Bovine trypanosomosis prevalence at the edge of Hluhluwe-iMfolozi Park, KwaZulu-Natal, South Africa

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The northern KwaZulu-Natal (NKZN) region of South Africa is the southern limit of the African tsetse belt. Entomological information on *Glossina brevipalpis* and *Glossina austeni* was generated following the outbreak of trypanosomosis in cattle in 1990. However, these data have not been supported by parallel studies on epidemiology of the disease and therefore there has been no control policy in place. This study presented the first intensive investigations to address the epidemiology of trypanosomosis in NKZN. Tsetse abundance, trypanosome herd average prevalence (HAP), herd average anaemia (HAA) and herd average packed cell volume (HA-PCV) were investigated at three communal diptanks located at the edge of Hluhluwe-iMfolozi Park by monthly sampling from June 2006 – November 2007. Seasonal trypanosome surveys were conducted at seven other communal diptanks. *Glossina brevipalpis* prevalence was high at two of the diptanks, Mvutshini and Ekuphindisweni, but low at Ocilwane, whilst *G. austeni* was only collected from Mvutshini. This high and low tsetse challenge presented different disease scenarios. Cattle at Mvutshini and Ekuphindisweni had the highest HAP of 12.3% and 8.9% respectively, both significantly different (p = 0.001) from the HAP obtained from cattle at Ocilwane (2.9%). These two cattle herds also had the highest HAA, 27.7% and 33.4% respectively, whilst cattle at Ocilwane had the lowest, 11.1% (p = 0.001). Conversely, cattle at Ocilwane had the highest HA-PCV, ranging between 29.0% and 32.0%, whilst cattle at Mvutshini and Ekuphindisweni had the lowest HA-PCV (24.0% – 29.0%). By combining the data from the three diptanks (1318 observations), 62.0% of the infected cattle were found anaemic, compared to 20.0% in the uninfected group. Trypanosome seasonal surveys showed that cattle at all the seven diptanks were infected with trypanosomes; mean HAP, HAA and HA-PCV of 10.2%, 46.6% and 23.7%, respectively. This study generated information on the epidemiological factors related to the wide spread of trypanosome-infected cattle and tsetse flies. Trypanosomosis is a disease of economic importance impacting the livelihood of resource-poor farmers in NKZN.

Introduction

In South Africa, animal trypanosomosis (also known as nagana) is restricted to parts of northern KwaZulu-Natal (NKZN) Province, covering an area of 16 000 km^2 extending from north of the uMfolozi River to the Mozambique border (Sigauque *et al.* 2000). The disease coincides with the presence of two species of tsetse, *Glossina austeni* and *Glossina brevipalpis* (Diptera: Glossinidae) (Kappmeier 2000). South Africa historically had four species of tsetse flies, namely *Glossina m. morsitans*, *Glossina pallidipes*, *G. brevipalpis* and *G. austeni*. *Glossina m. morsitans* disappeared shortly after the devastating rinderpest epidemic of 1896 that resulted in the removal of most bovid animals. *Glossina pallidipes* was eradicated by 1953, primarily using aerial application of dichlorodiphenyltrichloroethane (DDT). The two so-called minor vectors species, *G. brevipalpis* and *G. austeni*, continue to exist in the thickest coastal bush forest areas that were not suitable for *G. pallidipes* and considered unsuitable for cattle grazing (Du Toit 1954). The introduction of eucalyptus plantations for commercial purposes has been associated with artificial changes in land cover and the plantations, with their surroundings, became protected areas. Thicket expanded considerably after cattle farmers shifted to game ranching, thus increasing the conserved and protected tsetse areas. This man-made habitat resulted in the extension of the distribution and multiplication of both tsetse species, compared to the 1954 distribution maps (Esterhuizen *et al.* 2006).

In 1952, isolated cases of nagana were reported from Zululand, with most cases occurring around Lake St. Lucia, well known for high infestations with *G. brevipalpis* and *G. austeni* (Du Toit 1954). Kappmeier, Nevill and Bagnall (1998) reviewed the nagana situation up to 1990. The authors showed a rise in infections with trypanosomes on a number of farms in the lower Mkuze area. In 1987, an outbreak in the Nibela area was associated with clinical disease and mortalities. In 1990, during a severe drought, about 10 000 cattle died of nagana and 116 000 were treated with ethidium bromide in the low-lying areas of Zululand (Kappmeier *et al.* 1998). Other

control measures included the use of pyrethroid formulations in diptanks to protect cattle against ticks and to reduce the challenge by the vector tsetse fly. These were indications that nagana was not eliminated and the two remaining tsetse species, *G. brevipalpis* and *G. austeni*, continue to play a major role after the eradication of *G. pallidipes*.

Sixteen years after the nagana outbreak in 1990, a once-off sampling of 76 cattle at one diptank at the edge of Hluhluwe-iMfolozi Park showed that the incidence of nagana caused mainly by *Trypanosoma congolenese* had increased since 1990 (Van den Bossche *et al.* 2006). These authors concluded that the disease contributes significantly to the overall disease situation in NKZN and recommended that further research was needed to develop appropriate control methods.

In a more recent study, Shaw *et al.* (2014) worked out the economic benefits obtained from intervening against tsetse and trypanosomosis in six countries in East Africa. The results of the study indicated the potential benefits in the region to be around $2.5 billion, with an average benefit per square kilometre varying from $500 – $3300. The current incidence of trypanosomosis in NKZN is unknown; it is thought to be relatively high and is a cause of concern to veterinarians and livestock farmers as there has been no national control policy in place for the last 20 years. The aim of this present study was to unravel the epidemiology of nagana in cattle where tsetse flies are known to occur, and to obtain baseline data against which the success of future control and the benefits of operations can be measured.

Research method and design

Study area

The study was conducted in Hlabisa Municipality, around the edges of Hluhluwe-iMfolozi Park and along the iSimangaliso (St. Lucia) Wetlands Park, which are the two major conservation and protected areas in the district. This area falls within the 16 000 km^2 tsetse belt in NKZN where both *G. brevipalpis* and *G. austeni* occur (Kappmeier-Green 2002). The vegetation consists of natural bush and sand forest plantations. Average annual temperature ranges from 22 °C to 28 °C, rainfall is around 950 mm in summer and 260 mm in winter. This district has 200 000 head of cattle and 57 585 small stock. The human population in the area is about 572 340, of which 15 719 are stock owners (Emslie 2005).

Trypanosomosis survey

A total of 10 communal diptanks (cattle move freely) were selected for trypanosomosis surveillance (Figure 1). Three diptanks located at the edge of Hluhluwe-iMfolozi Park were selected for regular monthly surveys: Ekuphindisweni, Mvutshini and Ocilwane. Seasonal trypanosome surveys were conducted in cattle at seven other communal diptanks located at various tsetse-infested areas, of which four are located at the edge of iSimangaliso (St. Lucia) Wetland Park. Cattle at any of the diptanks constituted one herd as they graze together and get the same animal husbandry management; for example, they were rounded up for dipping on the same day. Each herd consists of about

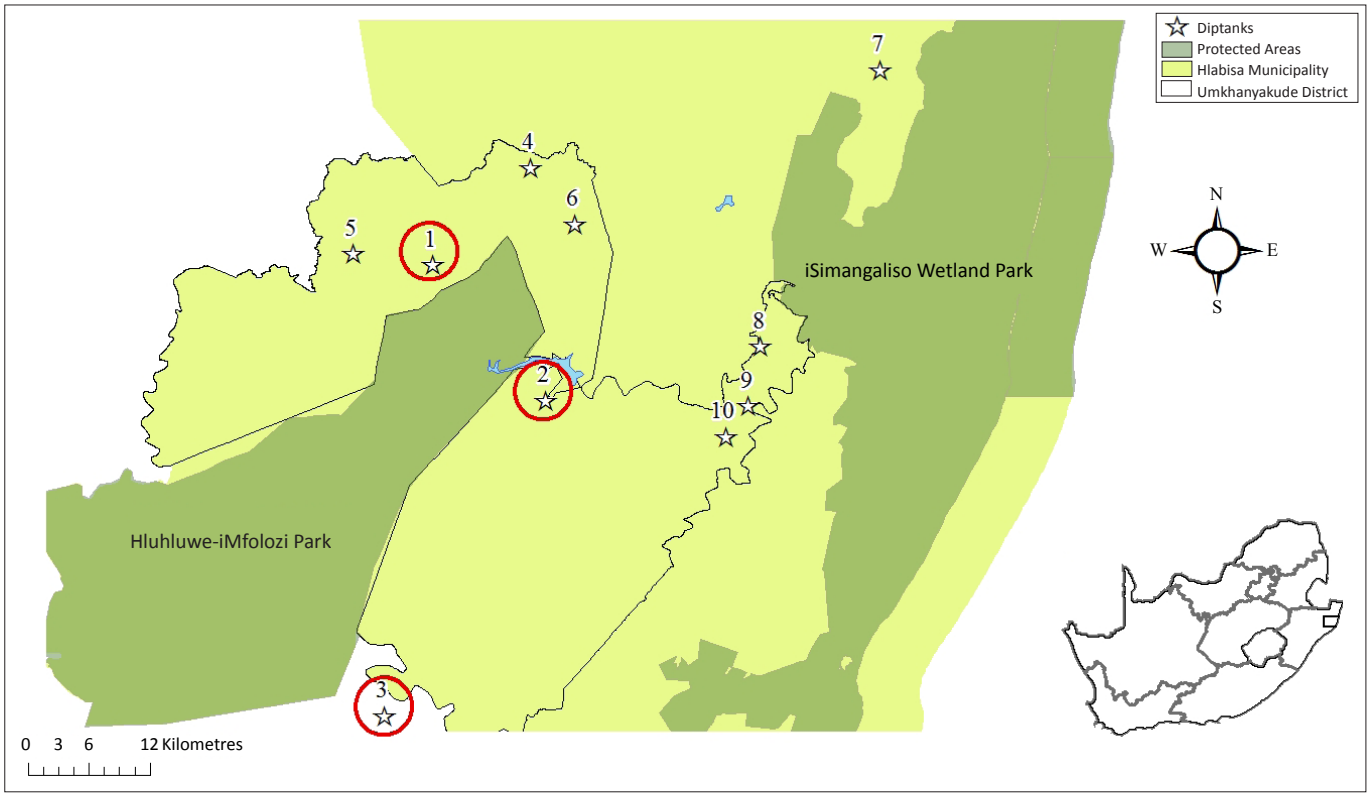

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FIGURE 1: Study area in northern KwaZulu-Natal Province, South Africa with diptank locations, (1) Ekuphindisweni, (2) Mvutshini, (3) Ocilwane, (4) Bukhipha, (5) Nhlwathi, (6) Mzineni, (7) Nibela, (8) Gwenyambili, (9) Qakwini and (10) Mahlambanyathi. Circled diptanks indicate surveillance sites.

1000 cattle owned by more than 100 small-scale farmers (communal farming). Cattle were sampled on the day when presented for dipping from June 2006 to November 2007. Each herd was sampled randomly; two to three animals were sampled in a crush of 30–40. The data generated over the study period at one diptank were considered as repeated observations on a herd over time.

The total number of cattle sampled at Ekuphindisweni, Mvutshini and Ocilwane were 398, 371 and 315, respectively. Cattle at five diptanks (Gwenyambili, Mahlambanyathi, Nhlwathi, Qakwini and Nibela) were surveyed 2–5 times per year to cover two seasons, mainly winter (May–September) and summer (October–April), whilst one sampling was carried out at two diptanks (Mzineni and Bukhipha). A total of 726 cattle were sampled.

Treatment against trypanosomosis by the local communities in NKZN has not been a regular practice and in most cases is non-existent. For ethical reasons, parasitologically positive as well as negative animals with a packed cell volume (PCV) equal to or lower than 24% were treated with diminazene aceturate (Berenil® R.T.U; Intervet S.A., Johannesburg, South Africa) at a dose of 3.5 mg/kg body weight.

Sampling and analysis

Blood was collected from the tail or jugular veins using 10 mL vacutainer tubes coated with EDTA (BD Vacutainer®; BD, Plymouth, United Kingdom) as anticoagulant. Blood from each sample was decanted into plain microhaematocrit centrifuge capillary tubes (Marienfeld-Superior, Lauda-Königshofen, Germany), sealed with cristseal and centrifuged for 5 min at 9000 rpm. After centrifugation, the PCV was determined. Animals with a PCV of 24% or less were considered anaemic (Murray & Dexter 1988; Van den Bossche, Shumba & Makhambera 2000). The buffy coat of each sample was extruded onto a microscope slide, covered with a cover slip and examined for motile trypanosomes under a compound microscope using 40× magnifications.

Trypanosoma prevalence in the present study refers to infections with *T. congolense*, the dominant species infecting cattle in the area (Mamabolo *et al.* 2009; Motloang *et al.* 2012; Van den Bossche *et al*. 2006) and identification of the parasites in the buffy coat during examination, based on its characteristic motility, difference from other species and stained thin smear examination. The level of bovine trypanosomosis of a herd at a specific site was calculated as the proportion of cattle with trypanosome infection and referred to as the 'herd average prevalence of trypanosome infection' (HAP) (Van den Bossche & Rowlands 2001). The percentage anaemia (i.e. percentage of cattle in a herd with PCV of 24% or less) was calculated. The PCV of cattle at each sampling was averaged and referred to as 'herd average PCV' (HA-PCV) (Van den Bossche & Rowlands 2001). Furthermore, the percentage of anaemic cattle in a herd was referred to as 'herd average anaemia' (HAA). HAP, HA-PCV and HAA values are considered as indicators of the health status of a herd (Trail *et al.* 1991; Trail *et al.* 1985) and were obtained from herds at each diptank.

Tsetse population monitoring at the study sites

Four odour-baited H-traps (Kappmeier 2000) were deployed and remained in place permanently for the duration of the study at Ekuphindisweni (May 2006 – December 2008), Mvutshini (May 2005 – December 2008) and Ocilwane (November 2007 – December 2008) diptanks. Flies were collected once every 2 weeks, identified to species and counted. The apparent density (flies per trap per day) was calculated for the three diptank sites (Esterhuizen *et al*. 2006).

Statistical analyses

HAA and HAP data were analysed using logistic regressions. Categorical explanatory variables were the diptanks and the month of sampling. In addition, the buffy coat result (positive or negative) was used as explanatory variable of HAA. PCV data were analysed in a linear regression using the buffy coat result, the location (one of the three diptanks) and the sampling month as discrete explanatory variables. *P*-values < 0.05 were considered statistically significant. Surveillance data were averaged per sampling site and date. Confidence intervals (95%) were calculated assuming a binomial distribution of HAA and HAP and a normal distribution of PCV.

Results

Tsetse abundance at the three diptanks

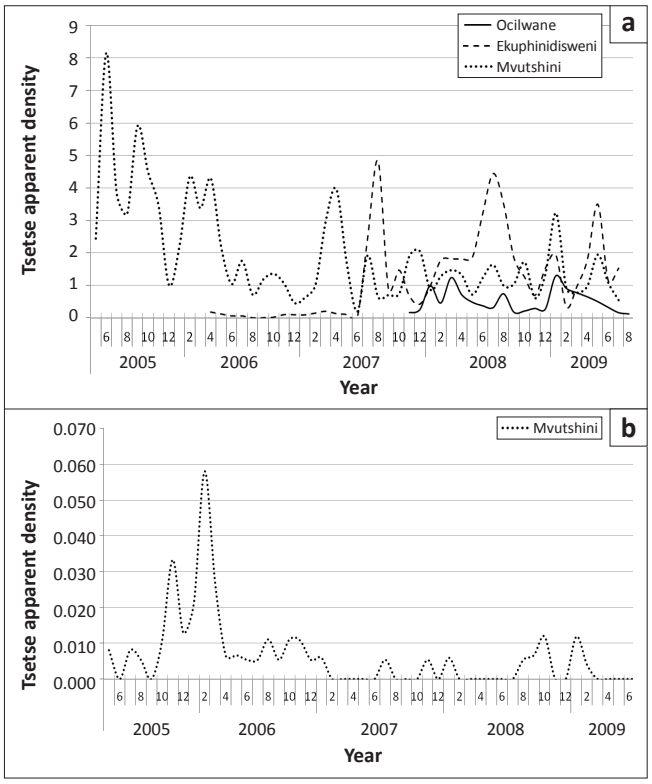
Both fly species were collected from Mvutshini diptank (Figure 2). In the areas around Ekuphindisweni (lying at the northernmost side of Hluhluwe-iMfolozi Park) and Ocilwane (lying at the southern side of the Park) diptanks, only *G. brevipalpis* was present (Figure 2). The apparent density of *G. brevipalpis* at Ocilwane diptank was lower than at Ekuphindisweni and Mvutshini diptanks. The apparent densities of both species were higher in the summer months (October–April) and lower in the winter months (May–September).

Trypanosome surveys at the three diptanks

Comparisons of HAP, HAA and HA-PCV are shown in Figure 3. Cattle at Mvutshini and Ekuphindisweni diptanks had the highest HAP, both significantly different ($p \leq 0.002$) from the HAP obtained from cattle at Ocilwane. The herds at Mvutshini and Ekuphindisweni diptanks also had significantly higher HAA than at Ocilwane, even when using the buffy coat result as explanatory variable ($p < 0.001$). Conversely, cattle at Ocilwane diptank had the highest HA-PCV even when using the buffy coat result as explanatory variable (about 3.0% more; $p < 0.001$). Infected animals had a PCV 4.2% lower (95.0% CI: 3.2–5.2) than uninfected animals ($p < 0.01$).

Trypanosome surveys at the seven diptanks

Table 1 shows the results of trypanosome surveys conducted at seven communal diptanks. Generally, *T. congolense*



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Note: Tsetse Apparent density – flies per trap per day of 4 traps.

FIGURE 2: Tsetse populations of, (a) *Glossina brevipalpis* and (b) *Glossina austeni* at Ekuphindisweni, Mvutshini and Ocilwane diptanks.

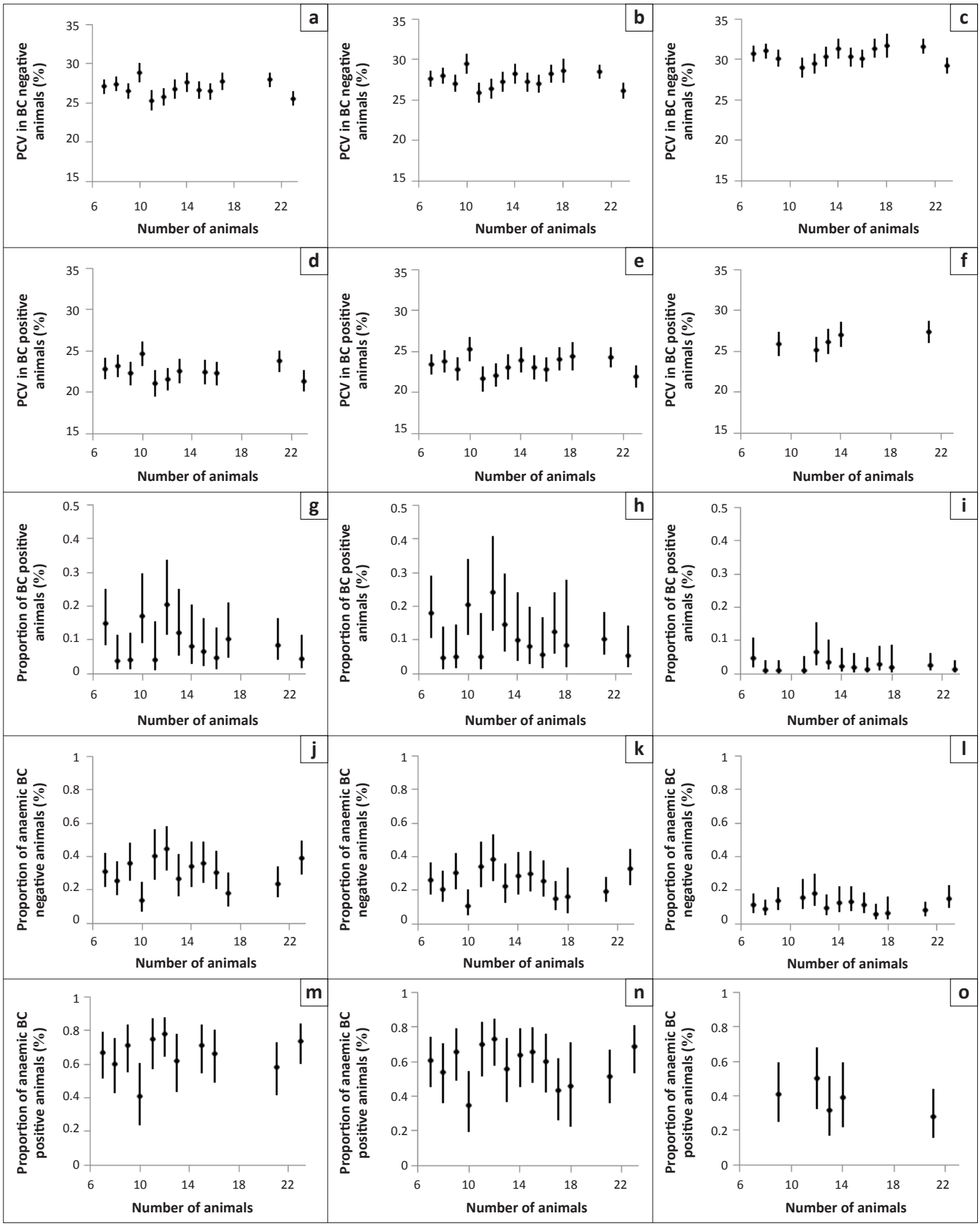
infection in cattle was found at all of the diptanks surveyed; HAP 10.2% ± 9.1%, HAA 46.6% ± 21.0% and HA-PCV 23.7% ± 1.6%. The standard deviation values were high for HAP and HAA parameters because of the different levels of trypanosome challenge at each location. The highest HAP (range 15.4% – 34.4%, n = 4) was recorded at Gwenyambili diptank. This high infection in the cattle herds produced high values of HAA (range 35.0% – 75.0%). This diptank is located inside a dense indigenous forest, a suitable tsetse habitat next to iSimangaliso Wetland Park. The rainy seasons did not result in improvement of the health condition of trypanosome-infected cattle as demonstrated by results obtained from HA-PCV, which approached or were below 25.0%.

Discussion

In 1990, during a severe drought in the tsetse-infested low lying areas of Zululand, about 10 000 cattle died of nagana and 116 000 were treated during this outbreak using ethidium bromide (Kappmeier *et al*. 1998). Further control measures included the use of pyrethroid dip after 4 years to reduce the challenge by the vector tsetse fly. Sixteen years after the 1990 outbreak, Van den Bossche *et al*. (2006) found the HAP of cattle sampled at one communal diptank at the edge of Hluhluwe-iMfolozi Park to be 34% and the HAA 83%. This survey demonstrated that nagana was still prevalent and control was required. The present results also demonstrated that the HAA at the seven surveyed diptanks was high (up to 60%). Nagana is considered a neglected disease in South Africa because no control policy has been implemented for over 20 years. The present study presents the first intensive epidemiological investigations to address the problem of animal trypanosomosis in South Africa since the 1990 outbreak and this information could be used in future control operations.

The relationship between trypanosome HAP, HAA and HA-PCV was investigated in cattle at three communal diptanks for 15 months. These three epidemiological parameters were previously shown to reflect the health condition in cattle in relation to tsetse challenge (Van den Bossche & Rowlands 2001). Although the percentage of HAA in infected cattle is high, more 'uninfected' animals could also have been anaemic, but trypanosome infections may have gone undetected by the conventional buffy coat examination employed in this study. The results obtained by Marcotty *et al.* (2008) confirmed the low sensitivity of the buffy coat test, which, despite parasite concentrations, failed to detect 66.0% of infected cattle in their study. This is the result of low parasitaemia levels in field cattle. Again, Van Den Bossche *et al*. (2006) found the infection rate in cattle at Hluhluwe-iMfolozi Park (our study sites) to be 34.0% using the buffy coat and 60.5% by using the polymerase chain reaction (PCR) molecular tool. Moreover, Mamabolo *et al*. (2009) found 91.0% positive for *T. congolense* using PCR analysis of samples collected from cattle at Mvutshini. Other sensitive molecular tools, when compared with conventional diagnostics, revealed higher levels of trypanosome infections in field cattle (Geysen, Delespaux & Geerts 2003). These studies confirm the low sensitivity of the buffy coat technique and support our results of a high percentage of aparasitaemic cattle with anaemia.

Cattle at Ocilwane diptank are subjected to irregular low tsetse challenge along the southernmost edges of the reserve. It is known that this is the most southerly distribution limit of tsetse in NKZN (Hendrickx 2002). Infections in cattle at Ocilwane were detected at only 5 out of 15 monthly samplings. Only a few animals were infected (2.2%) but all of the infected ones became anaemic (100%). There are some speculations about the infected cattle at Ocilwane: the natural population of *G. austeni* is very low at the study sites and emigration from the southernmost limit of this species may allow little fly movement to the diptank site; alternatively, the H-trap is not optimum for attracting and catching the species, although it was demonstrated to be the best available (Kappmeier 2000). All of the seven infected cattle became anaemic, which strongly suggests that these flies previously fed on buffaloes, thus transmitting highly virulent strains (Motloang *et al*. 2012). Cattle at the diptank could not have moved to graze inside the Park as there was no report of fatal Corridor disease in the herd for the duration of the study. Buffaloes in the parks in KZN are known carriers of *Theileria parva*, the cause of Corridor disease (*T. parva* infections in cattle associated with carrier buffalo) (Mbizeni *et al.* 2013). This is a unique situation where the interface with the irregular tsetse challenge and the presence of trypanosome reservoirs in game produced an epidemic character of the disease. Such interfaces are



Source: Authors' own creation
Note: Months from June 2006 to November 2007.
PCV, packed cell volume; BC, buffy coat.

FIGURE 3: Comparing herd average packed cell volume, trypanosomes herd average prevalence and herd average anaemia in positive and negative cattle at the three diptanks, (a, d, g, j, m) Ekuphindisweni, (b, e, h, k, n) Mvutshini and (c, f, i, l, o) Ocilwane (estimates and 95% confidence intervals without interaction between explanatory variables).

TABLE 1: Trypanosome survey at the seven communal diptanks showing means ± standard deviation and 95% confidence interval results of the herd average prevalence, herd average anaemia and herd average packed cell volume.

Diptank	Sampling date	HAP		HAA		HA-PCV	
		%	95% Confidence interval results	%	95% Confidence interval results	%	95% Confidence interval results
Gwenyambili	08 Oct. 2005	17.9	7.7–36.4	75.0	56.1–87.6	22.0 ± 4.0	20.5–23.5
	14 July 2006	34.3	20.6–51.2	68.6	51.7–81.7	23.0 ± 4.6	21.5–24.5
	24 Oct. 2006	15.4	7.1–30.3	33.3	20.4–49.3	26.0 ± 3.3	25.0–27.0
	28 Feb. 2007	21.9	10.8–39.3	35.1	21.6–51.5	25.9 ± 4.0	24.6–27.2
Mahlambanyathi	10 Oct. 2005	2.3	0.3–14.5	72.7	57.8–83.8	23.2 ± 4.0	22.0–24.4
	30 Nov. 2005	6.0	1.9–17	29.5	19.4–42.0	26.9 ± 3.6	26.0–27.8
	05 Sept. 2006	7.5	2.4–20.8	15.0	6.9–29.6	25.0 ± 4.0	23.8–26.2
	15 Sept. 2006	15.6	7.6–29.3	40.0	26.9–54.8	22.0 ± 3.0	21.1–22.9
	06 Mar. 2007	3.3	0.5–20.2	20.0	9.3–37.9	23.0 ± 4.0	21.6–24.4
Nhlwathi	05 Feb. 2006	2.4	0.3–15.1	62.2	47.4–75.0	23.2 ± 3.3	22.2–24.2
	06 May 2006	2.5	0.4–15.7	15.0	6.9–29.6	24.0 ± 4.0	22.8–25.2
	05 June 2006	2.5	0.4–15.7	18.0	8.9–33.0	23.0 ± 2.0	22.4–23.6
Qakwini	11 Oct. 2005	2.2	0.3–13.9	72.7	57.8–83.8	22.1 ± 3.6	21.0–23.2
	15 Aug. 2008	14.3	7.3–26.1	55.4	42.3–67.8	24.1 ± 4.6	22.9–25.3
Nibela	25 Nov. 2006	3.6	0.5–21.4	60.7	42.0–76.7	23.6 ± 3.6	22.3–24.9
	27 Jan. 2007	8.8	2.9–24.0	57.5	42.0–71.7	24.4 ± 3.6	23.3–25.5
Mzineni	20 Sept. 2006	18.9	9.3–34.7	45.9	30.8–61.8	25.4 ± 5.5	23.6–27.2
Bukhipha	23 Nov. 2006	5.6	1.4–19.7	70.2	55.8–81.5	23.4 ± 4.0	22.3–24.5

HAP, herd average prevalence; HAA, herd average anaemia; HA-PCV, herd average packed cell volume.

found along the Kasungu National Park and Nkhotakota Game Reserve in Malawi, along the Malawi National Park and along the Kwando River in the Zambezi (formerly Caprivi) region of Namibia (Van den Bossche *et al*. 2000).

Anaemia caused by trypanosome infections is the result of the parasite damaging red blood cells by releasing biochemical molecules and is non-regenerative (Murray & Dexter 1988; Murray *et al.* 1979; Nok & Balogun 2003; Suliman & Feldman 1989). The PCV of individual animals and the HA-PCV are useful indicators of anaemia and in trypanosome endemic areas are the most typical signs of nagana in domestic animals (Marcotty *et al.* 2008; Murray & Dexter 1988; Trail *et al*. 1991). In endemic tsetse areas, parasitologically negative animals that have a low PCV are regarded as having trypanosome infections. In the present study, 62% of the infected animals, using direct parasitological methods, were found to be anaemic and therefore the 20% of anaemic cattle that were aparasitaemic should be considered trypanosome-infected and receive treatment. There are some cattle breeds in western and eastern Africa that have been shown to be tolerant to trypanosome infection and able to limit development of anaemia by a process of erythropoiesis balancing the depletion of red blood cells (Naessens, Teale & Sileghem 2002). The cattle types in this study have no history of trypanotolerence, thus anaemia in an infected animal becomes chronic and progressive in absence of treatment.

The survey conducted at the seven diptanks under tsetse challenge highlighted the magnitude of nagana as a major risk to animal health. The HAP was very high (up to 31%), and consequently HAA was also high (up to 70%). Anaemia in cattle is clearly related to trypanosome infections as cattle continued to be anaemic during the rainy season and received no drug treatment. This is also demonstrated by comparing the HA-PCV and HAA conditions in cattle under high and low tsetse challenge; that is, Mvutshini and Ekuphindisweni versus Ocilwane, and the other seven diptanks versus Ocilwane. Several epidemiological factors and their associations with the vector tsetse fly, livestock, presence of game and the climate have been identified in trypanosomosis. The infection rate in tsetse flies is of prime importance (Connor & Van den Bossche 2004). Motloang *et al*. (2012) investigated the vector competence of *G. brevipalpis* and *G. austeni* collected from the same communal diptanks in the present study around Hluhluwe-iMfolozi Park and from other farms and game parks. They found the infection with mature parasites in *G. austeni*, which is considered the main vector, to be 8%. Moreover, *G. austeni* collected from the same sites and which fed on susceptible cattle under controlled conditions subsequently transmitted *T. congolense* and the animals had to be treated.

Low fly population density can cause a serious disease problem (Jenni *et al.* 1980; Molyneux & Jefferies 1986; Roberts 1981). This observation supports the HAP in cattle at all diptanks surveyed with low or no apparent *G. austeni* presence. The apparent abundance of *G. brevipalpis* was substantially higher than that of *G. austeni* in three main vegetation types in Zululand (Esterhuizen *et al.* 2005). It was not possible to attribute these findings to the real population density of the two species or to sampling bias favouring *G. brevipalpis* catches, although the H-trap was developed to target the two species and was more efficient than any other tested traps for *G. austeni* (Kappmeier 2000; Kappmeier & Nevill 1999).

A total of 59 diptanks (herds) were sampled in 1994 (Bagnall, in Kappmeier *et al*. 1998) to determine the prevalence of anaemia in cattle. The highest prevalence of trypanosomosis was recorded in Ubombo District (our study sites) at 10% – 15%. Van den Bossche *et al*. (2006) found 34% of cattle at Mvushini diptank were infected with trypanosomes. These results obtained over an extended period of time indicate that the prevalence of nagana has in fact increased and our

present results have confirmed this trend. On the other hand, the tsetse distribution and abundance has also increased. Our results have, for the first time, reported the presence of *G. brevipalpis* at Ocilwane diptank, previously thought to be the southernmost limit of the tsetse distribution. Commercial cattle farmers have shifted to game ranching and resorts, thus increasing the conserved and protected tsetse areas in national and provincial game parks and nature reserves. These man-made habitats have resulted in the extension of the distribution and multiplication of two tsetse species compared to the 1954 distribution maps (Esterhuizen *et al*. 2006). The limited grazing areas and degraded communal land have therefore forced cattle to move to such tsetse habitats, exposing them to nagana challenge.

Conclusion

The present study showed that nagana is prevalent at all 10 diptanks surveyed and affects mainly the resource-poor farmers. In South Africa, there is no control policy for tsetse and nagana and treatment using trypanocidal drugs is still not accessible to resource-poor farmers. The only response is to 'manage the crisis' when the problem is out-of-hand by the introduction of pyrethroid chemical acaricides in dips, which eventually kills the flies and ticks. However, the dipping policy is not enforced by law and has proved to be unsustainable over the years, as demonstrated in this study by the high level of trypanosome infections in cattle following removal of pyrethroid dips since 1992. What is required is a politically supported decision to eradicate tsetse flies in order to increase cattle productivity and alleviate poverty. A strategy for area-wide control to establish a tsetse-free zone in South Africa has been advocated (Kappmeier-Green, Potgieter & Vreysen 2007). Integrated control including treatment is an option but is also not sustainable because of migration and emigration of tsetse flies from the conservation and protected game parks, resulting in a high risk game–livestock–tsetse interface.

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

A.A.L. (Agricultural Research Council – Onderstepoort Veterinary Institute) was the project leader. L.N. (Makhathini Research Station), C.d.B. (Agricultural Research Council – Onderstepoort Veterinary Institute) and A.A.L. carried out the disease and tsetse surveys. T.M. (Institute of Tropical Medicine) performed the statistical analysis. All authors contributed to writing the manuscript.

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