Clinical Presentation and Occurrence of the Contagious Skin Diseases Mange and Orf in Goat Herds in Zambia

Katja Anton

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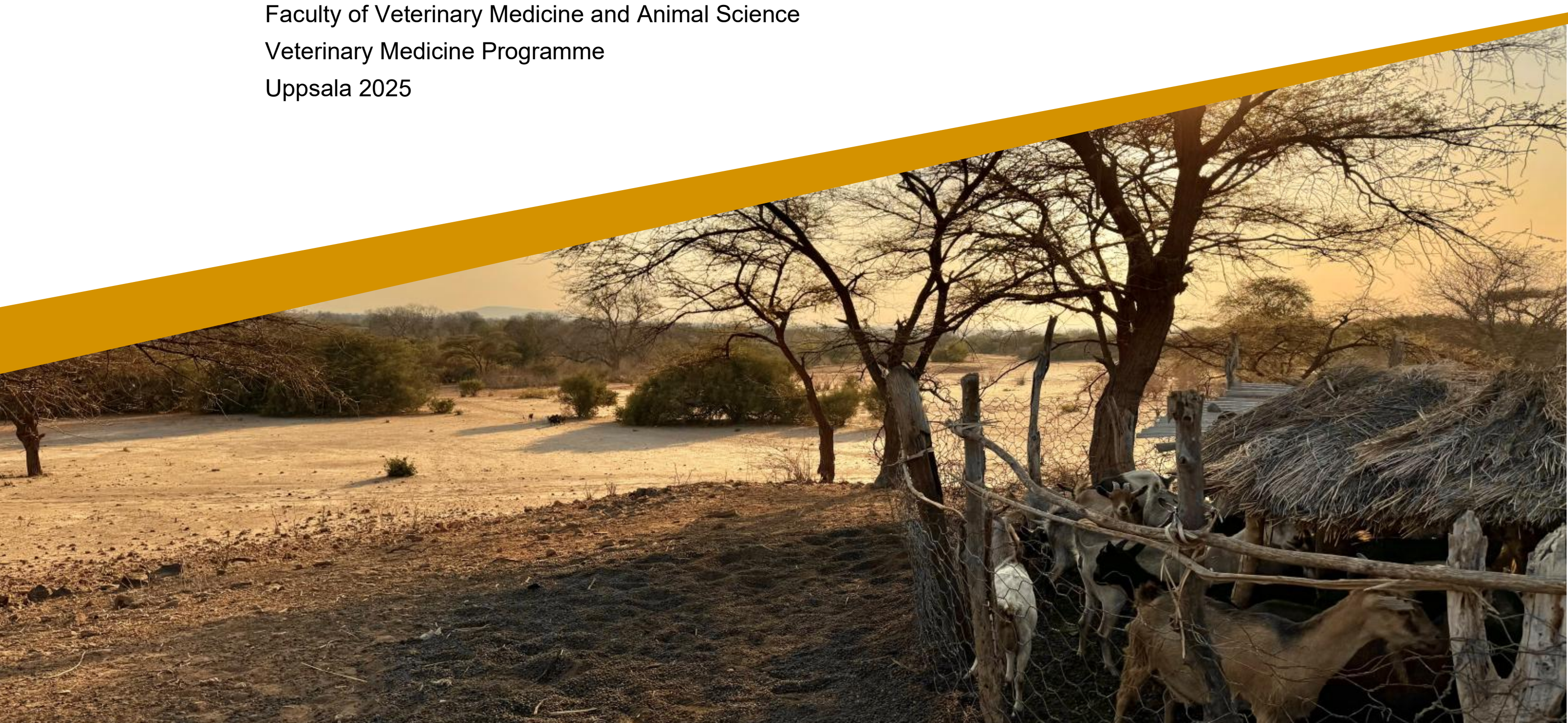

Clinical Presentation and Occurrence of the Contagious Skin Diseases Mange and Orf in Goat Herds in Zambia

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Supervisor:	**Jonas Johansson Wensman, Swedish University of Agricultural Sciences, Department of Animal Biosciences**
Assistant supervisor:	Giulio Grandi, Swedish University of Agricultural Sciences, Department of Animal Biosciences
Assistant supervisor:	Dinah Seligsohn, Swedish Veterinary Agency
Assistant supervisor:	Bertha Chitambo, University of Zambia, Department of Disease Control
Examiner:	Mikael Berg, Swedish University of Agricultural Sciences, Department of Animal Biosciences

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Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
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Abstract

In Zambia, small ruminants play an important role in securing the livelihood of resource-constrained smallholder farmers by contributing to income, social status and food security. Infectious diseases, such as mange and orf, can be major challenges to small ruminant production as they can cause big economic losses. Both mange and orf are among the top constraints faced by the farmers in the country today with only a few studies done on the prevalence. The aim of this study was to investigate the clinical presentation and occurrence of the contagious skin diseases mange and orf in goat herds in Zambia.

Skin scrapings were collected from goats with clinical signs of mange and eSwabs were taken from goats with clinical signs of orf in the Southern and Central province of Zambia. In total, twenty households were included in the study (10 in the Southern province and 10 in the Central province) and at each household, 10 goats were randomly selected for clinical examination with focus on the skin for mange and areas around the mouth, nose, teats and feet for orf. The material collected by skin scraping was digested in 10% potassium hydroxide followed by microscopic examination for detection of mange mites. For detection of parapoxvirus, DNA was extracted from the eSwabs followed by Real-Time PCR. For confirmation, a touch-down PCR was conducted followed by gel electrophoresis.

The herd occurrence of mange was 10% (1/10) in the Southern province and 10% (1/10) in the Central province of Zambia and the genuses of mange mite located were *Sarcoptes* spp. in the Southern province and *Demodex* spp. in the Central province. The major clinical sign of mange on the animals positive at microscopic examination was alopecia. The herd occurrence of orf virus was 10% (1/10) in the Central province and 0% in the Southern province. The clinical signs present in the positive herd was small lesions and pustules in the mouth.

The study shows that both mange and orf are present in goat herds in Zambia. The low occurrence is likely due to challenges in diagnostic techniques, mild clinical signs present and unfavorable seasonal conditions for mange mites. The study also found widespread use of acaricides, unclear control strategies against ectoparasites and a possible perception among farmer conflating mange with other skin conditions that present with similar clinical signs. Further research is recommended during the rainy season when conditions are more favorable for mange mites, along with investigations into the effectiveness of ectoparasite control strategies among farmers. The herd positive for parapoxvirus is most likely positive for orf virus but sequencing is needed for definite diagnosis. To better understand the distribution and impact of orf in goat herds across Zambia, further research on the seroprevalence of the disease is recommended.

Keywords: Southern province, Central province, mange mites, parapoxvirus, B2L gene, control strategies, season

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Abbreviations

Abbreviation	Description
ACEIDHA	Africa Centre of Excellence for Infectious Diseases of Humans and Animals
BCS	Body Condition Score
DNA	Deoxyribonucleic Acid
ELISA	Enzyme-linked Immunosorbent Assay
FAO	Food and Agriculture Organization
ML	Macrocyclic Lactone
WOAH	World Organisation for Animal Health
OP	Organophosphate
PCR	Polymerase Chain Reaction
SLU	Swedish University of Agricultural Sciences
SVA	Swedish Veterinary Agency
SP	Synthetic Pyrethroid
UD	Ulcerative Dermatosis
UK	United Kingdom
UNDP	United Nations Development Program
UNZA	University of Zambia
USA	United States of America
WFP	World Food Program

1. Introduction

Goats play an important role in securing the livelihood of resource-constrained smallholder farmers in low- and lower-middle-income countries by contributing to income, social status and food security (Perry *et al.* 2002; Mwaba 2011). In countries with an arid and unpredictable climate, such as Zambia in Southern Africa, goats can make a significant socioeconomic contribution to small farm systems in rural communities due to their prolific nature and profitability (Mwaba 2011; Aucamp *et al.* 1981 see Namonje-Kapembwa *et al.* 2019). Compared to other ruminants, they have a great ability to withstand heat stress and prolonged water deprivation, which makes them greatly adaptable to climatic and geophysical changes (Aziz 2010; Namonje-Kapembwa *et al.* 2019).

Diseases and mortality among goats can have devastating effects on the livelihood of smallholder farmers and the impact is likely to be proportionally greater for the poor (Perry *et al.* 2002; Pradère 2014). Infectious and parasitic diseases are major challenges for small ruminant production as they can cause major economic losses (Al-Assaf 2012). Orf caused by orf virus is for example an infectious and zoonotic disease with economic importance globally, denoting a risk to public health (Smith 2019). Both mange and orf are mentioned to be among the major constraints in goat production (Namonje-Kapembwa *et al.* 2019). According to the Ministry of Fisheries and Livestock (2024), the major constraint faced by the farmers in Zambia in 2023 was diseases, mange being the most reported (Ministry of Fisheries and Livestock 2024). At a workshop in November 2019, organized by the research project "Factors limiting sustainable small ruminant production in Tanzania and Zambia" (funded by the Swedish Research Council), external parasites were ranked among the top five health issues by almost all stakeholder groups (Fischer *et al.* 2020).

Goats were the second most common livestock animal in rural households in Zambia in 2023 (Ministry of Fisheries and Livestock 2024). The country is now undergoing an intensification in goat production, providing farmers, especially women, with opportunities in goat rearing and animal husbandry to help adapt to the climate change effects (United Nations Development Programme (UNDP) 2021). The Government of Zambia intends to intensify goat production by promoting and supporting the formation of cooperatives that will undergo training in marketing and management practices including the prevention of common goat diseases (Ministry of Fisheries and Livestock 2020). The intensification of goat production may increase the risk for infectious diseases if management improvements are not considered (Lysholm *et al.* 2020). Knowledge in goat management and disease control is poor among farmers in the country and research tends to focus on larger livestock rather than small ruminants (Fischer *et al.* 2020).

Considering this, the importance of investigating infectious diseases of goats in Zambia is high.

The aim of this study was to investigate the clinical presentation and occurrence of mange and orf in goat herds in Zambia to raise the knowledge among farmers in preparation for the planned intensification of goat production in the country.

2. Literature Review

2.1 Zambia

Zambia is a landlocked country located in Southern Africa. The country is divided into ten provinces (Southern, Muchinga, Lusaka, Eastern, Northern, Luapula, Central, Copperbelt, North-western and Western) and each province is divided into districts totalling 81 (Central Statistical Office (CEN) of Zambia n.d.). The climate is predominantly subtropical, characterized by three distinct seasons, the cool dry season (May to mid-August), the dry season (mid-August to mid-November) and the wet rainy season (mid-November to April) (World Bank 2024a; b). Zambia is subdivided into three agro-ecological regions based on rainfall (Akayombokwa & Mukanda 1998). The first region covers the semi-arid areas of Zambia, like the Zambezi, Luangwa and Lunsenfwa valleys, the Sesheke plateau in the south and south-west and Senanga in the west. This region is characterized by rainfall of less than 800mm annually and high temperatures. The second region includes the entire plateau from Eastern through Central and Lusaka Provinces to the Western Province. This region is characterized by rainfall from 800 to 1,000 mm annually. The third region covers the Northern, Copperbelt, Luapula, North-western and part of the Central Provinces and the annual rainfall in this region ranges from 1,000 to 1,500 mm annually.

The country is classified as a low-income country with more than half of the population living below the poverty line (World Food Programme (WFP) 2024) and 54.8% of the population living in rural communities (Food and Agriculture Organization of the United Nations (FAOSTAT n.d.). In the last decade, the impact of climate change has been severe on the country with frequent and prolonged droughts, high temperatures and floods threatening the livelihood and food security of many smallholder farming households (World Food Programme (WFP) 2024).

2.2 The importance of goats in rural households in Zambia

Small ruminants such as goats have an important role in securing the livelihood of resource-constrained smallholder farmers by contributing to income, social status and food security in low- and lower-middle-income countries (Perry *et al.* 2002; Mwaba 2011). They provide rural households not only with natural capital, such as meat, milk and manure, but plays an important role of financial capital by providing cash, insurance, savings, gifts and collateral for credits, as well as a social capital of being used in ceremonies and as a sign of wealth (Mwaba 2011). In countries with an arid and unpredictable climate, goats are generally considered more valuable than other forms of livestock by farmers because of their ability to convert poor-quality forage into milk and meat (Hoste *et al.* 2010). Additionally, goats have a great ability to withstand heat stress and prolonged water deprivation compared to other ruminants, which makes them greatly adaptable to climatic and geophysical changes (Aziz 2010; Namonje-Kapembwa *et al.* 2019). In cases of climatic changes leading to low yield or crop failure, goats work as an economic protection (Mwaba 2011). Due to their prolific nature, their ability to reach maturity early and their profitability, goats make a significant socioeconomic contribution to small farm systems in rural communities (Mwaba 2011; Aucamp *et al.* 1981 see Namonje-Kapembwa *et al.* 2019).

In Zambia, goats are the second most common livestock animal in rural households (Ministry of Fisheries and Livestock 2024). A total of 5.5 million goats were estimated in the country in April 2023 and 44.2% of rural households were engaged in livestock activities. Most goats are held by households in the Southern province, followed by the Eastern province, and 39.7% of goats were owned by female members of the household. For most households in Zambia, goats are not only an important source of income, but are used for social events, payment of dowry and as an insurance against crop failure (Namonje-Kapembwa *et al.* 2019). They are perceived to be able to manage themselves and are therefore released to graze freely in and around the farmland during daylight with little or no attention.

According to the Ministry of Fisheries and Livestock (2024), the major constraints faced by goat farmers in 2023 were diseases (37.4%) followed by theft (11.1%). Other constraints (16.4%) include inadequate feed and water, inadequate access to breeding technology, loss of animals to predators and limited access to veterinary drugs/vaccines (Ministry of Fisheries and Livestock 2024). Mange was the major disease reported to affect goats by households in 2023 at 20.5%, followed by heartwater at 17.8%. A survey conducted in the Gwembe district in 2014 showed mange, heartwater, helminthiasis, pneumonia and orf as the most common diseases/conditions reported by goat farmers, mange being the disease ranked as most important (Chembe *et al.* 2014; Fischer *et al.* 2020).

The lack of knowledge in goat management and disease control is high among goat farmers in Zambia. The reason to the limited knowledge being a perception of that small animals require minimal management and the limited access to extension services from the veterinary offices (Namonje-Kapembwa *et al.* 2019). In a survey conducted between 2012 and 2015 by Namonje-Kapembwa *et al.* (2019), less than 50% of households that reported disease incidents did not treat their animals and according to the Ministry of Fisheries and Livestock (2024), tick control was only used by 49.6% of livestock raising households in Zambia in 2023.

Healthy animals ensure social, economic and ecological sustainability (Rushton *et al.* 2017). Diseases affecting animals may have constraints on agricultural development, poverty alleviation, livestock productivity and human well-being. The impact of animal diseases is likely to be proportionally greater for the poor as their capacity to cope with diseases is smaller (Perry *et al.* 2002). Mortality rates in low-income countries are 3-10 times higher than in high-income countries (Pradère 2014). Factors such as poor housing, multiple species and poor nutrition as well as poor disease control in the country, enhances the risk of disease exposure (Perry *et al.* 2002). Infectious and parasitic diseases are major challenges for small ruminant production as they can cause major economic losses due to animal mortality and high treatment costs (Al-Assaf 2012). Zoonotic diseases present a particular risk to resource-poor livestock producers (Rushton *et al.* 2017) and the risk of multiple zoonotic infections is higher at the lower end of the income scale (Perry *et al.* 2002).

2.3 Contagious skin diseases in goats

2.3.1 Mange

Aetiology

Mange is a form of allergic dermatitis caused by mange mites (subphylum Chelicerata: subclass Acari: class Arachnida) (Bates 2012c) and hundreds of species of wild and domestic animals can be affected by the disease (WOAH 2022). In small ruminants, the most common genera of mites causing mange are *Psoroptes*, *Chorioptes*, *Sarcoptes* and *Demodex* (Bates 2012c). Other genera of mange mites that can affect small ruminants are forage mites and *Psorobia*. Mange mites can be divided into two groups: subsurface (burrowing) and surface (non-burrowing) mites (Jacobs *et al.* 2015). Most cases of mange occur between September and April in the northern hemisphere and between April and July in the southern hemisphere (FAO 2004).

Life cycle

For almost all mange mites, the life cycle is completed on the host. The life cycle of mange mites includes four developmental stages: egg, six-legged larva, eight-legged nymph (one to three instars), and the eight-legged adult (Baker 1999 see Bates 2012c). The female mite lays one egg at a time, but with a short generation time, 10-14 days for *Sarcoptes* spp. (Mellanby 1972 see Bates 2012c), 3 weeks for *Chorioptes* spp. (Sweatman 1957 see Bates 2012c) and 4-5 weeks for *Psoroptes* spp. (Bates 2012c), infestations can build up fast (Jacobs *et al.* 2015). The three-week life cycle of *Demodex* spp. (Jacobs *et al.* 2015) includes a hexapod larva with short legs, a hexapod protonymph, an octopod deuteronymph and the adult (Baker 1999 see Bates 2012c). For most mange mites affecting small ruminants, the male transfers sperm directly to the female.

Transmission

Due to the complete life cycle on the host, the transmission is mainly by direct contact between hosts (Jacobs *et al.* 2015), such as contact at mating, grooming, playing, close contact during feeding and sleeping, at markets or in livestock lorries (Bates 2012c). For *Psoroptes* spp., the transmission can also be indirect, through contact with residual mites in the environment, due to their relatively long survival time off the host (Bates 2012c).

Psoroptes

Aetiology

Mites of the genus *Psoroptes* are non-burrowing mites, that prefer to dwell in the ears and on other body regions of herbivores (Bates 2012c). *Psoroptes ovis*, is causing a disease known as 'sheep scab', that is the most severe form of ruminant mange. The severity of the disease in ungulates seems to vary according to the variant of *P. ovis* present (WOAH 2022). Infestation of *P. ovis* in goats is sparsely documented. In studies investigating the host preference of *P. ovis*, no clinical signs were seen on goats herded together with infested sheep, concluding the possibility of mites migrating to cryptic sites such as the ear canals (Meintjes *et al.* 2002) where they cause symptomatic but often asymptomatic psoroptic mange (Amorim *et al.* 2015).

Psoroptes ovis is most common during the winter months, from September to April in the northern hemisphere, but some cases have been seen on full fleeced or poorly shorn animals even in the summer months (Bates 1991a see Bates 2012c). Maximum survival is seen at high humidity and low temperature (Smith *et al.* 1999 see Bates 2012c). Increased temperature will decrease the survival of *P. ovis* and *P. cuniculi*. By removing the microclimate, the progress of the disease is arrested either temporarily or permanent since the mites get exposed to dehydration (Bates 1991a see Bates 2012c). *Psoroptes ovis* can on highly infested sheep migrate to 'latent sites' (i.e. the face, tear glands, foot or scent glands between the hoves, ears, inguinal pouches and the crutch), more often in the winter than summer in sheep (Spence 1949 see Bates 2012c). The hair coat of goat breeds might not be suitable for colonization by *Psoroptes ovis* considering the microclimate needed for mite survival (Graham & Hourrigan 1977 see FAO 2004). The survival time off the host can be up to 16 days depending on several environmental factors (O'Brien *et al.* 1994).

Psoroptic mites can also present with a subclinical infestation exclusively in the external ear canal in sheep and goats (Bates 1992a see Bates 2012c). Psoroptic otoacariasis in goats is caused by *P. cuniculi* (Bates 1992a see Bates 2012c) and is seasonal, with the highest infestation during the winter months in the northern hemisphere (Heath *et al.* 1989 see Bates 2012c). During the summer months, the external ear canal was shown to work as a cryptic site for the mites and could only be diagnosed post-mortem (Spence 1949 see Bates 2012c). In a goat herd, the highest infestation of *P. cuniculi* is seen in young individuals and in rams (Bates 1992a, Bates 1996a see Bates 2012c).

P. ovis and *P. cuniculi* have been proposed to belong to the same species and to be phenotypic variants of the same species, where *P. cuniculi* acts as a commensal of the ear canal and *P. ovis* as a pathogenic agent (Zahler *et al.* 1998; Bates 1999).

Pathogenesis

Psoroptic mites graze the moist periphery of the lesion and feed on serous exudate, skin secretion and lipids (Bates 1991b see Bates 2012c). Allergens from mite fecal pellets initiate an allergic reaction in the skin where the inflammation forms a microclimate of heat and humidity that enables mite survival and the leakage of serous exudate acts as nutrition substrate for the mite (Rafferty & Gray 1987 see Bates 2012c). As the host scratches the inflamed skin and the mite pierces the skin with its mouth, skin integrity is compromised. Breakage results in leakage of serum which initiates scab formation and skin thickening.

Morphology

Psoroptic mites (Figure 1) have an oval shaped and dorsoventrally flattened body, and the cuticula is striated with scattered setae and no spines (WOAH 2022). The legs are long (WOAH 2022) and the mouthparts prominent and capable of piercing and scraping the skin (Rafferty & Gray 1987 see Bates 2012c). Females can measure 550-750 µm, have four long and 16 short setae dorsally, an inverted U-shaped midventral ovipore and an anterodorsal cuticular plate behind the mouthparts (WOAH 2022). Males are smaller (about one-fourth), have two terminal posterior lobes bearing setae, a pair of adanal suckers posteroventral and a larger posterodorsal cuticular plate behind the mouthparts. The anterior two pairs of legs are thicker than the rest and pretarsal suckers are found on leg I and II in both sexes and on leg IV on the female and leg III in males. Psoroptic mites are pearly white in color.

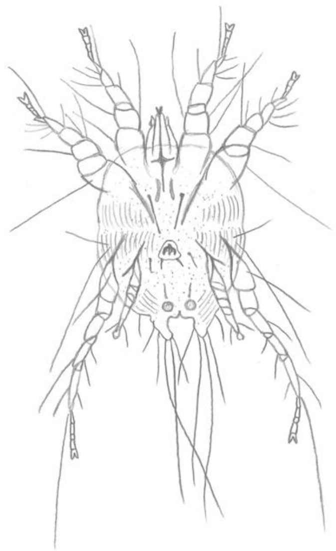

Figure 1. Psoroptes cuniculi *(Psoroptidae). Male, ventral view. (Adapted from Pritt* et al. *2012).*

Clinical manifestations

Infestation with *Psoroptes ovis* can lead to pruritic scab formation primarily on the woolly areas of the body (Spickler 2009). Infestation does not always lead to wool loss as some sheep might only present with dense matted fleece and be excessively covered in scab lesions. On the body, most lesions occur mainly from the neck to the mid-back but can also be found above the forelegs. Most animals are generally asymptomatic in early subclinical cases. Signs of infestation include rubbing against posts, stained areas of wool, head tossing, deranged or matted fleece and restlessness. In the later stages, the animal becomes more excessive in head tossing, scratching and alopecia. Sheep may also show a hypersensitivity reflex when being touched.

Caprine psoroptic otoacariasis (*P. cuniculi*) is generally subclinical, with no severe clinical signs other than occasional individual ear scratching (Munro & Munro 1980; Heath *et al.* 1983; Bates 1992a see Bates 2012c). Severe signs may include head shaking, ear twitching, head tilt, walking in circles and recumbency (Cook 1981; Lofstedt *et al.* 1994; Odiawo & Ogaa 1987 see Bates 2012c). The external ear canals can be plugged with brown, thick scab (Odiawo & Ogaa 1987 see Bates 2012c). Infestation can also spread to the body of old or debilitated animals, presenting in hair loss, lesions and pruritus (Munro & Munro 1980; FAO 2004; Bates 2012c).

Chorioptes

Aetiology

Mites of the genus *Chorioptes* infest the body surface and sometimes the ears of herbivores (Bates 2012c). There are two types of species infesting goats: *Chorioptes bovis* and *Chorioptes texanus*. The condition is generally less severe in goats than in cattle and sheep, and less severe than psoroptic or sarcoptic mange (Vercruysse *et al.* 2006). Chorioptic mites are surface (non-burrowing) mites, meaning they do not pierce the skin (Sweatman 1957 see Bates 2012c).

Chorioptic mange in goats are most common between February and March in the northern hemisphere but can be found throughout the year (Yeruham *et al.* 1999). In sheep, the survival time of *C. bovis* of the host can be up to 69 days (Liebisch *et al.* 1985 see Bates 2012c) and the prevalence of chorioptic mange is highest in young rams (Heath 1978 see Bates 2012c).

Pathogenesis

Chorioptic mites have chewing mouthparts and feed on debris and cutaneous scales on the surface of the hosts skin without piercing the skin (Barbet 2014; Sweatman 1957 see Sargison *et al.* 2000). Like *Psoroptes* spp. mites, they cause an allergic dermatitis initiated by themselves or mite by-products, resulting in lesions on the skin (Sweatman 1957 see Bates 2012c). The eggs are laid inside skin debris (Barbet 2014).

Morphology

Morphologically, the two species of *Chorioptes* are nearly identical in all stages (Baker 1999 see Bates 2012c). Adult *Chorioptes* spp. (Figure 2) are round, dorso-ventrally flattened and with a striated cuticula (WOAH 2022). The female is 400 µm long and the male is one-fourth smaller. Both sexes have anterior and posterior cuticular shields dorsally, short setae and a mouthpart adapted to feed on skin debris. The legs are moderately long and robust, except the third and fourth pair in the female which are slenderer and the fourth pair in the male which are shorter. All legs terminate in empodial suckers except for the third pair in females which ends in two long setae, and the third pair in males which ends in a pair of adanal suckers and a seta each. *C. bovis* has a nearly rectangular margin of its lobes with a long and whip-like seta and two shorter spatulate setae whereas the lobes of *C. texanus* are more angular with two longer spatulate setae.

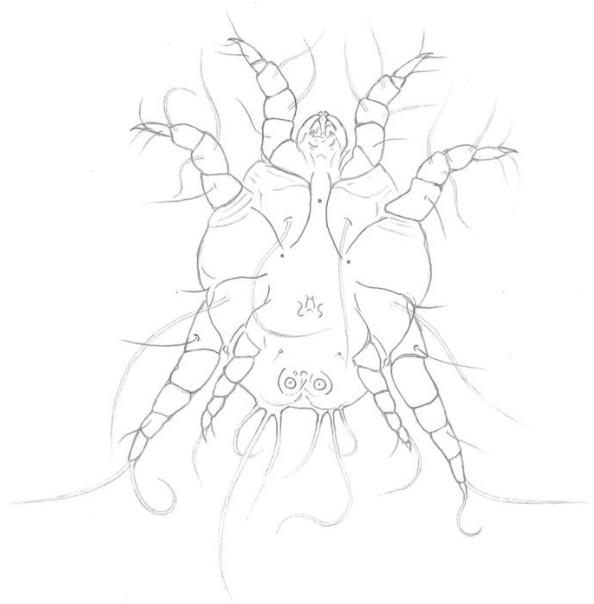

Figure 2. Chorioptes bovis *(Psoroptidae). Male, ventral view. (Adapted from Rehbein & Visser 2024).*

Clinical manifestation

Infestation with *Chorioptes* spp. tends to concentrate on the lower portions of the body (Bates 2012c). *Chorioptes bovis* typically affects the forelimbs with crusting found along the coronary borders of the outer hoof (Kirkwood & Littlejohn 1970 see Bates 2012c). In goats, lesions can be found on the coronet, in the interdigital cleft, muzzle, udder, scrotum and tail region (Kusiluka & Kambarage 1996). Other clinical signs of infestation are restlessness, foot stamping, itching, rubbing and scratching resulting in alopecia. Even at high infestation, most animals might not present with noticeable lesions or discomfort, indicating an asymptomatic disease (Mullen & O'Connor 2019). *C. texanus* can in some cases also infect the ears of the host (WOAH 2022).

Sarcoptes

Aetiology

Mites of the genus *Sarcoptes* are obligate, subsurface (burrowing) mites affecting sparsely haired parts of the body (Bates 2012c). Only one type of *Sarcoptes* species has been shown in studies; *Sarcoptes scabiei* (the itch mite), causing scabies in humans and mange in a wide range of wild and domestic animals (including goats; *Sarcoptes scabiei* var. *caprae*) throughout the world.

Sarcoptic mange in goats is most common in the winter and spring, in males (López-Olvera *et al.* 2015; Valldeperes *et al.* 2019) and in young animals (Bates 2012c), as well as during the following months after the wet period (Perez *et al.* 1997). The survival and reproduction of the adult mites are favored by low temperatures and high humidity and more severe lesions can be seen during this period (Valldeperes *et al.* 2019). Female Iberian ibexes have been shown to have lower mange prevalence and better body condition than males when infested by sarcoptic mange (López-Olvera *et al.* 2015). Survival time off the host under moderate conditions is about 10 days or less depending on the environmental conditions (WOAH 2022).

Pathogenesis

Sarcoptic mites excavate into the horny stratum corneum of the skin and feed on cells and fluid from the germinal layer of the skin (Purcherera & Boulakroune 1986 see Bates 2012c). Females can be found at the end of burrows and their single eggs can be found in the burrows (Mellanby 1972 see Bates 2012c). When the egg hatches, the larvae extend out onto the surface of the skin where it feeds and shelters in hair follicles. The larva then develops into two nymphal stages, starting to make short burrows, before developing into adults, either male or female. Mating occurs on the skin, thereafter the adult female makes a permanent burrow where eggs are laid before she dies.

Morphology

Adult *Sarcoptes* spp. (Figure 3) are round, dorsoventrally flattened (WOAH 2022), have two pairs of short legs both anteriorly and posteriorly and are 200-600 µm by 150-400 µm in size (Bates 2012c). Its cuticula is striated, the palps are one-segmented, pegs and setae vary between individual and tooth-like spines can be seen dorsally (WOAH 2022). Pre-tarsal suckers are found on leg I and II in both sexes and on leg IV in males. Males are smaller than females with smaller and a reduced number of tooth-like spines.

Figure 3. Sarcoptes scabiei *(Sarcoptidae). Female, ventral view. (Adapted from Niedringhaus* et al. *2019).*

Clinical manifestation

Infestation with *Sarcoptes scabiei*, can in goats present with itching, inflammation, exudation, papules, partial or complete alopecia, scabs and crusts or thickened and wrinkled skin because of the excavation of the mites on the surface of the skin that causes irritation (Christodoupoulos 2006 see Bates 2012c). Proliferation of the connective tissue occurs if left untreated resulting in hyperkeratosis and the affected area is often covered in thin white scabs. *Sarcoptes* spp. are usually found on sparsely haired parts of the body and areas mostly affected with alopecia are the medial aspect of the rear limbs, axillae, brisket and abdomen, extending to the trunk, udder and teats (Kusiluka & Kambarage 1996).

Demodex

Aetiology

Mites of the genus *Demodex* are worm-like, subsurface mites with short legs, spending their entire life in hair follicles and sebaceous glands (Bates 2012c; Jacobs *et al.* 2015). *Demodex* spp. is found on all domestic animals but is strictly host specific. There is only one type of species affecting goats: *Demodex caprae* (Bates 2012c). Certain goat breeds, such as the Saanen, tend to be more sensitive to *D. caprae* than other breeds (Mullen & O'Connor 2019). Demodectic mites cannot survive off their host for more than a few hours (WOAH 2022).

Pathogenesis

Demodectic mites invade the hair follicles were they feed on cells (Nutting 1976). As the mite invades the follicle, the cells are destroyed resulting in epithelial cell shedding, depilation and if bacteria are present, formation of papules and nodules. The invation into the hair follicles is followed by mite reproduction and hyperplasia of the follicular epithelium.

Morphology

The adult *Demodex* is cigar-shaped (Figure 4), with four pairs of short legs composed in three segments each (Jacobs *et al.* 2015; WOAH 2022). Adults are 250-850 µm long and have short anterior mouthparts with two-segmented palps and retractable needle-like stylets used to pierce the skin of the host (WOAH 2022). Their needle-like digits are used to push through the epithelium and the mite can then feed by sucking out the content of the underlying cells (Bates 2012c). The mite has a very thin cuticle, no setae and the opisthosoma is usually transversely striated (WOAH 2022).

Figure 4. Demodex caprae *(Demodecidae). Adult, ventral view. (Adapted from Zhao* et al. *2013).*

Clinical manifestation

Small numbers of mites can be carried by most animals as commensals on the skin, without the animals showing any clinical signs (Jacobs *et al.* 2015). Healthy animals almost never suffer from demodectic mange (WOAH 2022). Large infestation with *Demodex* spp. can in goats present with papules containing mites, usually on the face, neck, axillary or udder, but the whole body can be involved in severe cases (Mullen & O'Connor 2019). If the papules contain pyogenic bacteria, the mites can multiply within resulting in large nodules up to 4.0 cm in diameter that are easily palpable on the skin. If the nodules rupture, transmission of mites between goats can occur via exudate release. Severe infestation can also present with thick and scaly skin and alopecia. The animal may itch, rub and lick the area of lesions.

Diagnostics

The diagnosis of mange mite infestation can be done either direct or indirect (Bates 2012b). Direct diagnosis involves isolation and identification of the ectoparasites, while indirect diagnosis is based on the detection of antibodies produced by the host after being exposed to the parasite(s). The most apparent signs of mange are hair loss and crusty or scaly skin (WOAH 2022). Animals with clinical signs of mange should be isolated and examined thoroughly for skin lesions through palpation of the skin (Bates 2012b). *Psoroptes*, *Sarcoptes* and *Chorioptes* are all capable of producing a palpable scab lesion, whereas *Demodex* presents with smaller nodules. Palpable lesions are most likely in areas of matted, licked, chewed or dirty hair, usually in the predilection sites of possible ectoparasites or in areas of alopecia. Mites are in most cases located around the moist edge of the lesion, at the lowest point on the extremities where skin lipids naturally gravitate or furthest away from the head on the back of the animal (Bates 2009a see Bates 2012b).

In most cases, it is necessary to take skin scrapings to confirm the diagnosis of mange (Bates 2012b). Before skin scraping, the area should be clipped as close to the skin level as possible. For *Psoroptes ovis*, the skin scraping should be taken from the moist edge of the lesion and for sarcoptic mange, the scrapings should be taken from a hairless area or an area where nodules and pruritus are seen. For other mange mite species, the scraping can be done anywhere on the lesion (Bates 2012b), preferably where thick, crusty flakes are seen (Kettle 1995 see WOAH 2022). For surface mites, scrapings should be taken with the scalpel blade held at an acute angle, whereas for the subsurface mites, scrapings should be taken with the scalpel blade held at a right angle and the skin scraped until it oozes blood (Bates 2012b). Before the skin is scraped, a drop of liquid paraffin or glycerin can be placed on the skin or scalpel blade (Smith 1988 see Bates 2012b). For demodectic mange, mites can be found in the content of a pustule. Skin scrapings should be collected in small secure tubes or in sealable transparent plastic bags (Bates 2012b). After sampling, the scrapings can be stored at +4˚C for a few days.

In severe cases of sarcoptic mange, where lesions are present on the entire body and no leading edge is located, the mites may be in the regressive phase of infestation (Bates 2009a see Bates 2012b). Examination of the cryptic sites such as external ear canals, interdigital fossae, crutch or perineum may reveal mites in situ. For detection of ear mites or mites located at cryptic sites such as ear canals, an otoscope can be used for visualization and a cotton swab can be used to collect material for examination (Bates 1996a,b see Bates 2012b; Kettle 1995 see WOAH 2022).

An initial examination of the skin scraping under a dissecting microscope with overhead lighting can be done before any additional preparation, revealing obviously visible, alive and moving mites (Kettle 1995 see WOAH 2022). *Demodex* spp. may be embedded in oil and exudate and can be examined directly with a compound microscope after placing a small amount of material and some immersion oil or glycerin on a microscopic slide. Skin scrapings that contain dead mites or large amounts of scabs or hair, should be processed further by mixing the collected material with a 10% potassium hydroxide solution that can digest keratin without damaging the cuticle of the arthropods (Tiffin *et al.* 2020). After incubating the sample with potassium hydroxide solution, the slide can be examined under a compound microscope for the presence of mites.

The visual sensitivity and specificity of sarcoptic mange in Iberian ibex has been shown to be 87.15 and 60.71% respectively (Valldeperes *et al.* 2019). The probability of false negative diagnosis was 5.26 higher during the dry period compared to the wet season, hence the sensitivity was significantly higher during the wet period (92.01%) than in the dry (73.44%) ($p < 0.01$).

Examination of skin scrapings using microscopical techniques has a low to medium sensitivity (Meleney & Christy 1978 see Bates 2012b). A study on *Psoroptes ovis* found that the diagnostic sensitivity of skin scrapings can range from 18.2 and 66.7% depending on occurrence and severity of clinical signs, in contrast to the sensitivity in ELISA which can vary between 54.5 and 100% (Ochs *et al.* 2001). Skin scraping can be time consuming if the individual presents with subclinical lesions that need to be located and be inadequate in the diagnosis if small numbers of mites are present (Meleney & Christy 1978 see Bates 2012b). The quality of the skin scraping is directly related to the experience of the sampler (Bates 2009a see Bates 2012b).

Prevention and control

Chemicals used for control of ectoparasites are called ectoparasiticides and acaricides are ectoparasiticides used for acari (mites and ticks) (Bates 2012a). Which choice of ectoparasiticide to use and which method of control to use is dependent on accurate identification of the ectoparasite, ectoparasite resistance, effects of the treatment on other ecto- and endoparasites, effects on the environment, government policy, the use of the animal (meat, milk, breeding etc.), the size of the herd, whether the doe is pregnant or lactating, availability of facilities, weather and presence of other parasites (Bates 1993 see FAO 2004; Bates 2012a).

Methods for control include suppressive treatment, ad hoc or opportunistic treatment, curative treatment and strategic treatment (FAO 2004). Suppressive treatments are carried out towards eradication by treating the animal at short intervals to eliminate all the parasitic stages. This method increases the risk of acaricide resistance. In ad hoc or opportunistic treatments, farmers implement antiparasitic treatments and routine preventive procedures with general management practices such as weaning, dehorning or change of pastures. Curative treatments are performed when animals are showing clinical signs of mange and strategic treatment is performed before an expected increase in the number of mites as well as during subclinical mite infestation.

The choice of application of the acaricide depends on the management system and size of the herd (FAO 2004). Small-scale farmers might achieve control by using pour-on formulations or spray whereas medium to large-scale farmers might use dips or injectable formulations. The application method should be economically favorable, easy to apply, leave sufficient residual effect, not select for resistance and have minimal toxicological effects on animals and humans. Non-saturation methods such as spot-ons, pour-ons, injections, oral drenches and constant release capsules are more coveted by goat farmers in arid areas where saturation methods may not be possible due to scarce water supply (Bates 2012a).

There are several products available for the control of ectoparasites in goats, with various spectrum of activity. Synthetic pyrethroids (SPs) such as permethrin, fenvalerate, flumethrin, deltametrin, cypermethin and alphacypermethrin, are available as plunge dip formulations, pour-ons and spot-ons (Bates 2012a). They have a high selectivity and toxicity to arthropods (being active against both insects and arachnids) and are relatively safe to mammals (Miller 1988). Plunge dips containing SPs are more efficient than pour-on formulations (Bates 1993 see FAO 2004). Organophosphates (OPs) such as malathion, trichlorfon, diazinon and phoxim, are other ectoparasiticides effective against ectoparasites, but with a high toxicity to humans (Bates 2012a). Amidines such as amitraz, which is the commonest member of this group, has been shown to be effective against mites of the genuses *Sarcoptes*, *Psoroptes* and *Chorioptes* (Curtis 1985; Muñoz Cobénas *et al.* 1978 see FAO 2004). Amidines are very expensive and the dipwash must be stabilized using calcium hydroxide (Bates 2012a). Macrocyclic lactones (MLs) such as avermectins (ivermectin and doramectin) and milbemycins (moxidectin) have a broad spectrum anti-parasitic activity, including mites (FAO 2004), but with a relatively long withdrawal period (Bates 1993 see Bates 2012a). Ivermectin offers little or no residual protection against reinfestation whereas moxidectin has shown to both cure and provide residual protection against reinfestation for 28 days (Parker *et al.* 1999; O'Brian *et al.* 1996 see Parker *et al.* 1999). MLs can be formulated as oral drenches, intramuscular or subcutaneous injections, pour-ons or spot-ons, shower or plunge dips and automatic or hand jettings as well as constant release capsules (Bates 2012a). MLs are also effective against nematodes and are therefore referred to as endectocides since having efficiency against both internal and external parasites (Bates 1993 see Bates 2012a). ML injections are quicker and safer to use compared to plunge dips.

Psoroptes ovis is most effectively treated by ML injections (Bates & Parker 2007 see Bates 2012a). In sheep, a single subcutaneous dose of ivermectin (300μg/kg body weight) or moxidectin (2%) is effective against *P. ovis*. Clinical trials have shown that two dippings 10 days apart, with a 12.5% formulation of Amitraz, is 100% effective against *P. ovis* (Curtis 1985; Muñoz Cobénas *et al.* 1978 see Bates 2012a). In goats, *Psoroptes* spp. is most effectively treated with a single subcutaneous dose of ivermectin (600μg/kg body weight) or a topical application of deltamethrin (2%) (Mohanambal *et al.* 2022). Psoroptic ear mites are most effectively treated by a systemic injection of ML as topically administered acaricides will not be able to deliver an effective dose to the ear canal (Bates 2012a).

Chorioptes bovis has successfully been eradicated from goats by a single topical dose of the Amidine amitraz (0.05%) and the SP fenvalerate (0.05%) (Wright *et al.* 1988 see Bates 2012a). The use of ML as treatment against *C. bovis* may be limited by the mite feeding behavior (Sargison *et al.* 2000).

Ivermectin in injectable form has been used successfully in the treatment of sarcoptic mange in domestic species (Manurung *et al.* 1990; Zamri-Saad *et al.* 1990). A single subcutaneous or intramuscular injection of ivermectin at a dose of 0.4 mg/bw was effective against sarcoptic mange in Spanish ibexes (León-Vizcaíno *et al.* 2001). Eradication of mites of the species *Sarcoptes scabiei* using ivermectin, is dependent on the severity of the infection (Munang'andu *et al.* 2010).

Demodex spp. in goats has effectively been treated with the macrocyclic lactone avermectin (Strabel *et al.* 2003).

The problem of acaricide resistance is a serious concern globally (Küntüz *et al.* 2023). In mange mites, resistance to acaricides is present in *Psoroptes ovis* and *Sarcoptes scabiei*. The rate and probability of resistance development can be decreased by using less frequent applications of acaricides (FAO 2004; Küntüz *et al.* 2023).

In case of detection of ectoparasites, all animals in the herd should be considered infested and the whole herd should be treated regardless of clinical signs visible or not as others can carry subclinical disease (Bates 2012a). All treatments should be administered according to the manufacturer's instruction, injection requires accurately weighted goats and dip baths should be calibrated before use. Isolated animals should not be released back to the herd before the treatment is complete and clinical signs are still present. Treatment is most effective if given during the "cryptic phase" (where mange mites migrate to cryptic sites) using macrocyclic lactones as they will eliminate the source of infection for the next season (FAO 2004).

In Zambia, mange is prevented and treated by dipping in amitraz (also known by the brand names of Triatrix and Dazzel) or by injection of an antiparasitic drug like doramectin (known by the brand names of Doraject and Dectomax) or ivermectin (Els & van Vuuren 2019). In a survey towards goat farmers in the Gwembe district in Zambia conducted by Chembe *et al.* (2014), 74.4% of farmers treated mange using ivermectin alone, 17.9% used acaricides and ivermectin, 4.2% only sprayed their animals with acaricides and 3.2% used either pesticides or applied lemon juice and water to the affected parts of the body. A National Disease Prevention Calendar has been compiled by the Department of Veterinary Services in Lusaka Zambia to improve Animal health (Department of Veterinary services n.d.). In the Central and Southern provinces, farmers are recommended dipping once a week with an intensification (two times a week) in April for both provinces and in November for the Central province.

The risk of introducing mange mites in a herd is reduced through good biosecurity and closed flock policy (Bates 2012d). Newly purchased stock, overwintering stock, borrowed goats returning home or stock returning from the market can carry mange mites into the herd. All incoming stock should be placed in quarantine for a minimum of 4 weeks, examined for clinical signs of mange (animals can carry significant numbers of ectoparasites without presenting with clinical signs) and treated if necessary. The risk of introducing mange mites in a herd is higher if the flock is involved in communal grazing. Therefore, the neighboring properties must work together to attain equal standards of health. The accumulation and spread of mites can be minimized by avoiding overcrowding and maintaining hygiene (Kusiluka & Kambarage 1996). Vehicles and trailers used to transport goats should be thoroughly cleaned and disinfected after use (Bates 2012d). Since many mange mite species can survive off the host for longer periods, transmission to other goats can occur during this period through infected materials in the environment. Protective clothing, cutters, shearing combs that have been in contact with infected animals must be disinfected before leaving the property. Exposed areas on the skin of the handler must be washed with water after contact with an infested animal. After contact, it is advised not to visit any other flock/herd of sheep/goats before taking a hot shower and changing clothes.

Differential diagnoses

Differential diagnoses to mange are other skin conditions caused by allergic, physical or chemical reactions, other types of mites, arthropods such as lice, bacteria, virus or fungus, nutritional imbalance or immune responses (Bates 2012c; Valldeperes *et al.* 2019; WOAH 2022). Bacterial skin conditions include actinobacillosis, clostridial infections, staphylococcal folliculitis and staphylococcal dermatitis. Viral skin conditions include orf (contagious ecthyma, contagious pustular dermatitis, 'scabby mouth'), foot and mouth disease and border disease. Fungal skin conditions include mycotic dermatitis and ringworm. Other non-parasitic skin conditions include allergic reactions caused by flies, photosensitization, skin tumors, alopecia caused by other diseases and sunburn (Bates 2012c).

Epidemiology

The distribution of mange mites affecting small ruminants (*Psoroptes* spp., *Chorioptes* spp., *Sarcoptes* spp. and *Demodex* spp.) is worldwide (Bates 2012c). Mites of the species *S. scabiei* have been recorded in small ruminants in African countries like Tanzania, Mozambique, Uganda and Mali (Kusiluka & Kambarage 1996) as well as in Benin (Salifou *et al.* 2013), Nigeria (Ogundiyi *et al.* 2012; Davou *et al.* 2017), Kenya (Wafula *et al.* 2008), Ethiopia (Seid *et al.* 2016; Mana 2018; Fesseha *et al.* 2021, 2022) and Zambia (Chembe *et al.* 2014). Several studies have been conducted in Ethiopia on the prevalence of *Psoroptes* spp. (Yasine *et al.* 2015; Fesseha *et al.* 2021) and *Demodex* spp. (Seid *et al.* 2016; Mana 2018; Fesseha *et al.* 2021, 2022) in goats. *P. cuniculi* has been recorded in goats in African countries such as South Africa (Shilston 1915 see FAO 2004) and

Zimbabwe (Odiawo & Ogaa 1987 see FAO 2004), and *Chorioptes* spp. has been recorded in goats in Zambia (Chembe *et al.* 2014). To my knowledge, no studies on *P. ovis* have been conducted on goats in Africa.

A review on mange mite infestation in small ruminants in Ethiopia based on 18 cross-sectional studies carried out between 2003 and 2015, showed a pooled animal-level prevalence of 4.4% with a higher prevalence in goats in lowland agroecology (7.3%) than in midland agroecology (5.3%) (Asmare *et al.* 2016). In a study by Mana (2018) in Ethiopia, the overall animal-level prevalence of mange mite infestation in goats were 10.0%, from which 3.65% accounted for *Sarcoptes* spp. and 1.82% accounted for *Demodex* spp.

Mange mites have been recorded in domestic and wild animals across Zambia. *Psoroptes* spp. has been reported in cattle, sheep, rabbits and unspecified hosts (Mwase & Baker 2006). *Demodex* spp. has been recorded in cattle, pigs and dogs and *Sarcoptes* spp. has been recorded in cattle, pigs, goats, water kudu, hartebeest, silver jackal, African buffalo and human (Mwase & Baker 2006; Munang'andu *et al.* 2010; Chembe *et al.* 2014). Sarcoptic mange in goats have been reported in the Southern province (Chesikesi, Mazabuka and Gwembe districts) and in unspecified locations (Mwase & Baker 2006).

A study conducted between December 2013 to March 2014 in the Gwembe district in Zambia revealed mange in 37.6% of goat herds examined (Chembe *et al.* 2014). The district is situated in a drought-prone region of the Southern province. Mites were present in 8.7% (prevalence ranged from 0.8% to 37.3%) of animals with clinical signs sampled by skin scraping followed by digestion in 10% potassium hydroxide for 10 minutes. The most common mange mite species recovered from clinically affected animals was *Sarcoptes scabiei* (96.0%). *Psoroptes* spp. and *Chorioptes* spp. was found in 2.0% of clinically affected goats respectively. The study also found a significantly increased risk of infestation in female goats ($p < 0.05$) and goats in poor body condition ($p < 0.05$).

To my knowledge, no studies on *P. ovis*, *P. cuniculi* or *D. caprae* have been conducted on goats in Zambia.

2.3.2 Orf

Aetiology

Orf, also known as contagious ecthyma, contagious pustular dermatitis, sore mouth and scabby mouth, is a contagious disease affecting primarily small ruminants with a worldwide distribution (Smith 2019). The name Orf originates from the old English language and means "rough" (MacLachlan & Dubovi 2017). It is caused by orf virus, a parapoxvirus from the family *Poxviridae* (Mayr & Büttner 1990). Other diseases caused by closely related virus species of the genus *Parapoxvirus* are bovine papular stomatitis, pseudocowpox, red deerpox and sealpox (International Committee on Taxonomy of Viruses (ICTV) 2024). Parapoxviruses are linear double-stranded DNA viruses with a genome ranging from 134-139 kbp (Delhon *et al.* 2004).

Orf affects primarily domestic and wild ruminants such as goats, sheep, cattle, deer, musk oxen and antelope, but can also affect alpacas, camels and other camelids, dogs, seal squirrels and humans (Azwai *et al.* 1995; Robinson & Mercer 1995; Lawan *et al.* 2021; Spickler 2023), The disease is often more severe in goats than in sheep (McKeever *et al.* 1988). The Boer and Boer cross goats are most likely to attain a severe generalized infection (Spickler 2023). The disease is transmissible to humans, thus a zoonosis (Smith 2019).

The incubation time is short, 2 to 14 days (Smith 2019). The orf virus is very resistant to many environmental conditions and can persist for many years in dried scabs. Though wet conditions are less hospitable for the virus. The disease is seen any time of the year but usually in spring during the birthing season of kids and all ages are affected. However, kids are more susceptible to the disease than adults (Nandi *et al.* 2011).

Transmission

Orf virus is transmitted directly and indirectly by physical contact with a clinically infected animal, subclinical carriers or contaminated material (Lawan *et al.* 2021). The virus can also be transmitted mechanically by the common house fly (Raele *et al.* 2021). The virus can remain stable on the body and in the environment for several months after the affected animal has recovered from the disease (Lawan *et al.* 2021). Subclinical carriers without visible lesions may spread the virus (Lawan *et al.* 2021) and the virus can be transmitted to lambs at birth by infected mothers (Mayr & Büttner 1990). Transmission between species, such as sheep and goats, may occur, but experimental studies have shown no typical disease outcome in interspecies transmission (Smith 2019).

Pathogenesis

The virus enters the host through broken skin barriers or mucous membranes (Mayr & Büttner 1990). After virus multiplication occurs at the site of entry, a primary viremia develops and the virus spreads to other organs such as the lympho-reticular tissue, liver and bone marrow. If the virus replicates in these primary organs, a second viremic phase can occur with systemic distribution. The typical clinical manifestation of proliferative changes in the skin and mucous membranes is a result of viremia and not a primary virus infection. A subclinical and latent form of the disease can occur if the chain of pathogenetic events is interrupted and be reactivated by stress.

Clinical manifestation

Orf is characterized by acute crusting, proliferative lesions, usually on less hairy areas (Smith 2019). In young animals, the lesions are most common on the mucocutaneous junction of the mouth and nose. In older immunologically naive animals, lesions may occur on the udder or teats on does nursing affected kids, the external genitalia, interdigital, at the coronary band or on the conjunctiva of the eye. The labial form is characterized by blisters and pustules on the lips with extension up to the nose, ears and eyelids that with time develop into hard scabs (Mayr & Büttner 1990). In the podal form, changes are usually seen at the coronary edges of the hooves, interdigitally and at the pasterns. The genital form is less common, with crusts and pustules on the udder. Skin changes may also occur on the labia and the prepuce. Depending on the location of the lesions, animals may be reluctant to eat, nurse, be nursed or walk due to painful lesions (Smith 2019). Secondary bacterial infection is common in affected areas. In does, secondary mastitis may develop if severe infection occurs on the teats. Chronic cases and severe infections with stunting in growth have been reported, especially in goats and in younger animals that cannot feed properly (Zamri-Saad *et al.* 1992; Elzein & Housawi 1997; Smith 2019). Stress due to the disease may cause lower milk production, lower weight gain and lower quality of skin and wool (Nandi *et al.* 2011).

The lesions proliferate through stages of macules, papules, vesicles and pustules before encrusting (Smith 2019). After 3 to 6 weeks, scabs fall off and the area usually heals without scarring. During these weeks, the lesions usually undergo six stages: maculopapular stage, target stage, acute stage, regenerative stage, papillomatous stage and regressive stage. Animals that have undergone clinical disease are immune for up to several years after healing (Smith 2019) and serum antibodies can be detected after 15-20 days (Mayr & Büttner 1990).

In humans, the virus causes skin lesions, usually on fingers, hands, forearms and in the face (Hargis & Ginn 2001 see Lawan *et al.* 2021), often associated with pain, fever and pruritus (Maor *et al.* 2017). Transmission to humans is usually seen as an occupational exposure, meaning it is usually seen in people who handle infected animals, such as veterinarians, farmers, members of the family caring for young animals through bottle feeding and butchers (Nandi *et al.* 2011). Transmission between humans is rare (Maor *et al.* 2017).

Diagnostics

In a disease-endemic area, the diagnosis can be suspected in the field on naive animals with typical lesions around the mouth and nose (Smith 2019). Samples are collected by swabbing of lesions, collecting the content of pustules by swabbing or collecting dry crusts (Eriksson 2022). The diagnosis is confirmed by identifying the virus in early lesions with PCR, electron microscopy, immunohistochemistry or inoculation into susceptible animals. The gold standard for isolation and propagation of poxviruses is by cell culture (Hautaniemi 2012). Molecular techniques such as polymerase chain reaction (PCR) are often used for definite diagnosis (Inoshima *et al.* 2000). The genes B2L (major envelope) and VIR (virus interferon-resistance) are used frequently as markers for virus detection. Serologic techniques such as enzyme-linked immunosorbent assay (ELISA) can be used for detection of IgG and IgM antibodies (Hautaniemi 2012).

Prevention and control

As mentioned earlier, the lesions generally heal without scarring after 3 to 6 weeks and are usually in no need for medical treatment (Smith 2019). Due to the disease's self-limitation, the consequences following the disease are minor. Hard crusts should not be removed since it may delay healing and cause scarring. Orf virus produces an array of virulence factors that counteract the host immune response (Martins *et al.* 2014; Yang *et al.* 2014). Because of this, no antimicrobial therapy has proven to be effective as a treatment and control against orf. Treatment usually consists of supportive and asymptomatic treatment (Spickler 2023), but moist dressings and local antiseptics have been used in some cases (Lawan *et al.* 2021). If the animal is presenting with painful dry crusts, softening ointments can be applied to soften the crusts (Eriksson 2022). Secondary mastitis or other secondary bacterial infection is treated with antibiotics, topical disinfectant or other appropriate medication (Spickler 2023). Young animals may need to be bottle-fed if they are unable to nurse due to severe lesions either on the mouth of the kid or on the teats of the doe.

Due to the virus being very persistent in scabs and subclinical animals can be present in the herd, the infection is persistent on the premises and the virus is difficult to eradicate once the disease is established (Smith 2019; Spickler 2023). Prevention and control of the disease involves a good management system as the disease can be difficult to eradicate once it has entered a herd (Smith 2019; Spickler 2023). Management strategies to prevent infection involve nutritious diets based on the physiologic condition of each animal, constant access to water, well-constructed and ventilated housing (Lawan *et al.* 2021). Routine manure removal in the animal's compound and the use of bedding with minimal risk of causing injuries to the animals, such as rough or abrasive material, is key in animal health management. Since flies can spread the virus, insect repellents can be used for further control (Spickler 2023). Early detection of the disease by close observation of the animals is important in controlling the spread of the virus (Nandi *et al.* 2011). In case of infection, the infected animals should be quarantined, farmers and animal handlers should avoid contact with suspected infected animals and precautions should be taken when moving equipment and other materials that have been in contact with the animal from one farm to another, in order to prevent spread of the virus. During treatment and handling, personal protective equipment such as gloves, apron and boots should be used to avoid transmission between animals and humans (Spickler 2023). Limitations in movement of humans and vehicles in and out of the farm should also be practiced (Smith 2019). New arrivals should be quarantined to maintain a virus-free herd (Nandi *et al.* 2011; Spickler 2023). To prevent the spread across borders, strict control by monitoring the movement of animals and animal products should be considered (Nandi *et al.* 2011).

There are various vaccines available that can be used for the control of parapoxviruses (Lawan *et al.* 2021). Although vaccination against orf may reduce the number of animals with lesions, the efficiency of the current vaccines is threatened by the orf virus strain variability and many reports state vaccination failure (Musser *et al.* 2012; Lawan *et al.* 2021; Spickler 2023). Despite this, vaccination against orf with a live vaccine can be used for enhancing herd immunity but the obtained immunity is short (Bala *et al.* 2018; Eriksson 2022). The live vaccine should only be used in persistently infected animal herds and vaccinated animals should not have any contact with unexposed animals until the lesions are healed. The does are usually prioritised for vaccination to minimize the risk of damage to the udder and thereby minimizing the risk of mastitis (Eriksson 2022). For kids, a cell-mediated immunity is protective against the disease since it is seen that colostral antibodies do not have a preventive effect. Subunit vaccines are considered to be a potentially effective approach in vaccine development (Zhao *et al.* 2011).

In Zambia, orf is treated by applying iodine to the affected area daily (Els & van Vuuren 2019). If the animal is presenting with hard crusts, glycerin or vaseline can be applied to soften the crusts.

Differential diagnoses

Differential diagnoses to orf are bluetongue, sheep and goat pox, ulcerative dermatosis (Smith 2019), foot-and-mouth disease and peste des petits ruminants (Calvo *et al.* 2025). Ulcerative dermatosis (UD) can be distinguished from orf by the lesions which are crusted ulcers in UD compared to the crusted proliferations seen in orf (Smith 2019).

Epidemiology

The disease has been reported in goats in many parts of the world including Europe, North America, South America, Africa, Asia and Australia (Lawan *et al.* 2021). Reports on orf virus infections in small ruminants in Africa are available from Ethiopia (Gelaye *et al.* 2016; Tedla *et al.* 2018), Gabon (Maganga *et al.* 2016), South Africa (Scagliarini *et al.* 2012), Nigeria (Obi & Gibbs 1978; Adedeji *et al.* 2017, 2018), Cameroon (Nfi 1991 see Lawan *et al.* 2021), Egypt (Selim 2016 see Simulundu *et al.* 2017) and Zambia (Simulundu *et al.* 2017). In

Cameroon, between 1980 and 1989, the incidence rate of orf infection in goats was 88.5%, with a morbidity of about 80-90% and a higher incidence during the dry season (75%) (Nfi 1991 see Lawan *et al.* 2021). In the Akwalbom state in Nigeria in 2017, an outbreak of orf in goats showed a 100% morbidity and 3.3% mortality confirmed by PCR (Adedeji *et al.* 2017) and in Ethiopia in 2018, 12% of PCR examined goats were positive for orf virus (Tedla *et al.* 2018). Among naive animals, the morbidity is high (often >70%) (McKeever *et al.* 1988; Smith 2019; Spickler 2023). The mortality is low (usually less than 1%), but young animals may quit nursing and die of malnutrition if they have severe lesions around the mouth or have mothers that do not allow nursing due to severe lesions on the teats. Fatal outcomes may also occur due to secondary bacterial or fungal infections.

The first confirmed outbreak of orf in goats in Zambia was described in 2017 by Simulundu *et al.* (2017). The outbreak occurred on a farm in the Makeni area in Lusaka in October 2015. At physical examination, the goats, which were of a local cross-breed, had proliferative skin lesions and scabs mostly around the mouth, gums, nostrils and teats. They also presented with lethargy, generalized lymph node enlargement and emaciation. The whole herd was affected regardless of age or sex. Sampling was done by skin scraping from the lesions of 8 affected goats. Orf virus infection was confirmed by PCR amplification of viral DNA and sequencing of PCR products of the B2L and VIR genes. The orf virus strain detected was closely related to that found in South Africa in 2012. To my knowledge, there has been no studies conducted on orf in other susceptible animal species in Zambia.

2.3.3 The socioeconomic relevance of mange and orf

Mange is a major concern to goat farmers as the disease can seriously compromise the welfare of the animals and the herd (Bates 2012). Factors such as delayed growth, decreased weight gain as well as treatment, production and mortality losses and labor costs due to mange mite infestation, can lead to significant economic damage. Production losses include fatalities and other losses, reduced milk, meat, skin or leather yields, and effects on stock sale. For example, in 2005, the annual loss due to *P. ovis* in the UK was calculated to £8 million (Nieuwhof & Bishop 2005).

Orf is an economically important disease due to its endemicity in goat and sheep herds globally (Bala *et al.* 2018). Painful lesions around the mouth can lead to reduced appetite or anorexia (Spickler 2023) and in cases where the udder or teats are affected, orf may predispose for mastitis which can lead to big economic losses for dairy goat farmers (Simulundu *et al.* 2017). Furthermore, small ruminant farmers may experience economical losses as orf virus infected animals may require veterinary care, the economic impact of the disease cannot be ignored.

In Zambia, where small ruminant production contributes to household income, food security and national economic development, livestock diseases can have devastating effects on farmers who rely on their goats for their livelihood (Simulundu *et al.* 2017). To my knowledge, there is currently no ongoing national control program for contagious skin diseases in goats in Zambia.

3. Material and methods

3.1 Study area and study design

The study was part of an unpublished longitudinal study on climate-sensitive infectious diseases in goats in Zambia. The study was conducted in two selected district in the Southern province of Zambia, namely Chirundu and Lusitu, and in three selected districts in the Central province of Zambia, namely Serenje, Mkushi and Kabwe (Figure 5). Samples were collected in September and October of 2024. The Chirundu district in the Southern province shares international borders with Zimbabwe and the Serenje and Mkushi district in the Central province shares international borders with the Democratic Republic of Congo. The Southern and Central provinces were selected for the study through a stakeholder consultation at the start of the project and the households were selected by snowball sampling (existing study subjects recruit other study subjects). In total, 20 households were included in the study, 10 in the Southern province and 10 in the Central province. The study was conducted during the dry period with a maximum temperature at the time of 37°C in the Southern province and 30°C in the Central province. At the time of the visit in the Central province, heavy rains were experienced during the evenings.

The country was at the point of the study facing an extensive drought resulting in multiple power and water cuts. In the Central province, three households had sold all their goats before the visit due to economic constraints following the drought.

Figure 5. Map of Zambia showing the location of the households sampled in the Central and Southern province. Author's marking of the provinces on a map from https://sv.wikipedia.org/wiki/Fil:Zambia_provinces_named.png with permission to use according to GNU Free Documentation License.

3.2 Study population

To determine the clinical occurrence of contagious skin diseases in goats caused by mange mites and orf virus, the study population included all goats located on the farms included in the study.

3.3 Sample size and sampling method

At each farm in the Southern province, ten goats above one year were randomly selected for clinical examination with focus on the skin for signs of mange and areas around the mouth, nose, teats and feet for signs of orf. As the study is part of a larger research project on climate-sensitive diseases, the sample size was predetermined using the method described by Naing *et al.* (2022), based on the assumption of a 50% prevalence, 95% confidence interval, 5% precision and 80% power. To facilitate the farmers, the same goats were included in this part of the project as in the study on climate-sensitive diseases.

Only goats that showed signs of mange such as areas with alopecia, scaly and crusty skin etc. were selected for sampling by skin scraping. Goats that showed signs of orf such as lesions or scabs around the mouth, nose, teats or feet, were selected for sampling by swabbing of the lesions (eSwab®, 480CE, Copan, Brescia, Italy).

The selection method was revised in the Central province to enhance the possibility of finding clinical cases. Instead of only examining ten randomly selected goats, an overview of the skin health in the herd was conducted at arrival to pinpoint individuals showing an abnormal skin condition. Goats with apparent signs of a contagious skin condition were selected for sampling. Thereafter, goats were as in the Southern province, randomly selected for clinical examination, adding to a total of ten goats per household. If clinical signs of mange or orf were observed at clinical examination, the goat was selected for sampling. If orf was suspected, five randomly selected kids were selected for examination on orf-like lesions.

In the Southern province, the sampling was done in the morning before the goats were released by the farmers from their enclosure to graze. In the Central province, sampling was conducted during the whole day for logistic purposes.

3.3.1 General clinical examination

The skin of the goats was visually examined and thoroughly palpated for mange-like lesions and the mouth, nose, teats and feet were visually examined for orf-like lesions. The sex of each individual examined was recorded. Goats under 1 year of age were categorized as kids and goats over 1 year of age were categorized as adults. Body condition score was recorded on all goats examined, using the system described by Villaquiran *et al.* (2007). The scoring system ranges from 1.0 to 5.0 where a BCS of 1.0 is extremely thin with no fat reserves and a BCS of 5.0 is classified as obese. BCS was determined by the amount of muscle and fat over and around the spinous and transverse process of the lumbar vertebrae.

3.3.2 Sample collection, examination and identification of mange mites

The sample collection was done by skin scraping using a type 24 surgical blade. In the Southern province, skin scraping was done with liquid paraffin and in the Central province without any binding material. Samples were taken from the edges of the affected area and hair and scales were included in the sample. All skin scrapings were taken as deep skin scrapes, meaning scraping was done until capillary bleeding. Scales, hair and the surgical blade were placed in plastic bags or plastic containers. The samples were stored in a cooling box and a refrigerator during the field trip and in a refrigerator at the lab until microscopic examination.

Material, such as hair and crusts, was placed on microscopic slides and labeled by farm and individual. A couple of drops of 10% potassium hydroxide was added to the material on the slides and placed at a heating table at 70˚C for a couple of minutes to immerse the sample (Tiffin *et al.* 2020). Microscopic examination was then done at a magnification of x4 and x10. In cases of mange mite suspicion and identification, a magnification of x40 was used.

3.3.3 Sample collection, examination and identification of orf virus

The sample collection was done by swabbing of visible lesions using an eSwab. Three swabs were taken from areas in the mouth presenting with small papules and lesions. The swabs were stored in a cooling box during the field trip and in a refrigerator at the lab until analysis.

For detection of parapoxvirus, DNA was extracted from the eSwabs followed by Real-Time PCR. DNA was extracted with the GeneJET™ Genomic DNA Purification Kit (K0721; Thermo Fisher Scientific, Vilnius, Lithuania) according to the manufacturer's instructions. In brief, 400 µL of Lysis Solution and 20 µL of Proteinase K solution was added to 200 µL of sample. The sample was mixed thoroughly by vortexing to obtain a uniform suspension. The sample was incubited at 56˚C for 10 minutes with occasional vortexing until the cells were completely lysed. 200 µL of ethanol (96-100%) was added and the sample mixed. The prepared lysate was transferred to a GeneJET™ Genomic DNA purification Column inserted in a collection tube. The column was centrifuged at 6,000 x g for 1 minute. The collection tube containing the flow-through solution was discarded and the GeneJET™ Genomic DNA Purification Column was placed into a new 2 mL collection tube. 500 µL of Wash Buffer I (with ethanol added) was added and the sample and centrifuged at 8,000 x g for 1 minute. The flow-through was once again discarded and the purification column was placed back into the collection tube. 500 µL of Wash Buffer II (with ethanol added) was added to the GeneJET™ Genomic DNA purification Column and centrifuge at ≥12,000 x g for 3 minutes. The collection tube containing the flow-through solution was discarded and the GeneJET™ Genomic DNA Purification Column was transferred to a sterile 1.5 mL microcentrifuge tube. 200 µL of Elution Buffer was added to the center of the GeneJET™ Genomic DNA Purification Column membrane to elute genomic DNA. The sample was incubated at room temperature for 2 minutes, then centrifuged at 8,000 x g for 1 minute and the purification column was discarded. A mastermix containing 10 µL PerfeCTa qPCR Toughmix, 1 µL forward primer, 1 µL reverse primer, 0.2 µL probe and 4.8 µL nuclease-free water, was prepared per reaction (Nitsche *et al.* 2006). 3 µL of template and 17 µL of mastermix was added to a PCR tube. The sample was then run in a Real-Time PCR system (50°C, 10 min; 95°C, 3 min; 45 x [95°C, 3 s; 60°C, 30 s]) using the B2L gene sequence as the target for detection of parapoxvirus.

An additional Touch-down PCR followed by gel electrophoresis was conducted after the Real-Time PCR for confirmation of parapoxvirus using the sequencing primers for HiGC-POX (primers used to identify virus belonging to the genera *Parapoxvirus* and *Molluscipoxvirus*) and LoGC-POX (primers used to identify virus belonging to the genera *Capripoxvirus, Orthopoxvirus, Lepripoxvirus, Suipoxvirus* and *Avipoxvirus*). For the Touch-down PCR a mastermix containing 15 µL PerfeCTa qPCR Toughmix, 0.75 µL forward primer, 0.75 µL reverse primer and 8.5 µL nuclease-free water, was prepared per reaction (Li *et al.* 2010). 5 µL of template and 25 µL of mastermix was added to each PCR tube and the samples run through a Touch-down PCR system (95°C, 5 min; 2 x [95°C, 30 s; 65°C, 30 s; 72°C, 30 s]; 5 x [95°C, 30 s; 63°C, 30 s; 72°C, 30 s]; 5 x [95°C, 30 s; 61°C, 30 s; 72°C, 30 s]; 30 x [95°C, 30 s; 58°C, 30 s; 72°C, 30 s]; 72°C, 10 min; 4°C, ∞). 10 µL of the amplified product was then analyzed on gel electrophoresis at a 135-voltage using a 1.5% gel and a 1000 bp ladder.

3.3.4 Questionnaire

On each farm, a questionnaire in the local language was conducted including questions about the deworming and dipping strategy. As part of the longitudinal study, a questionnaire survey had been conducted by the research team at previous visits to the households. The questionnaire contained questions about constraints in goat farming, dipping strategy etc., and the data was shared by the research team beforehand. Out of the 36 households included in the longitudinal study, 20 households were visited during this part of the study.

4. Results

4.1 Clinical presentation and occurrence of mange and orf

A total of 198 goats were examined for skin conditions associated with mange and/or clinical signs associated with orf from 20 different households. In total, skin scrapings were obtained from 42 goats in 17 different households and eSwabs were taken from 3 goats in one household. The sex distribution of goats examined in the study was 86% females and 14% males and of sampled goats 83% and 17% respectively (Table 1). All goats were of local breed and all goats sampled for mange were over 1 year of age.

Table 1. Description of the goats examined for clinical signs of mange and orf, and goats sampled for mange.

		Total of goats examined for clinical signs of mange and orf (n)	Proportion of total (%)	Total of goats sampled for mange (n)	Proportion of total (%)
Total		198	100.0	42	100.0
Sex	Female	170	86.0	35	83.3
	Male	28	14.0	7	16.7
Age	<1 year	5	2.5	0	0.0
	> 1 year	19	97.5	42	100.0
BCS (on goats >1 year of age)	≤ 2	26	13.0	6	14.3
	2.5	83	43.0	15	35.7
	3	76	39.0	20	47.6
	3.5	5	3.0	0	0.0
	≥ 4	3	2.0	1	2.4
Location	Southern province	98		29	
	Central province	100		13	

The occurrence of mange infestation at herd level was 10% in the Southern pro-vince and 10% in the Central province (Table 2). The mange mite genus found in the Southern province was *Sarcoptes* spp. and the mange mite genus found in the Central province was *Demodex* spp. The major clinical sign of mange on the animals positive at microscopic examination was alopecia of the area sampled (Figure 6). At herd-level, the overall perception of the skin health of the animals was good in all households visited. When examined at a distance, only 1-2 animals per household showed apparent signs of a clinical skin condition and signs associated with mange infestation. The most common clinical signs of a skin condition on the animals examined were dry skin, alopecic patches, and matted fleece apparent on various parts of the body such as the neck, rump, face, ears and on the medial and caudal parts of the legs. Only on the ears of goats sampled, an active lesion could be located.

Table 2. The herd occurrence of mange in the Southern and Central province of Zambia.

Province	Households visited (n)	Positive households (n)	Occurrence (%)
Southern	10	1	10.0
Central	10	1	10.0
Total	20	2	10.0

Figure 6. Back leg with signs of alopecia sampled for mange (a) and Demodex *spp. found at microscopic examination of the area sampled (b). Author's photographs.*

The clinical and diagnostic occurrence of parapoxvirus on herd-level in this study was 10% in the Central province and 0% in the Southern province of Zambia. All goats sampled were from the same herd. One out of three individuals sampled for orf-like lesions were positive for the B2L gene on Real-Time PCR and two out of three individuals sampled were positive for the HiGC-POX PCR on gel electrophoresis (Table 3 and Figure 7). The individual positive for parapoxvirus on Real-Time PCR presented with a small lesion in the mouth (Figure 7). Sequencing of the HiGC-POX PCR product has not yet been performed.

Table 3. Clinical descriptive data and molecular findings of sampled individuals presenting with clinical signs of orf.

ID	Sex	Age	BCS	Clinical signs	B2L PCR	HiGC-POX gel electrophoresis
1	F	Adult	3	Small ruptured pustule containing pus measuring approximately 5 mm in diameter in the mouth, small, dried crusts on the teats	Neg	Neg
2	M	Adult	3	Small proliferative lesion measuring approximately 3 mm in diameter in the mouth	Pos	Pos
3	M	Adult	3	Small intact pustule measuring approximately 3 mm in diameter in the mouth, conjunctivitis, lacrimation	Neg	Pos

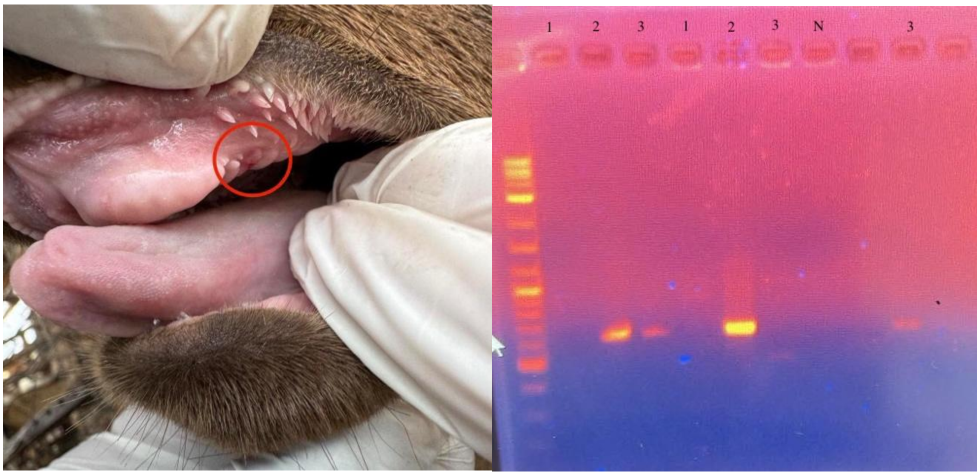

Figure 7. Small lesion in the mouth sampled of the animal positive for parapoxvirus on Real-Time PCR (a) and the result of the gel electrophoresis with wells marked with animal ID and negative sample (b). Author's photographs.

4.2 Questionnaire

Out of the 20 respondents on the questionnaire conducted by the research team in the spring of 2024, 11 reported mange as one of the three most common diseases in the herd. Four of the respondents reported mange as one of the most common diseases during the dry season and one reported mange as one of the most common diseases during the rainy season. Three of the respondents reported mange as one of the main constraints in goat production. One of the respondents reported orf as one of the three most common diseases in the herd and the same household reported orf as one of the most common diseases during the dry season. Other diseases mentioned when questioned about the three most common diseases were Heartwater, liver flukes, pinkeye, pneumonia and Foot and mouth disease, but the majority answered with clinical signs of disease such as circling, worms, abortion, wasting, lameness, coughing, diarrhea, weight loss and loss of appetite, rather than diseases.

16 of the respondents used prevention against ectoparasites and three did not use any prevention against ectoparasites (Figure 8). 15 of the 16 respondents using prevention against ectoparasites used acaricides as external parasite control. Out of the 16 households using prevention against ectoparasites in the last questionnaire, only 10 used preventions against ectoparasites when asked this time, i.e. autumn 2024 (50%). One household that did not use any prevention when asked last time, did by the second questionnaire treat their goats against ectoparasites. On the other hand, 7 households that used prevention against ectoparasites in the questionnaire conducted in the spring of 2024, did not use any prevention when questioned in the autumn of 2024.

The most common substance used for control of ectoparasites when specified was amitraz and the frequency of control ranged between once a week to once a year with the majority dipping once a week (80%). 65% of farmers questioned about dipping and deworming strategy, either used ectoparasite control or used ivermectin for deworming.

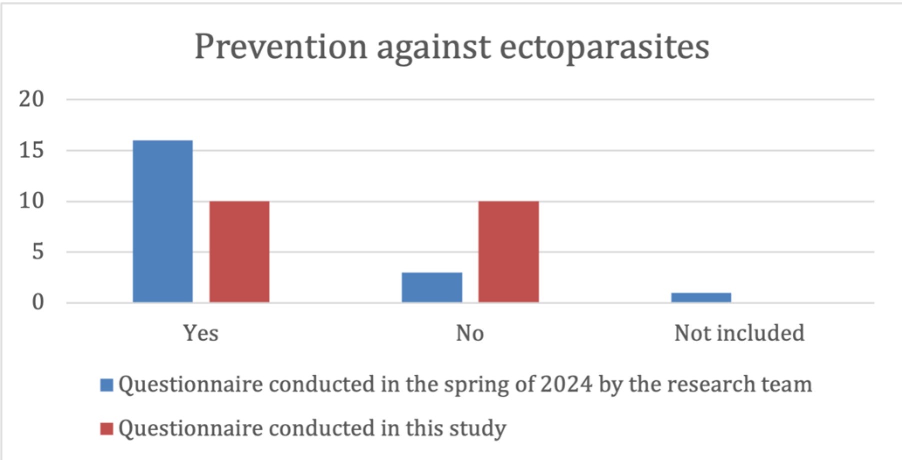

Figure 8. Number of households using prevention against ectoparasites.

5. Discussion

This study investigated the clinical presentation and occurrence of the contagious skin diseases mange and orf in goat herds in Zambia. In this study, the detected herd-level occurrence of mange was 10% in the Southern province and 10% in the Central province. The detected clinical and diagnostic herd-occurrence of orf was 10% in the Central province and 0% in the Southern province of Zambia.

Out of 27 goats sampled with clinical signs of skin conditions in the Southern province, one sample was positive for mange mites, containing a mite egg most likely belonging to the genus *Sarcoptes*, indicating the infestation of this mange mite species on this animal. The sample was collected from an area with alopecia caudally on a front leg. *Sarcoptes* spp. are usually found on sparsely haired parts of the body such as the medial aspects of the rear limbs, axillae, brisket and abdomen (Kusiluka & Kambarage 1996), making the location of the located egg unusual. No scabs, crust, thickened or wrinkled skin, or exudation was present on the area sampled, no active lesion could be located, and no adult mange mites were present at microscopical examination, indicating a mild mange mite infestation.

Out of 13 goats sampled with clinical signs of skin conditions in the Central province, one sample was positive for *Demodex* spp. This sample was taken from an area with alopecia medially on a rear leg. The presence of *Demodex* spp. Indicates the infestation of this mange mite species in this herd. Small numbers of *Demodex* spp. can according to Jacobs (2016) be carried as a commensal on the skin without animals showing clinical signs of infestation but if clinical signs are present, they are usually found on the face, neck, axillary or udder (Bates 2012c). As only one mite of the species *Demodex* spp. was present in the sample and no other clinical signs than alopecia was seen, it is more likely that this individual was carrying *Demodex* as a commensal on the skin. Additionally, the presence of mange mites in this herd can be due to the household not treating against ectoparasites.

The herd-level occurrence of mange in the Southern province (10.0%) was lower than the herd-level prevalence (37.6%) found by Chembe *et al.* (2014) in the Southern province of Zambia between December and March 2014. The higher prevalence can be due to the study being conducted in the wet rainy season where the conditions for mite survival might be more favorable than in the dry season in which this study was conducted. Mange is most common between April and July in the southern hemisphere (FAO 2004) and both sarcoptic and psoroptic mites are favored by low temperatures and humidity (Smith *et al.* 1999 see Bates 2012c; Valldeperes *et al.* 2019). The dry season in both the Southern and Central province of Zambia during this study can therefore be considered as an unfavorable climate for mange mite species.

Sarcoptic mange is according to Bates (2012) and Pérez *et al.* (1997) more frequent during the months following the rainy period in the southern hemisphere, thus explaining why the majority of households questioned about constraints in goat production in the questionnaire conducted by the research team in the spring of 2024, mentioned mange as one of the most common diseases in the herd as the questionnaire was conducted during the most favorable time of the year for mange mites.

The low occurrence can also be explained by the low degree of skin lesions in the animals sampled, especially in the Southern province. There, sampling was done from areas on the skin with a low suspicion of mange as the area looked rather healthy but had mild clinical signs compatible with mange. In the Central region on the other hand, a higher suspicion of mange mite infestation existed on the animals sampled resulting in a smaller sampling size. Mild skin alterations in the animals with mange-like lesions might result in a decrease in sensitivity of the skin scrapings obtained from these animals as the sensitivity increases with the severity of the lesions (Meleney & Christy 1978 see Bates 2012b). Valldeperes *et al.* (2019) found that the probability of false negative diagnosis was 5.26 times higher during the dry period due to the low sensitivity of skin scraping for diagnosis (73.44%) compared to the wet season. This shows the difficulties of correctly diagnosing mange by skin scraping in the dry period. As mites are less active and the lesions are less evident in the dry period (FAO 2004; Valldeperes *et al.* 2019), the sensitivity of skin scraping as a diagnostic tool decreases, resulting in an increased difficulty of detect mange mites in infested animals and correctly diagnose them as positive. Considering this, the low sensitivity in the method used during this season can explain the low occurrence of mange mites located in the goats sampled.

The clinical signs found on the animals sampled for mange were mostly dry skin, alopecia and matted fleece, which not only correlates with mange mite infestation but with other skin diseases such as infestation with other ectoparasites and dermatitis caused by allergic, physical or chemical reactions as well as by bacteria, virus, fungus, nutritional imbalance and immune responses. According to the Ministry of Fisheries and Livestock (2024), 20.5% of the households reported mange as the major disease affecting goats in 2023. Similarly, the stakeholder groups at the workshop held in Lusaka in 2019 mentioned external parasites among the top five health issues in goat production (Fischer *et al.* 2020) and in the questionnaire conducted by the research team in the spring of 2024, 55% of households mentioned mange among the top three most common diseases in the herd. The wide conception among goat farmers of mange being among the top diseases affecting their goats, implicates the disease to be a big problem in goat herds in Zambia. However, as this study shows a low occurrence of mange in goat herds sampled, it is hard to believe the farmers conception of mange being a big problem, especially in the dry season. As other skin conditions can present with similar clinical signs, the conception among farmers is more likely to be based on a combination of different skin diseases. In the questionnaire conducted by the research team in the spring of 2024, almost all farmers answered the question of 'most common disease in the herd' with clinical symptoms of diseases rather than specific diseases, enhancing the possibility of farmers referring to all kinds of skin conditions as mange.

Mange caused by *Sarcoptes scabiei* is more common in males than in females (Valldeperes *et al.* 2019). Only 14% of males were included in the study and only 16.7% of the animals sampled for mange were males. No correlation between mange mite infestation and sex, age or body condition could be drawn from this study due to limited numbers of positive samples as well as individuals sampled. However, the biased sex distribution could have contributed to the low occurrence of mites recorded.

The most common substance used for control of ectoparasites when specified was amitraz, which is the substance recommended in controlling and treating mange in Zambia (Els & van Vuuren 2019). Most farmers used acaricides every week to every second week (80%), which correlates to the recommendations described by the Department of Veterinary services of normal dipping strategy of once a week (Department of Veterinary services n.d.). However, the high frequency of treatment indicates a suppressive treatment approach, which normally is used towards eradication of mange mites. The widespread use of acaricides for ectoparasite control in Zambia collected from this questionnaire is likely to hasten the selection for resistance. As described by Küntüz *et al.* (2023) and the FAO (2004), the rate and probability of resistance development can be decreased by using less frequent applications of acaricides. This can be achieved by using alternative control methods, i.e. those defined as strategic treatments, described by the FAO (2004).

For deworming, ivermectin was the most common substance used by the households visited and the substance is effective against ectoparasites such as *Sarcoptes* spp. and *Psoroptes* spp. Even if ivermectin is effective against both nematodes and arthropods, the dose required for eradication of mange mites is considerably higher than the dose used for deworming (usually 0.2mg/kg bodyweight; see chapter on treatment for the doses recommended against mites). Hence, deworming with ivermectin should not have an effect on goats infested with mange mites, but it cannot be excluded that the underdosing of an effective drug can contribute to the selection for resistant mites.

Many of the farmers did not specify the product used or the choice of application used for controlling ectoparasites. Hence, the information gathered on ectoparasitic control strategies amongst the households visited can be considered incomplete. This can be explained by a miscommunication between parts involved in the questioning and by time pressure during the visits to the households. Additionally, there was an overall perception that many farmers were unsure about which product they used for controlling ectoparasites and lacked knowledge on how to use the product correctly, and therefore gave a random answer to facilitate the veterinarian asking the question (potential response bias). This perception was reinforced when comparing the questionnaires conducted at the two separate visits to the households (the first in the spring, the second in the autumn of 2024) as 8 out of 20 had changed their answer, 7 changing from yes to no. A more detailed description from the farmers on how they executed the method for control and which product and choice of application they used, would have been favorable in determining whether or not the strategy used was effective in controlling ectoparasites. Even if the farmers use the right product and have chosen an effective way of applying the product, the dose and execution of the method can be wrong leading to an ineffective control measure. It would be desirable that each farmer could record, even in a simple and effective way, which kind of treatments are performed on a certain farm (including substance used and frequency of treatment).

The risk of introducing mange mites in a herd is reduced through closed flock policy (Bates 2012d). All farms visited in this study used communal grazing, and in Zambia, where communal grazing is commonly used among farmers (Namonje-Kapembwa *et al.* 2019), the risk of introducing mange mites in a herd is high since the risk of contact between herds is high. As of this, other biosecurity measures are important in reducing the risk of mange mite introduction, such as placing incoming stock in quarantine for a minimum of 4 weeks, avoiding overcrowding and maintaining hygiene.

In this study, one household presented with clinical signs of orf and one out of three samples from this herd was positive for parapoxvirus by Real-Time PCR using the B2L gene as target sequence. As the sensitivity of the Real-Time PCR is high, with an analytical sensitivity of 4.7 copies per assay (Nitsche *et al.* 2006), the negative samples are most likely true negative samples. As parapoxvirus is present in the herd, it is most likely that the samples from the animals negative on Real-Time PCR contained a smaller amount of viral DNA which was not detected in the PCR. In the positive herd, three adults had small pustules in the mouth (measuring approximately between 3 and 5 mm in diameter), one had small, dried crusts on the teats, and one had crusts in the anal area and around the vulva. No sample was taken from the one with crusts in the external genitalia area as she was very sensitive to touch and was released before sampling could be conducted. Although the manifestation was mild, the clinical lesions were found in typical locations associated with orf.

As orf virus affects young animals too, an addition of 5 kids were included in the study on this farm. However, none of the kids examined had clinical signs of orf and no samples were collected from these animals.

Presence of orf virus in goats in Zambia has previously been confirmed in a study conducted by Simulundu *et al.* (2017), where all goats in the herd were affected by the disease regardless of sex or age. Among naïve animals, the morbidity can reach >70% (McKeever *et al.* 1988; Smith 2019; Spickler 2023). Only three out of 15 animals examined in the positive herd in this study had clinical signs of orf, indicating a lower morbidity which can be due to early stages of the disease and a low viral burden in the herd.

In contrast to the Real-Time PCR, where only one out of three samples were positive for parapoxvirus, two samples were positive in the HiGC-POX PCR, including the sample positive in the Real-Time PCR. The second positive sample could be due to contamination from the strong positive sample as no positive control was used. Regardless, orf virus is most likely present in the herd sampled as both clinical signs were present on sampled individuals and at least one sample was positive for parapoxvirus on both Real-Time PCR and gel electrophoresis, but sequencing is required for confirmation. No sequencing of the virus strain present in the positive herd was conducted in this study due to time restrictions.

The disease is according to Smith (2019) seen any time of the year but is usually seen in the spring during the birthing season of kids. In Zambia, the birthing season for goats is usually between July and September (Namonje-Kapembwa *et al.* 2019) but a peak is also seen between February and April (Ahmadu & Lovelace 2002). A higher incidence has been seen during the dry season in Cameroon (Nfi 1991 see Lawan *et al.* 2021).

As for mange, the risk of introducing orf virus in the herd is higher when goats are released to graze freely in and around the households as the risk of contact with other herds from other households increases. The season in which this study was conducted and the grazing strategy used by the farmers, can thereby be considered as favorable for virus transmission.

5.1 Sources of error

The method was revised between the two provinces to enhance the chance of finding positive clinical cases of mange and orf. By conducting an overview of the herd before randomly collecting goats for clinical examination, individuals with apparent clinical signs could be added to the study and thereby increase the chance of correctly identifying infected individuals.

In the Southern province sampling of mange-like lesions was conducted in a rush due to time pressure. As of this, all samples collected might not have been taken deep enough for a deep skin scraping. No hair was in this study clipped over the area sampled, making it harder to retrieve the material as it would easily stick to the surrounding hair. Additionally, the samples were collected in big Ziploc bags making it hard to retrieve the material for transfer to a microscopic slide at microscopic examination. For the second sampling in the Central province, smaller Ziploc bags were used for collecting the samples, facilitating the retrieval of material for microscopic examination.

At microscopic examination for mange mites, material such as hair and crusts were placed at a microscopic slide directly and potassium hydroxide was thereafter added to the sample. On some slides, too much material was added making the sample rather thick and therefore difficult to examine for mange mites. Less material would have been preferred on each slide to simplify the microscopic examination.

As described before, a low amount of collected samples for mange mites could lower the sensitivity of the method used. As of this, more material collected from each animal sampled might have resulted in a higher sensitivity, raising the possibility of correctly identifying positively infested animals.

5.2 Further research

To increase the possibility of finding mange mite infested animals, more animals from each herd should be included in the study, the hair over the area to be sampled should be clipped before sampling and more material should be collected from each suspected animal. Furthermore, less material collected by skin scraping should be placed on the microscopic slide before microscopic examination to simplify the identification of mange mites. Similarly, more goats from each household examined for clinical signs of orf will increase the possibility of finding animals with clinical signs for sampling.

Even if this study found mange mites to be present in goat herds in Zambia, further studies should be conducted on the prevalence of mange and the control strategies used for ectoparasites among farmers in the country. To determine whether the control strategy used is effective in controlling ectoparasites, the study should include data on substance used, how the substance is used and frequency of treatment. Additionally, a following study on the prevalence of mange should be conducted during the rainy period or in the months following the rainy period to investigate the difference in season for mange infestation in the country.

To further investigate the prevalence of orf in goat herds in Zambia, a study on the seroprevalence using antibodies for orf virus, might give a better indication on the distribution of orf in the country.

6. Conclusion

In conclusion, this study confirms the presence of mange in the Central and Southern province and orf in the Central province of Zambia. The herd-level occurrence of mange was lower in this study compared to earlier findings, likely due to the unfavorable seasonal conditions for mange mites, the mild clinical signs present and the limitations in diagnostic techniques during the dry period. The study also highlights the widespread use of acaricides, unclear control strategies against ectoparasites and a possible perception among farmers conflating mange with other skin conditions that present with similar clinical signs. Further research is recommended during the rainy season when conditions are more favorable for mange mites, along with investigations into the effectiveness of ectoparasite control strategies.

The herd positive for parapoxvirus is most likely positive for orf virus but sequencing is needed for definite diagnosis. The mild clinical manifestation and low morbidity observed in this study may indicate early stages of the disease or a limited viral burden in the herd. Dry season and management practices including grazing strategies influences the risk of orf transmission, emphasizing the need for strategic disease control measures. To better understand the distribution and impact of orf in goat populations across Zambia, further research on the seroprevalence of the disease is recommended.

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Popular science summary

Small ruminants, such as goats, play an important role in securing the livelihood of resource-constrained smallholder farmers in low-income countries by contributing to income, social status and food security. In Zambia in Southern Africa, goats can be a significant socioeconomic contribution to farmers in rural communities due to their great ability to adapt to climatic and geophysical changes. Goats are the second most common livestock animal in rural household in Zambia today. Diseases and mortality among goats can have a devastating effect on the livelihood of smallholder farmers, especially for the poor.

Mange is a skin disease characterized by crusting, itching and hair loss, caused by small organisms called mites living on or burrowing into the skin of the animal. The disease can affect all kinds of animals and the organisms can be transferred between animals by contact. The organisms are favored by low temperatures and high humidity. Mange mites are located by taking samples from the skin with a small blade and placing the material collected under the microscope for visualization. The disease is usually prevented and treated with chemicals called acaricides, as well as by limiting contact between infected animals.

Orf is a disease caused by a virus, characterized by painful blisters, lesions and crusts on less hairy areas on the body such as the mouth, nose, eyes, udders or teats, the external sex organs or on the feet. The disease can affect both young and adult goats and sheep and is spread between animals by contact. The disease can be transmitted to humans. The disease is usually seen in spring during the birthing season of kids. The virus is located by swabbing of lesions or collecting dry crusts on the skin. The sample is then run through a PCR machine which is used to detect virus DNA. Lesions generally heal without scarring and the animals are usually in no need for medical treatment. But as the lesions are painful, young animals might need to be tube-fed if they are unable to nurse. The disease can be prevented by limiting contact between infected animals and humans.

Both mange and orf can be a major challenge to goat production as they can cause major economic losses. Mange is one of the major constraints faced by farmers in Zambia today and only a few studies have been done on the occurrence of the disease in goats in the country. Orf has been found to be present in goats in the country in previous studies. With the country now undergoing an intensification in goat production, the importance of investigating diseases in goats increases. The goal of this study was to investigate the occurrence of mange and orf in goat herds in Zambia and to describe the symptoms present in goats affected by the diseases.

The study was conducted in two provinces in Zambia in September and October 2024. A total of twenty households were visited and ten goats in each household were examined for symptoms of the diseases orf and mange. All goats were categorized according to age, sex and body condition. Skin samples were collected from 42 goats with symptoms of mange and swabs were collected from the inside of the mouth of three goats with symptoms of orf. Material collected from the skin was placed in a small plastic bag and stored in a cooling box or refrigerator until microscopic examination. The material was placed on a slide and processed with potassium hydroxide before microscopic examination. The swabs were stored in a cooling box or refrigerator until analysis. Virus DNA was extracted from the swabs and the sample was then run through a PCR machine.

In addition, a questionnaire was conducted including questions about the strategy used for preventing and treating mange. Another questionnaire survey on the strategy used for control of mange and constraints faced by the farmers had been done by the research team in the spring of 2024 and was shared beforehand.

The study found the occurrence of mange in 10% of herds in the Southern province and in 10% of herds in the Central province, and orf in 10% of herds in the Central province of Zambia. Individuals positive for mange presented with hairless areas on the legs and the individual positive for orf presented with a small lesion in the mouth. The result of the study shows the presence of both diseases in the country.

The low occurrence of mange in this study can be explained by the dry climate in the country at the time of the study as it is unfavorable for the organisms as well as the mild signs of mange on the skin and challenges with the sampling method. The study also found a frequent use of acaricides, the chemical used for preventing and treating mange, unclear control strategies and a possible confusion between mange and other skin diseases. Further research is recommended during the rainy season when conditions are more favorable for mange mites, along with investigations into the effectiveness of the strategies used for preventing and treating mange.

The herd positive for orf is most likely positive for the disease as both symptoms were present on the animals and one sample was positive when run through the PCR machine, concluding the presence of virus DNA, but further analysis is needed for definite diagnosis. The dry season and the management practices used by the farmers in Zambia increases the risk of transmission of the disease, emphasizing the need for further control measures. To get a better understanding of the distribution of orf in goat herds in Zambia, further research is needed on the occurrence of antibodies against the disease.

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