Farmers' knowledge, perceptions, and practices on animal trypanosomosis and the tsetse fly vector: A cross-sectional study around Kenya's Arabuko-Sokoke Forest Reserve at the livestock-wildlife interface [version 1; peer review: awaiting peer review]

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Abstract

Background: Animal African trypanosomosis (AAT) is a veterinary disease caused by trypanosomes transmitted cyclically by tsetse flies. AAT causes huge agricultural losses in sub-Saharan Africa. Both tsetse flies and trypanosomosis (T&T) are endemic in the study area inhabited by smallholder livestock farmers at the livestock-wildlife interface around Arabuko-Sokoke Forest Reserve (ASFR) in Kilifi County on the Kenyan coast. We assessed farmers' knowledge, perceptions and control practices towards T&T.

Methods: A cross-sectional study was conducted during November and December 2017 to collect data from 404 randomly selected cattle-rearing households using a structured questionnaire. Descriptive statistics were used to determine farmers' knowledge, perceptions, and control practices towards T&T. Demographic factors associated with knowledge of T&T were assessed using a logistic regression model.

Results: Participants consisted of 53% female, 77% married, 30% elderly (>55 years), and the majority (81%) had attained primary education or below. Most small-scale farmers (98%) knew the tsetse fly by its local name, and 76% could describe the morphology of the adult tsetse fly by size in comparison to the housefly's (Musca...
domestica). Only 16% of the farmers knew tsetse flies as vectors of livestock diseases. Higher chances of adequate knowledge on T&T were associated with the participants’ (i) age of 15–24 years (aOR 2.88 (95% CI 1.10–7.52), (ii) level of education including secondary (aOR 2.46 (95% CI 1.43–4.24)) and tertiary (aOR 3.80 (95% CI 1.54–9.37)), and (iii) employment status: self-employed farmers (aOR 6.54 (95% CI 4.36–9.80)).

**Conclusions:** Our findings suggest that small-scale farmers around ASFR have limited knowledge of T&T. It is envisaged that efforts geared towards training of the farmers would bridge this knowledge gap and sharpen the perceptions and disease control tactics to contribute to the prevention and control of T&T.

**Keywords**
animal trypanosomosis, tsetse flies, wildlife–livestock interface, small-scale farmers, Arabuko-Sokoke Forest Reserve, Kenya

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Introduction

African trypanosomes (Trypanosoma) are flagellated parasitic protozoa that are cyclically transmitted by tsetse flies (Glossina spp.), causing neglected tropical disease, human African trypanosomiasis (HAT) and animal African trypanosomiasis (AAT) (Capewell et al., 2015). Tsetse flies, which are obligate blood feeders, are found in 38 sub-Saharan African (SSA) countries, including Kenya (FAO, 2016). However, mechanical transmission of animal trypanosomes has been documented to occur through other dipterans including tabanids and Stomoxys spp. The latter may explain the occurrence of AAT outside the continental range of tsetse flies. For instance, Trypanosoma evansi and T. vivax infections were reported in horses, mules, camels, and cattle found in Asia and South America (Desquesnes & Dia, 2003; Jones & Dávila, 2001; Mihok et al., 1995).

AAT is caused by parasitic T. brucei brucei, T. evansi, T. vivax, T. congolense, and T. equiperdum (Auyt et al., 2012; Giordani et al., 2016) and infects almost all domestic animals including cattle, sheep, goats, pigs, horses, camels, and dogs (Desquesnes & Dia, 2004; Desquesnes et al., 2013; Matete, 2003; Singh et al., 1993). Notably, wildlife act as key reservoirs of many pathogens, which are transmitted to humans and livestock by hematophagous biting flies particularly at the livestock-wildlife interface (Ebbodaghe et al., 2021). Previous studies have reported trypanosomiasis in wild animals, including warthog Phacochoenus aethiopicus, African buffalo Syncerus caffer, giraffe Giraffa camelopardalis, African savannah elephant Loxodonta africana, and hippopotamus Hippopotamus amphibious (Anderson et al., 2011; Clausen et al., 1998; Muturi et al., 2011; Snow et al., 1988). Recent studies on bloodmeal analyses in field-collected tsetse flies from the Kenya’s Shimba Hills National Reserve found that the warthog Phacochoerus africanus is the major cryptic reservoir of animal trypanosomes causing diseases in cattle kept at the wildlife-livestock interface (Ebbodaghe et al., 2021)

AAT is a serious veterinary disease that causes huge socio-economic burden in SSA (Shaw et al., 2014). The disease exacerbates poverty and contributes to food insecurity through (1) loss of draught power due to weakening of infected animals, (2) productivity losses (reduced milk and meat), (3) additional animal treatment costs, and (4) high morbidity and mortality in livestock (Fasina et al., 2021; Steverding, 2008). Occurrence of AAT, which is endemic in 38 of the 47 counties in Kenya (Kenya Ministry of livestock development, 2011), together with its tsetse fly vector, presents a major constraint to livestock production, thus hindering economic development among the small-holder livestock farmers. The benefits that could accrue from tsetse and trypanosomosis prevention and control could greatly improve the living standards of the pastoral communities inhabiting disease endemic regions bordering the wildlife reserves, for instance Arabuko-Sokoke Forest Reserve (ASFR), Kenya.

ASFR is the largest and most intact coastal forest covering an area of 420 km² (www.kenyaforestservice.org). This forest is inhabited by four species out of the 31 tsetse species and subspecies described broadly classified into three groups: the Morsitans (Savannah), the Fusca (Forest) and Palpalis (Riverine). ASFR is inhabited by two species of tsetse flies of the Savannah (G. pallidipes, and G. australis) and two of the Forest groups namely G. brevipalpis and G. longipennis, (Ngari et al., 2020). Human encroachment of formerly forested areas bordering the ASFR, in search of arable land and pastures for their livestock, promotes transmission of tsetse-transmitted diseases of veterinary and zoonotic importance through habitat sharing (Rutto et al., 2013).

Knowledge and perception towards vector-borne diseases and their transmitting vectors among the livestock keepers in endemic areas is crucial for disease prevention and control at household level (Tshimungu et al., 2008). However, acquired knowledge, perceptions, prevention and control practices among the community towards the vector and the disease are not well understood. We conducted a cross-sectional survey around the ASFR to determine farmers’ knowledge, perceptions, preventive and control practices towards tsetse fly and trypanosomosis (T&T).

Methods

Study design and study area

A cross-sectional study was conducted between November and December 2017 from three sub-counties of Kilifi County, namely Ganze, Kilifi North, and Malindi. The study was conducted at the wildlife-livestock interface around Arabuko-Sokoke Forest Reserve (ASFR) in Kilifi County, Kenya (Figure 1). Kilifi County lies between latitude 2° 20’ and 4° 0 South, and between longitude 39° 05’ and 40° 14’ East. The County borders Kwaile County to the southwest, Taita Taveta County to the west, Tana River County to the north, Mombasa County to the south, and Indian Ocean to the east. Kilifi County covers an area of about 12,609.7 km² with an estimated human population size of 1,453,787 people in 2019 (KNBS, 2019). The County has a total of seven sub-counties, namely Kilifi North, Kilifi South, Ganze, Malindi, Magarini, Rabai, and Kaloleni.

Our study area neighbouring the ASFR is mainly inhabited by the Giriama subtribe of the Mijikenda. Most people derive part of their livelihoods from small scale crops and livestock farming as well as fishing (MoALF, 2016). The livestock reared are of indigenous breeds including Coastal Zebu and Orma Boran, the exotic breeds including Friesian and Ayrshire, goats, sheep, poultry and beehivekeeping (KMALDFC, 2019).

Weather conditions

The average temperature in areas around ASFR where tsetse flies are endemic is 26.5 °C (24–32 °C; March and June are the warmest and the coldest months of the year respectively). About 900 to 1200 mm of precipitation falls annually. February and May are the driest and most wet months with a precipitation of ~21 mm and 173 mm respectively. The average relative humidity (R.H.) is 74% per annum with a maximum R.H. of 80% in May, and a minimum of 70% in February. The weather during the long rains between April and July is conducive for the replication of tsetse flies as they have a temperature limit between 26 °C and 32 °C and the vector can survive at an
R.H. range of 40–76% (Wamwiri et al., 2013). The typical habitat for the Morsitans group of tsetse flies is open woodland and woodland savanna ecosystem that is mainly composed of Brachystegia (Krinsky, 2002). ASFR has three types of forest cover including mixed forest comprising Brachystegia and Cynometra tree species preferred by G. austeni, Brachystegia woodland preferred by G. pallidipes and Cynometra forest, which is preferred by G. brevipalpis and G. longipennis (Cecchi et al., 2008; De Beer et al., 2021).

Study participants and the inclusion criteria
The study targeted households with participants aged ≥15 years, lived ~5 km from the border of ASFR, and kept livestock including cattle, sheep, and goats. We obtained a list of eligible households from the local administration (chiefs’) offices from which a sample size of 404 participants was obtained as described below.

Sample size determination
We calculated our sample size using an estimated prevalence of 50% to compute the sample size at a level of significance of 0.05 and precision of ±0.05, which resulted in a sample size of 385 (i.e. $1.96^2 \times 0.5(1-0.5)/0.05^2 = 385$) (Daniel, 1999). We adjusted this sample size of 385 upwards by 5%, thus giving a final sample size of 404 (i.e. $1.05 \times 385 = 404.25$) as a contingency plan to cover for the unexpected cases of withdrawal from the study by the selected participants.

Ethical considerations
Ethical approval was obtained from the Pwani University Ethics Review Committee (approval number: ERC/PhD/015/2016). Permission to conduct the study was granted by the area Chief, village elders, and livestock farmers after a series of sensitization and stakeholder meetings to engage the local community on the information about the proposed research. Subsequently, both verbal and written informed consent (Serem et al., 2022) were obtained from the eligible participants, and from the parents of those participants aged below 18 years (but not less than 15), prior to administration of the questionnaires.

Data collection
Eight sampling sites were randomly selected from 32 eligible locations that surrounded the ASFR as described in the inclusion criteria and these included Dida, Nyari, Chumani, Matsangoni, Mida-Majaoni, Mijomboni, Mongotini, and Ngerenya (Figure 1). Households for interviews (n =404) were chosen at random in each of the eight locations via the lottery method by considering the proportion of eligible participants in each location.

Figure 1. A map of Kenya showing the sampling locations surrounding Arabuko-Sokoke Forest Reserve in Kilifi County. The figure was generated using open-source software QGIS version 3.18 (RRID:SCR_018507). The annual rainfall data was obtained from Climate Hazards group Infrared Precipitation with Stations (CHIRPS).
The household heads were interviewed and in case they were not available we engaged the most knowledgeable member of the household, who actively engaged in livestock herding duties with experience of grazing animals at the border of ASFR.

The data was collected using structured questionnaires (Serem et al., 2022) adapted from Mwaseba & Kigoda (2017) from the consenting participants to determine their knowledge, perceptions and practices towards control of livestock animal trypanosomosis disease and its vector, the tsetse fly. The structured questionnaire as a tool consisted of four sections, namely demographics, knowledge, perceptions and practices. The tool included both closed and open-ended questions. Trained field assistants administered the questionnaires in Giriama language understood by the respondents.

Statistical analysis
Analysis of data was done using STATA software version 17.1 (RRID:SCR_012763). Data on farmer’s knowledge, perceptions, and practices towards tsetse flies and animal trypanosomosis were analyzed using descriptive statistics. Logistic regression was used to analyse the demographic factors associated with knowledge towards T&T. The following three criteria were used in scoring the knowledge of the participant (i.e. the dependent variable); the ability of the respondent to (1) state the local name of tsetse fly in a language spoken by the community, (2) provide accurate description of the tsetse fly, and (3) identify livestock diseases transmitted by tsetse flies.

Backwards stepwise binary logistic regression analysis was used to determine the demographic factors associated with the knowledge of T&T by retaining variables with P <0.1 in the multivariable model. The data were reported using both crude and adjusted odds ratios and their respective 95% confidence intervals. We assessed the goodness of fit and performance of multivariable regression model using the Hosmer–Lemeshow test and area under receiver operating characteristics curve (AUC). The sampling locations were organized into clusters and robust standard errors were computed to account for the clustering effect in the multivariable regression model.

Results
Demographic characteristics
Of the 404 participants, 53% (214/404) were female, about one third consisted of elderly aged ≥55 years (30%; 123/404), 12% (47/404) were single and the rest were either married, divorced, separated, or widowed. About 33% of the participants lacked formal education (134/404), and the rest attained the following levels of education: primary 47.5% (192/404), secondary 15% (61/404), and tertiary level 4.5% (16/404). Furthermore, 10% of the participants were in formal employment, while the rest were either self-employed or unemployed. The number of selected participants from each of the eight sampling sites is summarized in Table 1.

Knowledge of the livestock diseases
Nearly all participants (98%; 397/404) reported to have knowledge of tsetse flies and 87.4% (353/404) of them knew the local name of the tsetse Imbu in Giriama; Mbung’o (2.5%) in Swahili, and the Mijikenda subtribe of Chonyi call it Chibu (8.2%). The majority of the participants (76%) could only describe tsetse morphology based on size i.e., approximately the size of a housefly, while 161 participants (40%) reported their observation of the tsetse to have long mouthparts for blood-feeding. A further 23% of the respondents described tsetse flies by their body colour to be ‘brown-grey’ to ‘brown-dark’. Information on where livestock and tsetse flies most likely interact, the abundance of tsetse flies, challenges that tsetse flies pose to livestock, and the diseases transmitted by these vectors are summarized in Table 2. A small fraction of the respondents, 16% (65/404), were aware that tsetse flies are vectors of livestock diseases, from which only 61.1% (4/65) ably described the link between tsetse and trypanosomosis (nagana). About 80% of the respondents who knew that tsetse flies transmit trypanosomosis reported infections in cattle, while 43% reported infections in goats and sheep. Health problems associated with tsetse-transmitted trypanosomosis were reported by the participants (Figure 2).

Among the respondents, 75% of them had no prior access to any source of information about tsetse and trypanosomosis. However, 12% of the respondents reported to have previously received basic knowledge of tsetse, either through their encounters with these flies in the forest while performing livestock herding duties, or via engagement with their parents. Other secondary sources of information they received were from: school (6.2%), extension officers (3%), NGOs (1.5%), and mass media (0.2%). We also noted that there were differences in the level of knowledge on T&T in the study sites. Kakuyuni had the highest number of participants with adequate knowledge whereas in Mida and Ngerenya, none of the participants had adequate knowledge (Table 3). Dida had the highest number of participants with tertiary education at 33.33%.

<table>
<thead>
<tr>
<th>S/No</th>
<th>Sampling locations bordering ASFR</th>
<th>Sample distribution; Percentage % (*n/404)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Matsangoni</td>
<td>12 (47/404)</td>
</tr>
<tr>
<td>2</td>
<td>Dida</td>
<td>13 (51/404)</td>
</tr>
<tr>
<td>3</td>
<td>Chumani</td>
<td>13 (53/404)</td>
</tr>
<tr>
<td>4</td>
<td>Mjomboni</td>
<td>13 (53/404)</td>
</tr>
<tr>
<td>5</td>
<td>Mida</td>
<td>13 (54/404)</td>
</tr>
<tr>
<td>6</td>
<td>Ngerenya</td>
<td>11 (43/404)</td>
</tr>
<tr>
<td>7</td>
<td>Kakuyuni</td>
<td>13 (53/404)</td>
</tr>
<tr>
<td>8</td>
<td>Nyari</td>
<td>12 (50/404)</td>
</tr>
</tbody>
</table>

* represents the number of respondents from each sampling site.

Table 1. The number and site-specific distribution of randomly selected livestock-keeping respondents living near the border of Arabuko-Sokoke Forest Reserve (ASFR).

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respectively. A further 17% of the farmers were hopeful that the control methods were reliable for tsetse control, and only 7.4% of the participants expressed their opinion that the recommended control strategies were affordable. Three hundred and sixteen participants (78%) were neither sure whether the recommended tsetse control methods were easy to deploy nor effective, whereas 320 (79%) were not sure of the affordability of the control methods. Other parameters associated with the perceptions of the participants on the reasons for persistence of tsetse transmitted diseases are shown in Table 4.

Practices towards tsetse control
Among the 30% of the respondents who practiced tsetse control, the main tsetse control methods employed and the perceived reasons for persistence and effects of tsetse-transmitted diseases are summarized in Table 5.

Association of the demographic factors with the knowledge of tsetse fly vector
Sixty-five participants (16%, 95% CI 13 to 20%) had adequate knowledge of tsetse flies. In the univariate logistic regression models, males were associated with higher odds of adequate tsetse fly knowledge (crude odds ratio of 2.55 (95% CI 1.24–5.24)) than females (Table 6). Further, in comparison to the participants without formal education, both secondary and tertiary education levels were associated with higher odds of adequate knowledge of tsetse flies: crude odds ratios 3.90 (95% CI 1.47–10.32) and 5.58 (95% CI 2.01–15.50), respectively (Table 6).

Based on multivariable regression analysis, the participant’s aged between 15 and 24 years were associated with higher odds of adequate understanding of the tsetse (aOR 2.88 (95% CI 1.10–7.52)), relative to the older ones aged above 55 years. Further, attainment of secondary education (aOR 2.46 (95% CI 1.43–4.24)) and tertiary education (aOR 3.80 (95% CI 1.54–9.37)) was associated with higher odds of adequate knowledge of tsetse flies than lack of it (formal education). In addition, self-employment was associated with higher odds

### Table 2. Summary of the participants’ knowledge on tsetse fly, its ecology, seasonal fly densities, and vector-borne transmission of livestock diseases.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Percentage % (*n/404)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where do tsetse flies live?</td>
<td></td>
</tr>
<tr>
<td>Grassland</td>
<td>18.0 (74/404)</td>
</tr>
<tr>
<td>Bottom of valley</td>
<td>2.2 (9/404)</td>
</tr>
<tr>
<td>Bush area</td>
<td>84.0 (340/404)</td>
</tr>
<tr>
<td>Hilly areas</td>
<td>0.5 (2/404)</td>
</tr>
<tr>
<td>Where do livestock get into close contact with tsetse flies?</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>91.0 (368/404)</td>
</tr>
<tr>
<td>Riverine area</td>
<td>1.2 (5/404)</td>
</tr>
<tr>
<td>Un-forested areas</td>
<td>7.2 (29/404)</td>
</tr>
<tr>
<td>Don’t know</td>
<td>4.0 (16/404)</td>
</tr>
<tr>
<td>Which season of the year has the highest numbers of tsetse flies?</td>
<td></td>
</tr>
<tr>
<td>Rainy season</td>
<td>72.0 (289/404)</td>
</tr>
<tr>
<td>Dry season</td>
<td>7.9 (32/404)</td>
</tr>
<tr>
<td>Throughout the year</td>
<td>6.9 (28/404)</td>
</tr>
<tr>
<td>Don’t know</td>
<td>12.0 (48/404)</td>
</tr>
<tr>
<td>What problems do tsetse flies cause to the livestock?</td>
<td></td>
</tr>
<tr>
<td>Painful bites</td>
<td>81.0 (326/404)</td>
</tr>
<tr>
<td>Distract grazing activities</td>
<td>53.0 (216/404)</td>
</tr>
<tr>
<td>Transmit disease</td>
<td>16.0 (64/404)</td>
</tr>
<tr>
<td>Don’t know</td>
<td>7.9 (32/404)</td>
</tr>
<tr>
<td>Do tsetse flies transmit diseases to livestock?</td>
<td>16.0 (65/404)</td>
</tr>
<tr>
<td>Which livestock disease do tsetse flies spread? (N=65)</td>
<td></td>
</tr>
<tr>
<td>Homa (fever)</td>
<td>78.0 (51/65)</td>
</tr>
<tr>
<td>Nagana</td>
<td>6.1 (4/65)</td>
</tr>
<tr>
<td>Don’t know the disease</td>
<td>15.0 (10/65)</td>
</tr>
</tbody>
</table>

* n: represents the number of respondents for each category.

Perceptions of farmers
One hundred and nineteen (30%) participants adopted tsetse control techniques in order to prevent livestock infestation by tsetse flies. About 17% and 18% of the respondents felt that the recommended tsetse control measures were easy to use and effective, respectively, while 78% and 79% were not sure about the ease of use and effectiveness of the control measures, respectively. A further 17% of the farmers were hopeful that the control methods were reliable for tsetse control, and only 7.4% of the participants expressed their opinion that the recommended control strategies were affordable. Three hundred and sixteen participants (78%) were neither sure whether the recommended tsetse control methods were easy to deploy nor effective, whereas 320 (79%) were not sure of the affordability of the control methods. Other parameters associated with the perceptions of the participants on the reasons for persistence of tsetse transmitted diseases are shown in Table 4.

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Table 3. The number and site-specific distribution of randomly selected livestock-keeping respondents with adequate knowledge of tsetse flies and trypanosomosis.

<table>
<thead>
<tr>
<th>S/No.</th>
<th>Sampling locations bordering ASFR</th>
<th>Sample distribution; Percentage % (*n/65)</th>
<th>No formal education (%n/13)</th>
<th>Primary (%n/28)</th>
<th>Secondary (%n/18)</th>
<th>Tertiary (%n/16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Matsangoni</td>
<td>18.46 (12/65)</td>
<td>15.38 (2/13)</td>
<td>28.57 (8/28)</td>
<td>5.56 (1/18)</td>
<td>16.67 (1/16)</td>
</tr>
<tr>
<td>2</td>
<td>Dida</td>
<td>23.08 (15/65)</td>
<td>23.08 (3/13)</td>
<td>17.86 (5/28)</td>
<td>27.78 (5/18)</td>
<td>33.33 (2/16)</td>
</tr>
<tr>
<td>3</td>
<td>Chumani</td>
<td>13.85 (9/65)</td>
<td>0</td>
<td>17.86 (5/28)</td>
<td>16.67 (3/18)</td>
<td>16.67 (1/16)</td>
</tr>
<tr>
<td>4</td>
<td>Mijomboni</td>
<td>4.62 (3/65)</td>
<td>7.69 (1/13)</td>
<td>0</td>
<td>5.56 (1/18)</td>
<td>16.67 (1/16)</td>
</tr>
<tr>
<td>5</td>
<td>Mida</td>
<td>0 (0/65)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Ngerenya</td>
<td>0 (0/65)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Kakuyuni</td>
<td>26.15 (17/65)</td>
<td>46.15 (6/13)</td>
<td>28.57 (8/28)</td>
<td>16.67 (3/18)</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Nyari</td>
<td>13.85 (9/65)</td>
<td>7.69 (1/13)</td>
<td>7.14 (2/28)</td>
<td>27.78 (5/18)</td>
<td>16.67 (1/16)</td>
</tr>
</tbody>
</table>

Table 4. Summary of the participants’ perceptions on the reasons for the persistence of tsetse flies and effects of tsetse flies.

<table>
<thead>
<tr>
<th>Perceptions</th>
<th>Percentage % (*n/404)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What are the reasons for persistence of tsetse-transmitted livestock diseases?</strong></td>
<td></td>
</tr>
<tr>
<td>Lack of knowledge on nagana disease</td>
<td>2.2 (9/404)</td>
</tr>
<tr>
<td>Residing near ASFR</td>
<td>8.9 (36/404)</td>
</tr>
<tr>
<td>Lack of community animal health workers and other experts to train farmers</td>
<td>0.7 (3/404)</td>
</tr>
<tr>
<td>Presence of tsetse flies</td>
<td>3.0 (12/404)</td>
</tr>
<tr>
<td>I do not know</td>
<td>14.0 (55/404)</td>
</tr>
<tr>
<td><strong>What are the outcomes of tsetse flies’ infestation on community members?</strong></td>
<td></td>
</tr>
<tr>
<td>Painful bites</td>
<td>16.0 (64/404)</td>
</tr>
<tr>
<td>Disease transmission</td>
<td>18.0 (72/404)</td>
</tr>
<tr>
<td>Financial losses</td>
<td>2.7 (11/404)</td>
</tr>
<tr>
<td>I do not know</td>
<td>68.0 (273/404)</td>
</tr>
</tbody>
</table>

Table 5. Practices towards tsetse control.

<table>
<thead>
<tr>
<th>Practices against the tsetse fly vector</th>
<th>Percentage % (*n/404)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you tried to prevent tsetse fly flying near animals?</td>
<td>30.0 (119/404)</td>
</tr>
<tr>
<td>If yes, what ways of tsetse control have you tried before?</td>
<td>% (*n/119)</td>
</tr>
<tr>
<td>Avoiding tsetse-infested areas</td>
<td>9.2 (11/119)</td>
</tr>
<tr>
<td>Burnt herbs near livestock herds to repel tsetse</td>
<td>19.0 (23/119)</td>
</tr>
<tr>
<td>Spraying livestock with commercially available insecticides</td>
<td>51.0 (61/119)</td>
</tr>
<tr>
<td>Applying used engine oil on the animal’s body</td>
<td>0.8 (1/119)</td>
</tr>
<tr>
<td>Using fly traps and targets</td>
<td>0.8 (1/119)</td>
</tr>
<tr>
<td>Clearing neighbouring tsetse-infested bush</td>
<td>18.0 (21/119)</td>
</tr>
</tbody>
</table>

*n: represents the number of respondents for each category.
of adequate tsetse fly knowledge (aOR 6.54 (95% CI 4.36–9.80)) relative to formal employment (Table 6).

We tested the effectiveness of our multivariable regression model AUC (95%) and found its predictive performance to be 0.76 (95% CI 0.70–0.81) and, also, the Hosmer–Lemeshow goodness of fit test value for the model was 5.06 and P = 0.75.

**Discussion**

In this study conducted around the ASFR in Kenya, we assessed the knowledge, perceptions, and practices of smallholder livestock farmers on tsetse flies and the disease they transmit, animal African trypanosomosis using a structured questionnaire for data collection. Our survey revealed important socio-demographic characteristics of the small-scale farmers living at the wildlife-livestock interphase in ASFR. Three parameters: age, level of education and employment status, were significant demographic characteristics in a logistic regression model which had an association with knowledge of T&T. These observations corroborate results by Laskowski et al. (2011) who found that age, sex, level of education and occupation played an important role in the epidemiology of communicable diseases.
diseases. From this survey, only 19% had secondary level or tertiary level of education. Contrary to other studies where the respondents were predominated by men (Mwaseba & Kigoda, 2017; Uba et al., 2016), more than half (53%) of the respondents in this study were female and about a third of them were elderly. The higher number of women could be explained by the fact that women dominate livestock keeping in the Giriama community, and the higher number of older people sampled in this study could be due to their preference to live in villages, as opposed to the younger educated generation who prefer to live and work in the major towns of Kilifi and Malindi within the County.

Therefore, the intervention measures for the prevention of AAT would mainly target the elderly, those with low levels of education and the self-employed farmers, who are the primary livestock keepers among the Giriama community surrounding ASFR. Due to the low levels of education among the participants, it would be necessary to package the health education message in a simple way as the level of education may affect the act of reading and subsequent understanding of the information, education and communication (IEC) material. Though sex was not a statistically significant parameter in the regression model, we noted that women were the main “care givers” of livestock in the study area and thus it would be important to prioritize them during health education.

Nearly all participants (98%) reported to have knowledge of tsetse flies and identified them by the local name of the tsetse fly, whereas 77% of the respondents could describe the tsetse based on the size of the adult fly, which is approximately the size of G. austeni, which is endemic in this region. However, overall, only 16% of the participants had adequate knowledge on T&T. Inadequate knowledge about a disease poses a major challenge in eradicating or reducing its transmission. The limited knowledge on T&T among the study participants shows the challenge of reducing transmission in this setting. One third of the participants were either elderly or had no formal education suggesting the need for more targeted training in language the farmers can understand using existing systems like the veterinary officers or local administration.

Our study findings are comparable to those of the farmers living near Shimba Hills National Reserve in Kenya where only 23.1% of farmers could link the causal association between tsetse flies and trypanosomosis (Machila et al., 2003). Another study, in similar setting as ASFR, carried out among participants living near Serengeti National Park in Tanzania, showed that the majority of the respondents could only identify tsetse flies by size and could not distinguish them from other similar dipteran (Mwaseba & Kigoda, 2017). In a study done among people living in and around Serengeti National Park, the participants, especially those living in the park, had adequate knowledge of trypanosomosis (Kinung’hi et al., 2006). The reason for the high level of knowledge in the Serengeti may be attributed to the high number of respondents (45%) who had attained secondary education. The latter level is higher in comparison to 15% for those with secondary and post-secondary education (4.5%), those without formal education (33 %) and those with primary level education comprising 47.5% in this study. This also underscores the fact that knowledge levels could change over time (Bates, 2015) and this needs to be assessed from time to time and the identified gaps filled through health education.

Knowledge is important in the management of diseases and participants who are familiar with the clinical signs of AAT are more likely to seek veterinary assistance because they can identify sick animals early before their body conditions deteriorate (Seyoum et al., 2013). Most of the respondents were unable to describe the clinical signs of an animal suffering from trypanosomosis. We also noted that though most of the people in formal employment had post-primary education, the self-employed farmers in this study had better knowledge of tsetse flies. This could be due to the fact that most of the employed work away from the villages and are not directly involved in livestock keeping as opposed to the farmers, the majority of which had primary or no formal education. Overall, participants in Kakuyuni had the highest level of knowledge on T&T (26%) compared to other study sites sampled despite only 16% having post primary education. This may be due to the fact that Malindi Sub County, where Kakuyuni is located, has consistently had the highest number of trypanosome cases in the entire Kilifi County (Director Veterinary Services quarterly reports (Serem et al., 2022)) and probably more farmers have seen many cases of AAT. The other location with higher levels of knowledge was in Dida, Ganze sub-County (23%), where members of the community reported increased numbers of tsetse flies especially when elephants go to the water point at the edge of the forest and it had the highest number of participants with post primary level of education (61%).

Any type of illness is referred to as “homa” by the Giriama, which means “fever”. In this study 78% of those who knew that tsetse flies transmit diseases believed that tsetse fly bites cause “homa” in humans and in livestock. Furthermore, the limited knowledge among the participants on T&T negatively influenced their perception towards prevention and control measures against T&T. About 30% of the participants were aware of the control measures and may have used one or more practices to prevent tsetse flies from biting their animals. However, only a small fraction (17%) of the participants felt that the control measures were reliable and only 7.4% felt that tsetse control strategies were affordable. Though some of the participants knew what should be done to control the flies, they could not implement the control measures due to affordability of the cost. It has, however, been observed that community willingness to contribute resources and participate in control activities is influenced by knowledge of tsetse flies and the control measures towards trypanosomosis (Sindato et al., 2008). We believe that once the farmers are knowledgeable on T&T, and the potential losses they could incur if they do not implement the control measures, their perceptions and priorities will change.

Among the respondents who implemented tsetse control practices, we observed that some of the farmers dipped or sprayed
their livestock, though they were unaware that some acaricides could prevent tsetse flies from contacting and biting their livestock. While this study did not look into the types of acaricides used by farmers in Uganda found that farmers use acaricides to which tsetse flies are resistant but only effective against ticks (Bardosh et al., 2013) thus jeopardizing tsetse control. Some of the participants tried to burn some herbal plants near the herd in order to repel tsetse flies while others cleared bushes around the herd holding area so as to prevent resting sites for the tsetse flies. Though smoke from wood (Colophospermum mopane) and cow dung has been shown to repel tsetse flies (Torr et al., 2011), it would also be important to carry out more studies on the herbs used by farmers in the study area to assess their real potential in repelling tsetse flies.

In a study by Kumaran et al. (2018) it was found that disease knowledge does not always correlate with control practice, and participants with high knowledge levels may not practice preventive measures. Understanding of how AAT affects cattle owners and how they deal with the disease is vital to development of effective, locally tailored disease control programmes (Holt et al., 2016) which may include changing their perception. Our results corroborate the observation by Alobuia et al. (2015) that low level of education among communities negatively influences preventive and control practices. Moreover, low level of education leads to community vulnerability and may require a lot of support to integrate them into preventive and control programmes to mitigate diseases (Kumaran et al., 2018). Improving the knowledge levels of the small-scale livestock farmers near ASFR could be done with the support of extension officers incorporating the members of the community. Such collaborations could ensure sustainability of the intervention programmes (Sindato et al., 2008). The acquired knowledge would influence the perception and downstream prevention and control practices of T&T for effective community engagement in limiting the spread of the AAT.

The knowledge, perceptions and preventive practices surveys, such as in the current study, could help to identify gaps in community participation in prevention and control measures towards tsetse and trypanosomosis. This could make it easier for T&T management at community level, which could contribute towards sustainability of disease control programmes. However, this study relied solely on data collected by interviewing the farmers, which could be skewed due to reporting bias as described by Bandura’s self-efficacy theory (Bandura, 1986). In addition, knowledge levels may change over time considering the current advances in technology. With the spread of smart phones, many members in the community own phones and may have access to new information from Internet sources, therefore there is need to conduct fresh surveys to validate data from previous studies from time to time.

The key findings of this study show a knowledge gap on tsetse flies and trypanosomosis among the majority of smallholder livestock farmers around the ASFR in Kilifi County, particularly among women and the elderly who make up the majority of herders in the community. Therefore, training of farmers should be considered as a way to harness the much needed human resource by involving the community members in sustainable deployment of tsetse and trypanosomosis control programmes. Our findings provide key baseline information to guide further studies, for instance those focused on disease control.

Data availability
Underlying data

This project contains the following underlying data:
- Data file 1: Underlying data.csv
- Data file 2: Clinical cases of trypanosomosis.xlsx
- Data file 3: Statistical analysis.do
- Supplementary file: Data dictionary.xlsx

Extended data
Open Science Framework: Extended data for ‘Farmers’ knowledge, perceptions, and practices on animal trypanosomosis and the tsetse fly vector: A cross-sectional study around Kenya’s Arabuko-Sokoke Forest Reserve at the livestock-wildlife interface’. https://doi.org/10.17605/OSF.IO/MQFKC (Serem et al., 2022).

This project contains the following extended data:
- Supplementary file: Consent form and questionnaire.docx

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

Consent
Written informed consent for publication of the participants’ details was obtained from the participants.

Acknowledgements
We thank the chiefs, village leaders, livestock farmers and the director of veterinary services of Kilifi County, Dr. Cornel Malenga, and Caren Kikwai whose support made this study possible. We also thank Dr. Noah Maritim, Nancy Jerotich, Raphael Wanjie, and Annie Willets for support during the preparation for/and data collection.

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