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# A survey of bovine cysticercosis/human taeniosis in Northern Turkana District, Kenya

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ABSTRACT

Bovine cysticercosis is a zoonosis that is mainly of socioeconomic and public health importance. A survey of this disease was carried out in Northern Turkana District, Kenya to estimate the prevalence through both serology and meat inspection, to determine the prevalence of the adult tapeworm in the human definitive host, and to determine risk factors for cattle seropositivity. This information is of public health importance and will be of use in assessing economic losses due to downgrading, refrigeration or condemnation of infested carcasses.

The study area was stratified into the three livestock grazing regions of Oropoi to the south, Lokichoggio–Mogilla centrally and Kibish in the north for the purposes of the serological and questionnaire ($n$ = 53 herd owners) data. Five *adakaars* (grazing units) were selected and 34, 63, 49, 75 and 571 cattle serum samples obtained from these. The slaughter slabs of Lokichoggio and Kakuma were visited and 188 serum samples were obtained from slaughter cattle and compared to results of meat inspection. Human stool samples were collected in each of the three grazing areas and 66, 97 and 78 samples were obtained.

The seroprevalence of cysticercosis in cattle was estimated at 16.7% (95% CI 13–20.9%) using a secretory–excretory antigen detection ELISA. There was poor agreement between meat inspection and serology ($k$ = 0.025; $p$ = 0.2797). The prevalence of taeniosis was estimated as 2.5% (95% CI 0.8–5.6%) by microscopy.

A backwards elimination logistic regression analysis indicated that the grazing unit (*Adakaar*), the deworming history of household members and the distance (>2 km) of grazing fields from the homestead were significant explanatory variables for cattle being found to be positive on serology. An intra-cluster correlation coefficient (ICC) of 0.07 (0.02–0.12); $p < 0.0001$ was calculated for bovine cysticercosis in this area.



## 1. Introduction

Bovine cysticercosis like other metacestode infestations in livestock is a zoonosis of socioeconomic and public health importance (FAO, 2005; OIE, 2006). Bovine cysticercosis is economically important to the Kenyan meat industry and losses incurred are conservatively estimated at approximately USD 850,000 per year from condemnation, downgrading and refrigeration of carcasses (Onyango-Abuje et al.,

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1996a,b). Taeniosis, which is the infestation in humans, is a food-borne disease where the consumption of meat containing a viable cysticercus may result in the development of a tapeworm and patients are frequently asymptomatic, however, they may present with mild symptoms of nausea, abdominal discomfort, flatulence, epigastric pain, diarrhoea, vitamin deficiency, excessive or loss of appetite, weakness and loss of weight, digestive disturbances, and intestinal blockage may occur. Variably adult tapeworms release motile distal segments containing eggs and their independent motility is the reason for various disorders such as appendicitis, biliary tract obstruction and anal pruritus (Neva and Brown, 1994).

In Kenya, the earliest estimates of prevalence were by Froyd (1960) where, 1000 cattle examined 317 had cysticerci of *Taenia saginata*, of which 227 had live cysts. Before this, abattoir findings of this infestation published in the annual reports of the Department of Veterinary Services, Kenya (1954–1958) showed figures ranging between 20 and 35% for cysts of *T. saginata*. Elsewhere in Kenya, Cheruiyot (1981) found prevalence to range from 0.74% in the Coast Province to 18% in Kisii District in Nyanza Province. In another study to estimate the prevalence of *T. saginata, Echinococcus granulosus* and *Fasciola gigantica* using meat inspection and serology from districts in three provinces namely, Rift Valley, Eastern and Northeastern provinces, the Rift Valley was found to be the most seriously affected and the highest prevalence of cysticercosis was recorded for Narok District, where 31.47% and 80.42% of the animals were detected using meat inspection and Ag-ELISA, respectively while only 9.09% of these animals were detected using Ab-ELISA (Onyango-Abuje et al., 1996a,b). Other prevalence figures reported from Kenya were 38% and 62% (Over et al., 1992). Prevalence estimates have never been done in Turkana District, which is inhabited by the nomadic Turkana pastoralists.

Most of these prevalence studies were based on meat inspection but were insensitive at diagnosing cysticercosis, inspite of a good attempt by the meat inspectors in locating cysticerci at predilection sites. Several studies (Dorny et al., 2000; Onyango-Abuje et al., 1996a,b; Kyvsgaard et al., 1990; De Giovanni et al., 1985; Geerts et al., 1981) have shown that the true prevalence of bovine cysticercosis as detected by the classical meat inspection techniques (carried out properly) is underestimated by at least a factor of 3–10. Diagnosis by serology in cattle has been done (Geerts et al., 1981; Harrison et al., 1986, 1989; Smith et al., 1991; Brandt et al., 1992; Hughs et al., 1993; Onyango-Abuje et al., 1996a,b; Dorny et al., 2000, 2002; Wanzala et al., 2002; Ferrer et al., 2003) with varying successes. Studies have indicated that antigen detection by ELISA (Ag-ELISA) is 2–10 times more sensitive than routine meat inspection and that this technique may therefore be recommended for epidemiological surveys (Geerts et al., 1981; De Giovanni et al., 1985; Kyvsgaard et al., 1990; Onyango-Abuje et al., 1996a,b; Dorny et al., 2000, 2002). The sensitivity of Ag-ELISA has been shown to vary with the live cyst burden (Onyango-Abuje et al., 1996a,b), in addition due to its unexplained false positive and negative reactions it can at best be used as a screening test and not as a diagnostic test (Wanzala et al., 2007). Such an Ag-ELISA was used in this study as a screening test.

Studies to establish the prevalence of *Taenia*sis in humans have been done elsewhere with various results (Rodrıguez-Hidalgo et al., 2003; Martinez-Maya et al., 2002; Allan et al., 1990, 1996a,b; Sarti et al., 1992; Díaz et al., 1991; García et al., 1996; Rodriguez-canul et al., 1999; Asci et al., 1998) but never in Turkana. Apart from the macroscopic observation of the adult worm or its segments the other means of diagnosis are through microscopy and ELISA on faecal extracts (copro antigen test) (Allan et al., 1990).

This study was done as part of a wider study in Northern Turkana District, Kenya on livestock diseases and natural resources. The main aim was to estimate the prevalence of zoonotic diseases and the documentation of natural resources ahead of the setting up of an export slaughterhouse in this region. The objectives of the present study were to estimate the seroprevalence of cysticercosis in cattle in Northern Turkana and the determination of the risk factors that might be contributing to its occurrence. Another objective was to estimate the prevalence of taeniosis in humans in the study area through coproparasitoscopy. The results of this study in addition to being of public health importance to other stakeholders, give an indication of the magnitude of this condition and are therefore of use in calculating the losses due to carcass condemnation, refrigeration and downgrading.

## 2. Materials and methods

### 2.1. Study area

The study was done in Northern Turkana District, Kenya, bordered by Uganda to the West, Sudan to the Northwest, Ethiopia to the North and Kakuma Division to the South. The area consists of seven administrative divisions, namely Lokichogio, Kibish, Oropoi, Kakuma, Kaaleng, Lapur, and part of Lokitaung. The area is predominantly inhabited by the Turkana pastoralist people and covers approximately 20,000 $km^2$. The estimated livestock population comprises 136,575 cattle, 1,379,000 goats, 689,100 sheep, 98,670 camels and 22,940 donkeys, which represent 70% of the livestock population in the district (AMREF, 2004). The district comprises both arid and semi-arid lands and is characterized by a warm to hot climate with temperatures ranging between 24 °C and 38 °C. Rainfall patterns are erratic and generally unreliable. The topography comprises of low-lying open plains, with an attitude of between 300 m and 900 m above sea level and a few mountain ranges that rise up to 1800m above sea level. The vegetation is mainly composed of dwarf shrubs and grasslands. Pastoralism is the main economic activity (Gok, Turkana District Development Plan 2002–2008, 2003).

### 2.2. Selection of study sites and sampling frame

For the purpose of sampling the study area was stratified into the three main regions of, Oropoi and Songot ranges to the south, Lokichoggio and the Mogilla ranges centrally, and Kibish to the northwest, based on the concentrations of the cattle grazing areas. The pastoralist

households were organized into grazing units (*Adakaars*), which would sometimes merge into larger groups to secure their herds against rustlers and a household may have more than one herd in different locations. The livestock management was such that the calves, lambs and kids remained near the homestead while the adult animals were grazed far.

A visit was made to the *adakaars* present and accessible in the area at the time of the study: with the help of the *adakaar* heads, a list of all households within each adakaar was made. The selection criteria for the households from these lists were based on them fulfilling the conditions that the head of the household was present to give consent, that they owned cattle, and, that the head agreed to participate in the study after they were informed on the objectives and sampling procedure. Individual animals of all ages in a herd were selected for bleeding through systematic sampling by taking every $N/n$th animal where $N$ was the number in the herd and $n$ the required sample size from the herd. The blood samples were kept overnight at 4 °C, serum was harvested and stored at −20 °C until testing.

### 2.3. Sample size calculation

#### 2.3.1. Adakaar cattle sample size

The sample size of animals to be bled was computed according to the method of Martin et al. (1987), using the following formula:

$$n = \frac{Z_\alpha^2 pq}{L^2} \quad (1)$$

Where $n$ being the required sample size, $Z_\alpha$ = is the normal deviate (1.96) at 5% level of significance, $p$ is the estimated prevalence and $q = 1 - p$, and $L$ is the precision of the estimate.

With $p$ set at 0.8 (Onyango-Abuje et al., 1996a,b) and $L$ at 5%, a sample size of 245 was required. This sample size was tripled to take care of the effect of clustering into adakaars, to a final required sample size of 735 cattle.

#### 2.3.2. Slaughter slab cattle sample size

A sample size of 245 was calculated according to the method of Martin et al. (1987) and based on the prevalence estimates by Onyango-Abuje et al. (1996a,b) using Eq. (1).

#### 2.3.3. Human stool sample size

The sample size of humans to be selected to provide a stool sample was computed according to the method of Martin et al. (1987) using Eq. (1).

With $p$ set at 0.0499 based on the prevalence estimates of Rodrıguez-Hidalgo et al. (2003) and $L$ at 5%, a sample size of 75 persons was calculated. This sample size was tripled to take care of the clustering effect, to a final required sample size of 225 subjects (Martin et al., 1987).

### 2.4. Sample collection

#### 2.4.1. Collection of serum samples

Blood samples were collected from cattle in the three regions of the study area between 20th October 2006 and 6th November 2006. The blood samples were taken using the Vacutainer system (Becton and Dickinson), approximately 10 ml from each animal.

Blood samples were also collected from cattle slaughtered at the Lokichoggio and Kakuma slaughter slabs between September 2006 and January 2007 for the purposes of determination of agreement between meat inspection and serology. Meat inspection data was obtained from the veterinary and public health departments.

#### 2.4.2. Collection of stool samples

Stool samples were collected from the Turkana pastoralists between January 2007 and April 2007 at four locations in the study area with at least one location in each region as follows Nanam in Lokichoggio the region, Natira in Oropoi, and both Kokuro and Kaikor in Kibish region. The stool samples of volunteers were collected through the treatment with praziquantel and purged with bisacodyl. The stool samples were preserved as two aliquots, one in 99% ethanol and the other in 5% formol-saline containing 0.3% Tween-20 until analysis could be done. The tapeworms collected were washed and kept frozen at −20 °c in a solution of phosphate buffered saline (PBS) containing 0.3% Tween-20 until speciation could be done.

### 2.5. Assessment of risk factors

A semi structured questionnaire with both closed and open ended questions was administered to all 53 herd owners individually concurrent with blood sampling to obtain data on possible risk factors for cysticercosis in cattle. The questionnaire was in English although translation to Swahili or Turkana languages was required most of the time using interpreters.

The questionnaire collected information on the respondents' identity, location, personal information, in addition the household characteristics, meat preparation practices, livestock management practices, meat hygiene practices, and it also included a section on the respondent's remarks regarding their knowledge of cysticercosis.

### 2.6. Laboratory analysis

#### 2.6.1. Detection of circulating antigen

Antigen ELISA was conducted as previously described by Harrison et al. (1989). Circulating parasite antigen was detected using the mouse McAb, HP10 in an antigen trapping ELISA. Linbro polyvinyl chloride microtitre plates (Dynatech Laboratories, Inc., VA, USA) were coated with a monoclonal antibody (McAb), 100 μl per well of HP10 an IgM isotope that detects glycoproteins as antigens of viable *Cysticercus bovis* at a concentration of 10 μg/ml in Carbonate/Bicarbonate buffer pH 9.6. The plates were covered to prevent evaporation and incubated overnight at 4 °C. The plates were washed twice with 0.9% (w/v) NaCl–0.05% (w/v) Tween-20 washing solution at a 5 min interval between washes, blocked with 200 μl per well of phosphate buffered saline, pH 7.3 (PBS) containing bovine serum albumin (BSA) and Tween-20 and incubated for 1 h

at room temperature. After washing the plates three times and allowing them to stand for 5 min between washes, undiluted test serum samples were added, 100 μl per well and incubated at 37 °C for 1 h. The plates were washed three times as above and biotin-conjugated McAb HP10, diluted at 1:2500 in PBS/BSA/Tween-20, was added 100 μl per well and further incubated at 37 °C for 1 h. The plates were washed three times as above and streptavidin biotinylated horseradish peroxidase conjugate diluted at 1:10000 in PBS/BSA/Tween-20, was added 100 μl per well and the plates were further incubated at 37 °C for 1 h. The plates were then washed as above and 100 μl of the substrate, 3′3′5′5′-tetramethylbenzidine (TMB), was added to each well and then incubated for 10–30 min. The reaction was stopped with 100 μl of 0.2 M $H_2SO_4$ per well and the absorbance was read at 450 nm wavelength on an ELISA reader (Humareader). The optical density (OD) cut-off point used to differentiate positive from negative ELISA results was based on a mean of Sample to Positive ($s/p$) values plus five standard deviations (S.D.) of negative control sera readings. This IgM isotope based assay has sensitivity of 60.00–80.00%, specificity of 60.00–100% (Wanzala et al., 2007).

*2.6.2. Detection of Taenia saginata eggs*

The stool samples were processed using the faecal concentration method according to the protocol set by the WHO. Approximately 1 g of faecal sample was mixed with 10% formol-saline to an emulsion and then sieved through a cotton gauze mesh. Three milliliters of ethyl alcohol was then added and mixed thoroughly. This was then centrifuged at 2500 × $g$ for 5 min. The supernatant was poured off and the residue observed under a microscope at 10× magnification for the typical *Taenia* eggs.

*2.7. Data handling and analysis*

All statistical analyses were performed using Stata 8 (Stata Corporation, College station, Texas). This will eliminate the repetition of Stata 8 in the proceeding sections.

*2.7.1. Risk factor data analysis*

The unit of statistical analysis was the individual cattle. The questionnaire data were combined with the serology data in a MS Excel (Microsoft Corporation) spreadsheet, the overall seroprevalence was computed with owner/herd as the random effect, similarly the responses to the questionnaire were modeled in a logistic regression model with owner/herd a random effect, to adjust for, using the serological test result of individual animals as the outcome. For the purpose of modeling these data, explanatory variables were first explored for any associations with the serology result using Chi-square and Fishers Exact test where applicable and a liberal $p$-value (0.15) was used to determine significance (Dohoo et al., 2003). Correlations between the explanatory variables were assessed to identify highly correlated variables (>0.5) this was then followed by a backwards elimination logistic regression proceeding from the variables with the highest $p$-values to arrive at the most parsimonious model. A threshold $p$-value of 0.1 was used in order to include only those variables that are strongly significant. The likelihood ratio test statistic ($G^2$) was used to test the goodness of fit of the final model, confounding and interactions were assessed following the procedures outlined in Dohoo et al. (2003) in the final model.

*2.7.2. Slaughter slab samples*

Descriptive analysis was done for the slaughter slab data and the level of agreement between the detection of circulating and meat inspection findings was examined using the *kappa* ($\kappa$) measure of consistency.

*2.7.3. Human samples*

Descriptive analysis and computation of prevalence was done for the collected samples.

*2.7.4. Ethics review and approval*

Studies and data collection methods were approved by the African Medical and Research Foundation (AMREF) and University of Nairobi ethical review committees. All the study participants were consented before their participation in the research. Animal experimentation was conducted according to the International Guiding Principles for Biomedical Research.

## 3. Results

*3.1. Field cattle*

The numbers of sampled cattle were distributed in the three regions as follows, Kibish 569 (71.8%), Lokichoggio–Mogilla 124 (15.66%), and Oropoi–Songot 99 (12.5%). The proportion of infested cattle, measured by Ag-ELISA was approximately 17% in Kibish, 31% in Lokichoggio–Mogilla, and 19% in Oropoi–Songot; the overall estimated seroprevalence of this condition for this area was 16.7% (13–20.9% CI). There were 53 herds sampled and of these 31 (58.5%) were in Kibish, 9 (17%) in Lokichoggio–Mogilla, and 13 (24.5%) in Oropoi–Songot. The herds were also distributed as follows among the *Adakaars*: Edoe 5; Lotiragae 31; Ngiwoiyasike 8; Nginyamakidiok 1; and Ngitoroboi 8. The average herd size was 15 with a range of 6–21 and out of 53 herds 7 (13.21%) were negative and 46 (86.79%) had at least one positive animal.

*3.2. Slaughter slab cattle*

The slaughter slab samples collected were distributed as follows 96 from Lokichoggio and 92 from Kakuma. A majority (147) of these samples were from cattle brought in from across the borders while the rest (41) were sourced locally. On ELISA 44 were positive while only 6 were earlier found to be positive on meat inspection. The proportion found positive in the serum samples was 28% (27/96) from the Lokichoggio slab and 19% (17/92) from the Kakuma slab. There was no significant difference between these proportions ($p = 0.1149$). A *kappa* value of 0.0252 ($p = 0.2797$) was obtained using the *kappa* inter-rater agreement for two unique raters procedure, indicating

poor agreement between serology and meat inspection. From records at the public health office, Turkana, three carcasses were found to have *C. bovis* cysts out of the 669 cattle slaughtered at the Kakuma slab in 2006 giving an estimated prevalence of 0.5% from this slab. From records at the District Veterinary Office, Turkana, the slaughter figures were based on the monthly slaughter at Lokichoggio slaughter slab and out of 330 cattle in 2006, 8 carcasses were found to have *C. bovis* cysts giving an estimated prevalence of 2.4% from this slab. Out of approximately

**Table 1**
Description and contigency test results for explanatory variables used in the logistic regression analysis.

| No. | Category | Variable | Level | ELISA | | Chi-square | Fishers exact | $p$-Value ($\chi^2$) |
|---|---|---|---|---|---|---|---|---|
| | | | | − | + | | | |
| 1. | Location | Region | Kibish | 483 | 86 | 16.7 | | <0.0001 |
| | | | Lokichoggio–Mogilla | 86 | 38 | | | |
| | | | Oropoi–Songot | 80 | 19 | | | |
| | | Adakaar | Lotiragae | 496 | 90 | 17.3 | | 0.002 |
| | | | Edoe | 26 | 8 | | | |
| | | | Ng'iwoiyasike | 33 | 16 | | | |
| | | | Ng'inyamakidiok | 40 | 18 | | | |
| | | | Ng'itoroboi | 54 | 11 | | | |
| 2. | Personal information of household heads | Gender | Male | 360 | 80 | 0.0107 | | 0.9 |
| | | | Female | 289 | 63 | | | |
| | | Education | None | 596 | 138 | 3.7653 | | 0.052 |
| | | | Primary | 53 | 5 | | | |
| 3. | Household characteristics | Cattle slaughtered in 2006 | None | 222 | 46 | 0.2175 | | 0.64 |
| | | | At least one (1–5) | 427 | 97 | | | |
| | | Distance of water source | Near (<2 km) | 519 | 115 | 0.0149 | | 0.9 |
| | | | Far (>2 km) | 130 | 28 | | | |
| | | Latrines | Absent | 568 | 129 | 0.8 | | 0.37 |
| | | | Present | 81 | 14 | | | |
| | | Household members dewormed in 2006 (deworming history) | None | 428 | 79 | 5.8271 | | 0.016 |
| | | | At least one | 221 | 64 | | | |
| | | Frequency of deworming | When affected | 644 | 141 | | 0.616 | |
| | | | Yearly | 5 | 2 | | | |
| | | Way of life | Nomadic | 514 | 123 | | 0.095 | |
| | | | Semi-nomadic | 11 | 3 | | | |
| | | | Settled | 124 | 17 | | | |
| | | Water source sharing | Shared | 644 | 140 | | 0.161 | |
| | | | Not shared | 5 | 3 | | | |
| | | Treatment of infected meat | Thorough cooking | 148 | 26 | | 0.48 | |
| | | | Disposed | 19 | 2 | | | |
| | | | Nothing | 7 | 1 | | | |
| | | | I don't know | 340 | 77 | | | |
| | | | Other | 135 | 37 | | | |
| 4. | Preparation of meat | Roasting | Yes | 616 | 130 | 3.4377 | | 0.064 |
| | | | No | 33 | 13 | | | |
| | | Frying | Yes | 80 | 20 | 0.2925 | | 0.589 |
| | | | No | 569 | 123 | | | |
| | | Drying | No | 644 | 141 | | 0.616 | |
| | | | Yes | 5 | 2 | | | |
| 5. | Livestock management practices | Distance of grazing grounds | Near (<2 km) | 75 | 6 | 6.9145 | | 0.009 |
| | | | Far (>2 km) | 574 | 137 | | | |
| | | Type of water source for cattle | Surface | 90 | 17 | 1.0205 | | 0.6 |
| | | | Ground | 414 | 89 | | | |
| | | | Both | 145 | 37 | | | |
| 6. | Meat hygiene | Frequency of meat inspection | Never | 589 | 234 | | 0.565 | |
| | | | Always | 43 | 6 | | | |
| | | | Sometimes | 17 | 3 | | | |
| | | Meat inspector | None | 589 | 134 | 1.2833 | | 0.257 |
| | | | CAHW | 60 | 9 | | | |
| * | Personal remarks/ knowledge of cysticercosis | | Knowledge of existence of larval stages of worms in meat/viscera: yes, no, not sure<br>Location of these on the carcass: intestines, muscles, heart, abdominal cavity, other<br>Their appearance: white cysts, adults, fluid-filled cysts, cysts on viscera, other<br>Source of infection for cattle: pasture, water, other<br>Risk of people getting infected with these: yes, no, not sure<br>Source of infection to humans: undercooked meat, not sure, other | | | | | |

*Objective*: Estimation of the seroprevalence of bovine cysticercosis and prevalence of human taeniosis and the determination of the risk factors in Northern Turkana, Kenya. Sample size: cattle, $N = 735$ and human stool, $N = 225$.

**Table 2**
The variables remaining in the final model with odds ratios, confidence intervals of odds, and the *p*-value for the log ratio test for each of the remaining terms.

| Variable | Levels | Odds ratio (OR) | 95% CI | *p*-Value (LR $\chi^2$) |
|---|---|---|---|---|
| Grazing unit (*Adakaar*) | Lotiragae | 1 | – | 0.025 |
| | Edoe | 1.7 | 0.7–4.3 | |
| | Ngiwoiyasike | 2.9 | 1.4–6.1 | |
| | Nginyamakidiok | 2.4 | 1.2–5.0 | |
| | Ngitoroboi | 1.4 | 0.6–3.0 | |
| Deworming history | No household member dewormed | 1 | – | 0.0024 |
| | At least one member dewormed | 2.0 | 1.3–3.3 | |
| Distance of grazing area | Near (<2 km) | 1 | – | 0.0098 |
| | Far (>2 km) | 3.2 | 1.2–8.4 | |

*Objective*: Estimation of the seroprevalence of bovine cysticercosis and prevalence of human taeniosis and the determination of the risk factors in Northern Turkana, Kenya. Sample size: cattle, $N = 735$ and human stool, $N = 225$. $G = 23.23$, d.f. = 7, $p = 0.0016$.

1290 cattle slaughtered and inspected in 2006 in the Lodwar, Kakuma, Lokichoggio and Lokitaung slabs which are the main slabs in the study area, an overall estimated prevalence of 0.87% was found.

According to the Meat Inspection Act CAP 356 of the laws of Kenya carcasses found with 1–5 cysts shall be frozen at below 10 °C for 10 days and released unconditionally, those with 6–20 cysts shall be treated similarly and released conditionally, and those with generalized infection shall be condemned.

### 3.3. Human stool samples

The sampled human stool samples were distributed as follows in the three regions, Kibish 77 (37.7%), Lokichoggo–Mogilla 60 (29.5%), Oropoi–Songot 67 (32.8%), females accounted for 89 (43.6%) while males accounted for 115 (56.4%), 47% of those sampled were between the ages of 13–20 years, 36% between 21 and 60 years, and 17% between 1 and 12 years. The prevalence of taeniosis for this region was estimated as 2.5% (0.8–5.6%) by microscopy, 4/5 (80%) of which was accounted for by Kibish region, 1/5 (20%) by Lokichoggio region, and none by Oropoi region. The specimens collected were subsequently identified as *T. saginata* using a conventional PCR by a separate worker at the Salford University, United Kingdom (Alice Tembo, unpublished results).

### 3.4. Risk factors for seropositivity in cattle

Questionnaire data with household heads was translated into explanatory variables which were assessed for association with the outcome of an animal being found to be positive on serology using the Chi-square and Fishers Exact tests where appropriate. The grazing unit (*Adakaar*), deworming history of household members, roasting as means of meat preparation, distance of grazing grounds from the homesteads were found to have significant association as shown in Table 1.

Of the 18 variables introduced in the logistic regression model grazing unit, deworming history of household members, and 'distance of the grazing area from the household' remained in the model after backward selection as significant risk factors for cattle seropositive for bovine cysticercosis (Table 2). Interaction was detected between grazing unit and distance of grazing area from households with the Lotiragae and Ngitorooi grazing units explaining most of the effect of grazing area.

An intra-cluster correlation coefficient was calculated using the ANOVA method using the survey data, an ICC of 0.07 (0.02–0.12 CI) and the grouping effect of herds was significant ($p < 0.0001$). Herds were the level at which clustering was assessed and in this study there were 53 herds with an average of 15 sampled cattle (range of 6–21).

## 4. Discussion

In this study, an Ag-ELISA was used to estimate the seroprevalence of bovine cysticercosis in 'field cattle'. The point estimate was lower than the 38% overall prevalence figure for Kenya (Over et al., 1992). The circulating antigen was detected in 152 out of 792 animals 16.7% (13–20.9% CI). This figure was about 20 times that obtained from meat inspection (0.87%) records of slabs in this area. The true seroprevalence figure was calculated to be 20% (15–25%) using the method of (Rogan and Gladen, 1978). These results are in disagreement with those of similar studies done elsewhere (Kyvsgaard et al., 1990; Onyango-Abuje et al., 1996a,b; Dorny et al., 2000, 2002; Rodrıguez-Hidalgo et al., 2003) where the estimate of prevalence's by Ag-ELISA were between 2 and 10 times those estimated by meat inspection. One of the explanations for the type of meat inspection results obtained in this study lies in the quality of personnel charged with the responsibility of meat inspection in most of the slabs in this area. The Kakuma slabs record the highest numbers of kill, an average of 60 cattle per month, but it was not until the commencement of this study that the first case of *C. bovis* was observed according to data from the Public health officer, Lodwar. The Lokichoggio slab taken alone for the year 2006 had an estimated prevalence of 2.4% according to data from the District Veterinary Officer for Turkana District and this can be attributed to the better trained meat inspector stationed there. Considering the meat inspection results from the Lokichoggio slaughter slab only, the prevalence of *C. bovis* is underestimated by a factor of about eight by meat inspection. The risk factor analysis revealed that the grazing unit, deworming history

of household members and distance of the grazing area from the homesteads were significantly associated with cattle testing seropositive for *C. bovis*. In a similar study in herds from northern Belgium; location, number of cattle slaughtered, flooding and free access to surface water were considered significant explanatory variables for *C. bovis* (Boone et al., 2007), despite the dissimilar climatic conditions with Turkana. Prior to the start of this study it was expected that there would be some clustering of the data at the level of the grazing unit (Adakaar) or the herd, therefore the sample size for this study was adjusted accordingly and during analysis herd owner was found to be a significant grouping effect. The analysis yielded intra-cluster correlation coefficient (ICC) consistent with those documented for other helminth infestations (Otte and Gumm, 1997).

The stool sample results suggest a higher prevalence of taeniosis estimated at 2.5% by microscopy. Studies elsewhere showed prevalence estimates of taeniosis to be 1.2% in Mexico (Martinez-Maya et al., 2002), 1.6% in Ecuador (Rodrıguez-Hidalgo et al., 2003) without differentiating between *T. saginata* and *T. solium*, and 2.3% in Turkey (Asci et al., 1998) using the concentration technique were found. According to the annual laboratory report (2005/2006) for the AMREF community based health care (CBHC) project, there were no *Taenia* species eggs observed in 329 stool sample examinations by direct saline examination during this period. It is worth noting that in the laboratory data/findings annex of the CBHC technical progress report for the period October 1998 to October 1999 out of the 2513 stool samples examined 14 contained *Taenia* species eggs. In the present study, there was difficulty collecting stool samples for detection of adult tapeworms and/or their eggs due to low participation of subjects from the target population, prevalence therefore may be underestimated due to participation bias. *Taenia* carriers were encountered in the Lotikipi plains in Lokichoggio Division and in the Kaikor area of Kaaleng Division showing that several divisions are affected. The specimens collected were subsequently identified as *T. saginata* using a conventional PCR by a separate worker at the Salford University, United Kingdom (Alice Tembo, unpublished results).

As expected there was poor agreement between the serology and meat inspection and this was in agreement with the findings of Onyango-Abuje et al. (1996a,b). The problem of standard meat inspection not being a good test to detect carcasses infested with cysticerci should lead to a broader discussion on and whether or not a more sensitive test should be used at the slaughter house level. The proposal for more incisions to be incorporated in the current meat inspection has the advantage of being able to detect more infected carcasses but the disadvantage of carcass mutilation. The use of serology (Ag-ELISA) has the advantage of detecting infested animals before slaughter, but lacks the required sensitivity to detect lightly infested carcasses. Obviously, the introduction of more sensitive tools is related to costs of testing, and an increased number of infested carcasses, which might require freezing or condemnation. However, these additional costs should be weighed against the benefits of decreased human infections and the potential to break the transmission cycle of bovine cysticercosis in the region, which will also benefit the export market.

In conclusion, an export market for beef and its products can only be safeguarded by the implementation of a control programme that has to include intervention efforts at various points of the lifecycle, the adoption of improved detection methods for bovine cysticercosis and the integration of other stakeholders such as health workers, veterinarians, meat inspectors and the Turkana pastoralists in order to be effective.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.prevetmed.2009.02.010.

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