
13. Autres (*Spontané*)____		

____
____
____
____

I6. De cettes causes de mort, quelle est la cause la plus importante dans votre troupeau?

Spécifiez le code

Code _______ *Le décrivez-vous s'il vous plaît*

____
____
____
____
____

Questionnaire Gestion du troupeau N° d'interview 5- ______ Page___

I7. A côté de cette cause de mort, quelle autre cause est aussi d'une grande importance?

Spécifiez le code

Code _______ *Le décrivez-vous s'il vous plaît*

____

____

____

____

I8. Faites-vous quelque chose pour améliorer la survie des veaux dans votre troupeau?

Les décrivez-vous s'il vous plaît

____

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Fin de l'interview. Nous vous remercions de votre collaboration

Questionnaire Gestion du troupeau *N° d'interview 5-* ______ *Page*___

13.2 Interview about calf mortality

Interview sur les causes de pertes des veaux

“ *Nous étudions la mortalité et les pertes des veaux avec le but de développer des stratégies pour les réduire. Pour ce faire nous vous prions de partager avec nous vos connaissances sur la dernière perte d'un veau dans ce troupeau. Toutes les informations seront traitées de façon anonyme. Nous vous remercions de votre aide”*

N° d'interview *4*-_______

A. Identification

A1. N° du troupeau ________

A2. Date de l'interview ____ ____ ________ *(jj, mm, aaaa)*

A3. Répondant

Berger	Propriétaire	Autres____

A4. N° du veau __________

A5. Date de la perte _____ _____ __________ *(jj, mm, aaaa)*

A6. Age du veau _____ mois ____ jours

A7. Race du veau _______________________________________

B. Cause de la perte

B1. Quelle est la cause de cette perte?

Décrivez l'histoire raconté par le répondant

____

____

____

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____

Questionnaire Cause de mortalité N° d'interview 4-________ Page___

B2. Comment peut-on classifier la cause de cette perte? *Marquez la cause la plus importante*

C Accident	☐	*Exécutez la section C*
D Mort de faim (sans maladie)	☐	*Exécutez la section D*
E Empoisonnement	☐	*Exécutez la section E*
F Faiblesse générale	☐	*Exécutez la section F*
G Maladie	☐	*Exécutez la section G*
H Attaqué par une prédateur	☐	*Exécutez la section H*
I Egaré	☐	*Exécutez la section I*
J Volé	☐	*Exécutez la section J*
K Abattu	☐	*Exécutez la section K*
L Vendu / Don	☐	*Exécutez la section L*
M Inconnu	☐	*Fin de l'interview*

C. Accident

C1. Comment l'accident est-il arrivé? *Marquez seulement une catégorie*

Accident de la route	Tombé	Se noyé pendant l'abreuvage	Ecrasé par d'autres bœufs
Autres (*spécifiez*)________________________________			

C2. Où était le veau quand il a eu l'accident ? *Marquez seulement une catégorie*

Enclos	Pâturage	Route	Etable	Point d'eau	Autres (*spécifiez*)____________

C3. L'accident était-il mortel? Oui ☐ Non ☐ *Marquez oui ou non*

Si non

C4. Avez-vous abattu le veau après l'accident ? Oui ☐ Non ☐ *Marquez oui ou non*

Fin de l'interview

D. Mort de faim

D1. Pourquoi ce veau est-il mort de faim? *Marquez seulement une catégorie*

Vache a rejeté le veau	Vache n'a pas (assez) de lait	Veau n'a pas voulu téter	Inconnu
Fermeture de l'estomac par des déchets	Veau malade	Trop faible pour sucer	Vache morte
Autres (*spécifiez*)________________________________ ________________________________ ________________________________			

D2. Avez-vous donné de la nourriture ou des liquides au veau?

Marquez non ou toutes les catégories justes

Non	Résidus de récoltes	Fourrage concentré	Herbes	Lait	Eau	Foin	Restes de cuisine
Autres (*spécifiez*)________							

Si vache n'a pas assez de lait, continuez avec question D3

Si veau était trop faible pour sucer, continuez avec question F1

Si veau était malade continuez avec question G1 *Fin de l'interview*

D3. Pourquoi la vache n'a-t-elle pas eu assez de lait ?

Malade	Perte des trayon(s) à cause des infections	Perte des trayon(s) à cause des tiques
Mauvaise laitière	Autres (*spécifiez*)________	

Fin de l'interview

E. Empoisonnement

E1. Comment ce veau était-il empoisonné? *Marquez seulement une catégorie*

Inconnu	Morsures scorpions	Déchets	Morsures serpents	Insecticides	Médicaments
Autres (*spécifiez*)________					

E2. D'où ce veau était-il empoisonné? *Marquez seulement une catégorie*

Inconnu	Enclos	Pâturage	Route	Point d'eau	Etable
Autres (*spécifiez*)________					

Fin de l'interview

F. Faiblesse générale

F1. Pourquoi ce veau était-il si faible? *Marquez inconnu ou toutes les catégories justes*

Inconnu	Naissance jumelle	Vache n'a pas assez de lait	Naissance avant terme
Vache malade	Naissance difficile	Ne s'est pas rétabli d'une maladie	Handicapé
Vache morte	Vache l'a rejeté	Ne s'est pas rétabli d'un accident	Veau malade
Autres (*spécifiez*)________ ________			

Si veau était malade ou ne s'est pas rétabli d'une maladie, continuez avec question G1

Si vache n'avait pas assez de lait continuez avec question D2 *Fin de l'interview*

Questionnaire Cause de mortalité N° d'interview 4-________ Page___

G. Maladie

G1. De quelle maladie ce veau est-il mort? *Marquez inconnu ou donnez le nom de la maladie*

Inconnu ☐ Nom____

G2. Quels symptômes avez-vous observé chez le veau malade?

Marquez tous les symptômes spécifiés spontanément (Spontané) et puis tous les symptômes affirmatifs au demande (Demande)

Symptômes	**Spontané**	**Demande**
1 Abcès		
2 Apathie		
3 Inflammation des yeux		
4 Diarrhée		
5 Ecume à la bouche		
6 Fièvre		
7 Inflammation du cordon ombilicale		
8 Insuffisance respiratoire		
9 Isolation des autres animaux		
10 Jetage (Flux nasal)		
11 Maigreur		
12 Paralysie		
13 Pas de faim/soif		
14 Perturbations de la coordination		
15 Toux		
16 Ventre ballonné		
17 Vésicules dans la bouche ou entre les onglons		
18 Autres (*spécifiez*)____		

G3. Avez-vous traité le veau malade avec quelque choses *Marquez oui ou non*

Oui ☐ Non ☐

Si oui, continuez avec question G4

Si non, continuez avec question G8

G4. Décrivez les traitements *Voyez le sachet ou la boîte du médicament*

	Premier traitement	Deuxième traitement	Troisième traitement
Nom			
Ingrédient			
Dosage			
Répétitions			
Application			
Fonction/Effet			
Efficacité			
Coût			
D'où l'avez-vous procuré **			

** *Spécifiez le code*

1 Au marché	2 *Chez un vendeur ambulant*	3 *Herbes/ Ecorces des champs*	4 *Au service vétérinaire*	5 *Herbes/ Ecorces sauvage*	6 *Chez un guérisseur traditionnel*
7 Autres (spécifiez)________________________________					

G5. Avez-vous consulté quelqu'un pour le traitement? Non ☐

Marquez non ou toutes les catégories justes

Autre bouvier	Vendeur ambulant	Propriétaire	Guérisseur traditionnel	Service vétérinaire
Autres (*spécifiez*)________________________________				

G6. Qui a payé pour le(s) traitement(s)? *Marquez toutes les catégories justes*

Propriétaire	Bouvier	Autres (*spécifiez*)________________________

G7. Qui a décidé du type de traitement à utiliser ? *Marquez toutes les catégories justes*

Propriétaire	Bouvier	Vétérinaire	Autres (*spécifiez*)__________________

Fin de l'interview

G8. Pourquoi n'avez-vous pas traité le veau? *Marquez toutes les catégories justes*

Trop occupé	Mort trop brusque	Absent	Veau n'était pas valable	Pas de traitement connu
Traitement très cher	Autres (*spécifiez*)________________________			

Fin de l'interview

Questionnaire Cause de mortalité *N° d'interview 4-*________ *Page*___

H. Attaqué par une prédateur

H1. Quelle espèce d'animal a attaqué le veau? *Marquez seulement une catégorie*

Inconnu	Chien	Animal sauvage (*spécifiez*)________________________________

H2. Où était le veau quand il était attaqué ? *Marquez seulement une catégorie*

Enclos	Route	Pâturage	Point d'eau	Etable	Autres (*spécifiez*)____________________

Fin de l'interview

I Egaré

I1. D'où ce veau s'égarait-il? *Marquez seulement une catégorie*

Pâturage	Route	Point d'eau
Autres (*spécifiez*)________________________________		

I2. A-t-il eu des causes extraordinaires quand le veau s'est égaré? *Marquez seulement une catégorie*

Tourmente	Nuit	Mélange des plusieurs troupeaux
Autres (*spécifiez*)________________________________		

Fin de l'interview

J. Vol

J1. D'où ce veau était-il volé? *Marquez seulement une catégorie*

Pâturage	Route	Etable	Enclos	Point d'eau
Autres (*spécifiez*)________________________________				

Fin de l'interview

K. Abattu

K1. Pourquoi ce veau était-il abattu *Marquez seulement une catégorie*

Blessé	Malade	Vache pas (assez) de lait	Empoisonné	Faible	Handicapé	Vache morte
Consommation	Autres (*spécifiez*)________________________________					

Si veau était malade continuez avec question G1, *Si veau était blessé continuez avec question C1*

Si veau était faible continuez avec question F1 *Si veau était empoisonné continuez avec question E1*

Fin de l'interview

Nous vous remercions de votre collaboration!

Questionnaire Cause de mortalité N° d'interview 4-________ Page___

13.3 Bayesian models for the analysis of overdispersed clustered parasite counts

Models developed by Dr. Penelope Vounatsou (STI) in WinBugs v. 1.4 (Imperial College & Medical Research Council, London, UK)

1. Negative binomial model with 6 covariates but without random effects

```
model {
r~ dgamma(0.1,0.1)
for( i in 1 :N ) {
total[i]~dnegbin(p[i],r)

p[i] <- r/(r+mu[i])
q1[i]<-b[1]+b[2]*equals(age[i],2)+b[3]*equals(age[i],3)+b[4]*equals(season[i],2)
        +b[5]*equals(season[i],3)
q2[i]<-b[6]*mana[i]+b[7]*breed[i]+b[8]*sheep[i]+b[9]*treat[i]

log(mu[i])<-q1[i]+q2[i] }
for (k in 1:9){

b[k]~dnorm(0,0.01)}
alpha<-1/r}
```

2. Negative binomial model with 6 covariates and two random effects to account for the clustering in herds and the repeated sampling of individual calves

```
model {
r~ dgamma(0.1,0.1)
for( i in 1 :N ) {
total[i]~dnegbin(p[i],r)

p[i] <- r/(r+mu[i])
q1[i]<-b[1]+b[2]*equals(age[i],2)+b[3]*equals(age[i],3)+b[4]*equals(season[i],2)
+b[5]*equals(season[i],3)
```

```
q2[i]<-b[6]*mana[i]+b[7]*breed[i]+b[8]*sheep[i]+b[9]*treat[i]
log(mu[i])<-q1[i]+q2[i]+a1[herd[i]]+a2[calf_id[i]]}

for (k in 1:9){
b[k]~dnorm(0,0.01)}

for (k in 1:38){
a1[k]~dnorm(0,tau1)}
tau1~dgamma(0.01,0.01)
sigma1<-1/tau1

for (k in 1:656){
a2[k]~dnorm(0,tau2)}
tau2~dgamma(0.01,0.01)
sigma2<-1/tau2

alpha<-1/r
effect<-sigma1/(sigma1+sigma2)}
```

13.4 Curriculum Vitae

Full Name	Monica Natalie WYMANN
Date and place of birth	11th August 1976 in Basel, Switzerland
Nationality	Swiss
Marital status	Married
Address	Bachlettenstrasse 76, CH-4054 Basel, Switzerland

Education

1983 – 1987	Primary School in Basel, Switzerland
1987 - 1995	Grammar school in Basel, Switzerland, Matura type natural sciences and mathematics (C)
1995 - 2000	Studies in Biology I, University of Basel, Switzerland
2000 – 2001	University of Basel and University of the Witwatersrand, Johannesburg, South Africa Diploma (equivalent to a Master of science (MSc)) in Integrative Biology. Thesis title: "The familiar and the fecund: the mate preference continuum examined in a lizard" and "Foraging ecology of rainbow skinks (*Mabuya margaritifer*) in southern Africa" Supervision: Dr. M.J. Whiting and Prof. Dr. S.C. Stearns
2001- 2005	Swiss Tropical Institute, Basel, Switzerland and Laboratoire Central Vétérinaire, Bamako, Mali. PhD in Epidemiology. Thesis title: "Calf mortality and parasitism in periurban livestock production in Mali" Supervision: PD Dr. J. Zinsstag and Prof. Dr. M. Tanner

Practical training and employment

1995	Practical training in plant cultivation, Birr Castle, Birr, Ireland
1995-2001	Part-time positions as shop and office assistant, Basel

1998	TBA (Tropical Biology Association) Darwin Course in Tropical Ecology, Kibale, Uganda
1998	Practical training, Institute for Environmental Sciences of the University of Zurich, Switzerland. Project title: "Influence of plant species diversity on spider populations in grassland ecosystems"
1999 - 2001	Student research assistant positions, Zoological Institute of the University of Basel
2001	Practical training, Swiss Tropical Institute, Basel. Project title: "Parasite-host interactions in *Plasmodium falciparum"*
2001-2005	PhD Student, Swiss Tropical Institute, Basel

During my studies I attended lectures and courses given by the following lecturers:

C. Baroni-Urbani, B. Bauer, B. Bruderer, R. Brun, P. Duelli, D. Ebert, M. Frey, A. Hänggi, H. Hauri, H. Imhof, C. Körner, C. Lengeler, E. Lüdin, J. Meier, P. Nagel, B. Obrist, E. Parlow, G. Pluschke, H.F. Rowell, W. Rudin, P. Sander, G. Schatz, H. Schneider, D.G. Senn, U. Séquin, H. Siegel, T. Smith, S.C. Stearns, J. Stöcklin, M. Tanner, P. Vounatsou, M. Weiss, N. Weiss, A. Wiemken, S. Zschokke, J. Zinsstag

Publications

Wymann, M.N., & M.J. Whiting. 2002. Foraging ecology of rainbow skinks (*Mabuya margaritifer*) in southern Africa. Copeia 2002:943-958.

Wymann, M.N., & M.J. Whiting. 2003. Male mate preference for large size overrides species recognition in allopatric flat lizards (*Platysaurus broadleyi*). Acta Ethologica 6:19-22.

Whiting, M.J., S.P. Lailvaux, L. Reaney, & M. Wymann. 2003. To run or hide? Age-dependent escape behavior in the lizard *Platysaurus intermedius wilhelmi*. Journal of Zoology (London) 260:123-128.