DU Undergraduate Research Journal Archive

Volume 4 | Issue 1 Article 6

2-24-2023

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Overall, more marabou storks were found at the largest abattoir, where the most animals are slaughtered daily. More storks were seen in areas where abattoir workers throw the birds offcuts. An apparent association between the number of marabou storks and the level of human disturbance exists, with more storks found in areas of higher disturbance. However, this is likely influenced by the presence of free food. The presence of other scavenging birds did not have any effect on the presence of marabou storks under statistical analysis using a chi-square test (χ^2, df =1, n = 90, $\alpha = 0.01$).

Keywords

Marabou storks, Abattoirs, Urban adaptations, Scavenging birds

FACTORS AFFECTING PRESENCE AND OCCUPANCY OF MARABOU STORKS *(LEPTOPTILOS CRUMENIFERUS)* AT ABATTOIRS AND SLAUGHTER SLABS NEAR JINJA, UGANDA

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Abstract

This study examined the factors affecting the presence and occupancy of marabou storks at abattoirs and slaughter slabs near Jinja, Uganda. The average number of storks per unit area was compared across different areas within one large abattoir, including an analysis of the presence of free food, human disturbance, and other scavenging birds (pied crow, piapiac, spur-winged lapwing, and cattle egrets). Occupancy across two abattoirs and one slaughter slab was compared and related to the number of animals slaughtered daily at the facility. Direct observations at abattoirs and slaughter slabs were conducted for ten minutes with five minutes between observations. All observations were taken at the same time of day. Brief interviews with officials at each facility provided information about the number of animals slaughtered and the areas that make up the abattoir.

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1 INTRODUCTION

1.1 Background Information

Uganda, located in East Africa, is known to have several breeding colonies of marabou storks, which were last mapped by Pomeroy, and in 1973 there were colonies present in both rural and urban areas[1]. Marabou storks can feed either on natural food such as fish, carcasses, and insects or on anthropogenic waste from human activities[2]. In urban areas such as Jinja, storks feed almost entirely on human refuse at landfills, abattoirs, and fisheries[1,2]. This study focused on abattoirs and slaughter slabs in the Jinja and Buikwe districts, where marabou storks are present. Uganda produces 142,000 metric tons of meat per year[3] at abattoirs and slaughter slabs. Similar activities occur at abattoirs and slaughter slabs. A result of this is the production of organic waste in various forms, which attracts many scavengers. In an increasingly urban world, more animals are adapting to urban environments. Urban animals have shown decreased vigilance and "neophobia," or fear of new things[4]. This is oftentimes an effect of a form of habituation, in which "an initial disposition to escape from humans wanes and is replaced by tolerance of human presence"[5]. This process can be sped up through attraction, such as the offering of food, which leads to animals with a positive attitude toward humans, a process known as provisioning. The main difference between habituated and provisioned animals is the positive attraction to humans found in provisioned animals. This often occurs because humans feed or otherwise praise animals, which can lead to begging behaviors in animals. This can eventually lead to violence toward people when the food source is removed or not provided in the volume the animals desire[5]. Furthermore, provisioning "localizes the animals," meaning that they return to the same area on a routine and sometimes change their regular schedules to be close to the food

source[5].

Marabou storks have a long and complicated history with humans. Locally known as karoli in Uganda, these birds were historically hunted for their down feathers[6]. Due to low prices, selling marabou stork meat has become a more common practice despite legal restrictions placed due to health concerns over the spread of zoonotic diseases[7].

The Ugandan parliament further warns about zoonotic diseases emerging from marabou storks, even removing marabou stork nests from nearby the parliament building to protect members of parliament from this potential health risk[8]. Studies have found that marabou stork feces can contain E. coli, Salmonella, and other harmful bacteria[9]. These issues will become more prevalent if the population of marabou storks continues to grow out of control, so research on these birds is vital.

Marabou storks, however, can also be beneficial aids to waste management, especially in urban areas. For this reason, according to staff at the abattoirs, workers generally enjoy having the birds around and workers even encourage marabou stork's presence by throwing them food regularly.

1.2 Study Area

Dumping grounds near abattoirs and slaughter slabs are the main area of focus for this study. Three locations were studied to provide a stratification of various-sized abattoirs: Jinja City Cattle Association (JCCA), Bugembe slaughter slab, and Njeru Municipal Abattoir Association (NMAA), with JCCA being the largest and NMAA the smallest.

Figure 1. Map of JCCA

Figure 2. Map of Bugembe Slaughter Slab

Figure 3. Map of NMAA

1.3 Problem Statement and Objectives

As waste management continues to pose challenges for communities worldwide and especially in Africa, many animal species have adapted to increasingly urban and polluted environments[10]. Marabou storks are one such species that benefit from the year-round food sources in urban environments.

It was predicted the marabou stork population would continue to grow until food becomes a limiting factor[11]. No further research on marabou storks feeding in urban environments has been conducted, but stork populations continue to rise. As marabou stork populations continue to grow at very high rates, issues concerning the spread of zoonotic diseases (diseases spread from animals to humans), hygiene, and the general nuisance nature of these birds grow as well[1;9;8;12].

Area Number	Description	Area m²	Presence of Marabou Storks	Level of Human Disturbance
1	Temporary storage of horns and bones	250	None	1
2	Processing of collected blood	280	None	1
3	Livestock enclosures	2360	Some	2
4	Livestock grazing	4020	Many	2
5	Back of building	790	Many	3
6	Directly outside the slaughter building	260	Many	3
7	Slaughterhouse roof	800	Some	1
8	Processing of legs	290	None	1
9	Small shops for workers	700	None	3
10	Entrance	1650	Many	2

Table 1 Description of JCCA Areas

Learning more about the role these birds play in urban ecosystems and how their presence can be controlled is an important step in managing these species. If the population is allowed to grow out of control, there could be an increase in detrimental effects on humans. By understanding these birds, efforts to mitigate negative future impacts of them, such as disease and nuisance, can be made while preserving the benefits of their presence, such as waste management and ecological scavenging services.

This study determined the factors affecting the presence and occupancy of marabou storks at abattoirs and slaughter slabs near Jinja, Uganda. Four main objectives were identified:

i. To compare the occupancy of marabou storks in areas where they are thrown food (entrance, slaughter building, and back area) to areas where they are not (7 areas, Table 1) at Jinja City Cattle Association.

ii. To relate the occupancy of marabou storks to the level of human disturbance in each area at Jinja City Cattle Association.

iii. To compare the occupancy of marabou storks as related to the number of animals (cows, goats, and sheep) slaughtered at each abattoir and slaughter slab (Jinja City Cattle Association, Bugembe Slaughter Slab, and Njeru Municipal Abattoir Association).

iv. To relate the presence of marabou storks to the presence of other scavenging birds present at abattoirs (pied crow, piapiac, spur-winged lapwing, and cattle egret).

It is predicted that the occupancy of marabou storks will be highest in areas where they are thrown free food by the workers. Abattoirs with more animals slaughtered per day will have more birds, as this creates more waste for them to scavenge. Lastly, it is thought that marabou storks are highly adapted to the urban environment, so the level of human disturbance will not affect their occupancy.

2 METHODOLOGY

2.1 Methods

The researcher visited multiple locations in and around Jinja, Uganda over a period of two weeks.

Direct observations of the number of storks took place from 7 am-10 am by walking around the facility and taking note of the number of birds in each area. According to Jimmy, an employee of the facility, this time provided information about the maximum occupancy of marabou storks during feeding time since this seems to be the time when the most storks were present. GPS coordinates were used to estimate the area and create a map for reference. The researcher walked around the facility, taking note of the number of birds in each area. Three counts were conducted five minutes apart at each location. This was to account for small variations in the number of birds leaving and entering each area. Five one-hour periods and four half-hour periods were spent at JCCA. Two one-hour periods each were spent at Bugembe slaughter slab and NMAA. Data from the manager or owner of the abattoir or slaughter slab about the number of animals slaughtered per day and descriptions of the activities in each area of the abattoir or slaughter slab were obtained through brief interviews with officials at each location.

2.2 Data Analysis

Non-parametric tests were selected to account for non-Normal data distributions. A residual plot of the parametric ANOVA test was used to determine whether a nonparametric test should be used. Since residuals of this test were not randomly distributed, a nonparametric test was used. A categorical bar chart re-

lating the number of birds per m2 within each area at JCCA was created. A Kruskal-Wallis test was used to determine if there were any significant differences between any two of the areas observed. The Steel-Dwass method was then used to further categorize this relationship and determine if there was a statistically significant difference.

Similarly, a categorical bar chart showing the average number of birds per square meter at the three levels of human disturbance was created.

A chi-squared analysis of a contingency table relating the presence of marabou storks with each other species of bird was performed to determine if the presence of marabou storks was independent of that of other bird species.

3 RESULTS

3.1 Presence of Food

The highest number of storks per square meter at JCCA was found in the back area and behind the slaughter building, followed by the entrance and the roof of the slaughter building. A Steel-Dwass method showed differences between bars labeled with different letters in Figure 7 (Appendix 3). Measurements of different areas were not taken at Bugembe slaughter slab or NMAA due to their small size and lack of separation of activities.

3.2 Human Disturbance

Three levels of disturbance, as defined in Table 1, were recorded and the number of birds in each area graphed. The Steel-Dwass method showed a significant difference between each pair of the three datasets, as shown with different letters in Figure 5. These data were only recorded at JCCA.

3.3 3.3 Number of Animals Slaughtered

JCCA had the most marabou storks by far as well as the highest number of animals slaughtered per day.

3.4 Presence of Other Scavenging Birds

The presence of marabou storks and other scavenging birds was recorded each day, and a chi-square analysis was conducted. Chi-square results show that the null hypothesis, stating that there is no relationship between the presence of marabou storks and other birds, cannot be rejected. No significant dependence between the presence of marabou storks and cattle egrets, piapiac, pied crows, and spur-winged lapwings was found (Appendix 4).

4 DISCUSSION

4.1 Presence of Food

The occupancy of the marabou storks varied significantly depending on the presence of food. The most storks by far were found at JCCA, which is the only location that throws offcuts to the birds. This further points to the reliance of the marabou storks on free food from the abattoir workers. JCCA and Bugembe slaughter slab were unable to estimate this value themselves.

Marabou storks were mainly found in areas with free food, which indicates their reliance on anthropogenic activities. This means that the marabou storks are inevitably here to stay if human activities proceed, which affirms Pomeroy's prediction of a steadily increasing population of storks until food resources become limited [11].

4.1.1 A case study: Jerry the Electrocuted Stork

One marabou stork at JCCA, known by the abattoir workers as "Jerry," was electrocuted on a nearby telephone wire several months before the study. Due to this injury, Jerry stays at the abattoir every night, and he is completely reliant on food from the abattoir. Natural selection is not in his favor, and he likely would have died soon after his injury if not for the food from abattoir workers. This is one example of the reliance these birds have on the abattoir workers for food.

4.2 Human Disturbance

More birds were found in areas of higher human disturbance. The presence of free food overlaps with the categories of human disturbance, wherein abattoir workers primarily throw free food to storks in areas with higher human disturbance, making this a confounding variable.

Additionally, human tolerance of storks highly influences this relationship. The occupancy of storks in different areas was only recorded at JCCA due to its size, but the treatment of storks here is also likely impactful on the storks' presence. Ssenga, an employee at JCCA, states that they generally enjoy the storks' presence and throw them free food. This is not the case at other abattoirs such as NMAA, where workers actively chase off the birds when they come near the slaughtering area. This points to the importance of human tolerance in addition to the provisioning of storks.

Marabou storks were found in many areas with high levels of human disturbance, indicating that human activity is not a deterrent. To keep marabou storks out of residential or business areas, deterrents other than human activity may be needed. The provisioning of storks has led to their perpetual presence at abattoirs, which may become a problem in the future as their population continues to grow. Throwing food to these

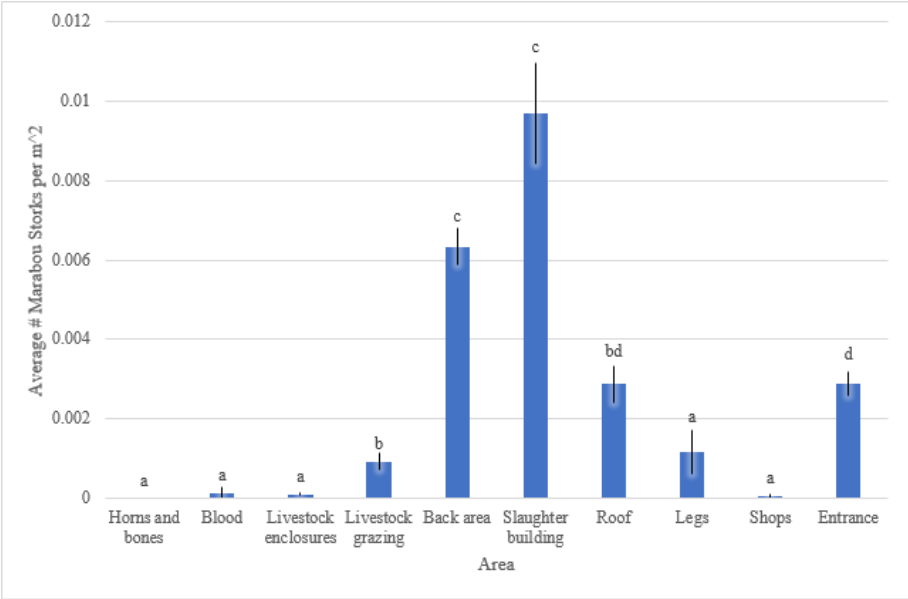

Figure 4. Average Number of Marabou Storks per Square Meter by Area ($\chi^2 = 199.4860$, $p < 0.001$, $df = 9$).

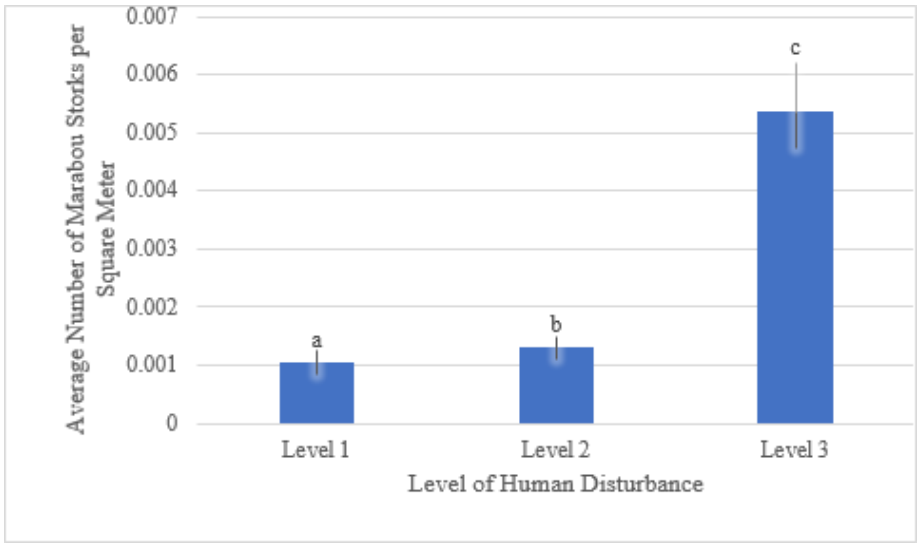

Figure 5. Average Number of Marabou Storks per Square Meter by Human Disturbance Level at JCCA ($\chi^2 = 48.3130$, $p < 0.001$, $df = 2$).

birds may eventually cause problems for abattoirs as the birds become more demanding or even violent towards the workers.

4.3 Number of Animals Slaughtered

The most marabou storks were observed at JCCA (Table 2), which is where the most animals were slaughtered. There is an apparent association between the number of animals slaughtered and the number of marabou storks seen, but more data from abattoirs is needed to further classify this relationship. Large abattoirs should invest in more research around these birds and their role in the micro-ecosystems created at these facilities to better inform practices such as throwing food and chasing the birds off.

4.4 Presence of Other Scavenging Birds

No significant dependence of occupancy between marabou storks and any other scavenging bird (pied crow, piapiac, spur-winged lapwing, or cattle egret) was found. Even though marabou storks were seen taking food from other birds, especially pied crows, this did not affect their presence. This is likely because of the different ecological niches each of these species offer. This follows theories of resource partitioning, which predict that species will evolve to fill all possible niches in an

Facility	Animals Slaughtered	Marabou Storks
Jinja City Cattle Association	75	18.89
Bugembe Slaughter Slab	22.43	0.33
Njeru Municipal Abattoir Association	18	0.5

Table 2 Average Number of Marabou Storks and Animals Slaughtered per Day by Facility. The total number of animals slaughtered, and the average number of marabou storks counted per day at each location.

Figure 6. Marabou Storks Awaiting Food Scraps outside the JCCA Slaughter Building. This behavior is characteristic of provisioning.

Figure 7. Jerry the Electrocuted Stork

environment[13]. The coexistence of these birds suggests that they all occupy different niches in this environment through Gause's competitive exclusion principle[14].

Further research about the number of each species of bird in each area may show an association. Marabou stork presence was found to be independent of the presence of piapiacs, pied crows, and spur-winged lapwing. However, very few birds of prey such as black kites and hooded vultures were spotted because they occupy a similar ecological niche. More research about competition between these species is needed to inform conservation efforts as species such as the hooded vultures are declining in population.

5 CONCLUSION

Marabou storks have only been minimally studied since the last census of the species in 1973[11] despite their precipitous increase in population and prevalence since then[2]. These birds are very common in urban areas, and they are increasingly viewed as nuisances[2]. Understanding the role these birds play in urban ecosystems and factors influencing population growth helps to inform further research and potential population control efforts as marabou storks increasingly become urban-dependent animals.

This study was largely limited by its small sample size. Significant differences were found among some variables, but others require more data to classify their relationship. For example, only three abattoirs and slaughter slabs were visited, which was not enough to account for the high amount of variation within each facility. Visiting more abattoirs and slaughter slabs with a wider range of the number of animals slaughtered would allow this relationship to be further characterized. Furthermore, only two days each were spent at NMAA and Bugembe slaughter slab, which does not provide enough data to draw meaningful conclusions on this objective.

Another limitation was the inconsistency in the time of data collection. The plan was to record data from 7-8 am at each location, but this was not always possible due to the limited transportation availability. Data collection usually began around 7:30 (Appendix 5 for details), when many of the birds were already starting to leave due to the heat. In addition, many workers reported that marabou storks are present only early in the morning (7-8 am), but this was not observed by the researcher. On days when observations were delayed due to outside factors, more storks were present. The relationship between the number of birds and the time of day should be further explored.

The time of day with the maximum number of birds may also vary among abattoirs and slaughter slabs due to differing practices. For example, Bugembe slaughter slab is very busy earlier in the morning and there are not a lot of perches for storks to look over the activity, so many birds do not come until after most people have

left. At JCCA, however, more birds were present when there were people because of how frequently workers throw food to the birds. At NMAA, workers also reported more birds later in the day when there were fewer people because many of the workers chase off the birds. These differing practices may affect the maximum number of storks present throughout the day and the time at which this occurs.

Furthermore, abattoirs and slaughter slabs were only able to provide estimates for the number of animals slaughtered each day, thus, it is likely that the number of animals reported to be slaughtered daily differs from the actual number. To draw conclusions around the number of animals slaughtered, this would need to be measured directly instead of obtained through interviews.

More research on this topic would benefit ecological efforts to maximize the use of waste management as an ecological service that marabou storks provide. To further this study, more research on the reliance of storks on abattoir workers is needed, including an analysis of how much food workers throw to them daily. Studying the times of day most marabous are present will also help to inform these efforts.

Effects of large open areas and perches on the presence of marabou storks may also be explored. In this study, they were often observed on perches or just outside the study area, which appears to be a necessity for their presence. In areas where birds could not watch from nearby, they were mostly not present.

This study contributes to the body of research surrounding animal adaptations to increasingly urban environments through provisioning, human disturbance, and competition with other animals.

6 ACKNOWLEDGEMENTS

This research project would not have been possible without the generous help of the staff at SIT: Uganda, including Dr. Charlotte Mafumbo and Paul Musungo, and SIT: Tanzania, including Dr. Oliver Nyakunga, Oscar Paschal, and Kaiza Kaganzi. Advising from Hamlet Mugabe helped to make this project possible. A special thanks to Ssozy Musa Ssenga and Nabwire Judith from Jinja City Cattle Association (JCCA) for helping with translation, transportation, and so much more!

7 EDITOR'S NOTES

This article was peer-reviewed.

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8 APPENDICES

8.1 Appendix A: Ethical Considerations

The marabou storks in this study were observed from a range of 10-100 meters. These birds are adapted to urban environments and are not bothered by the presence of people. Workers at JCCA that helped provide background information about their facility or the presence of birds were compensated monetarily for their time in addition to assistance in transportation and translation.

Area 1	Area 2	Z	p-value
Back	Horns/bones	6.76204	<0.0001
Back	Enclosures	6.55026	<0.0001
Entrance	Horns/bones	6.75344	<0.0001
Entrance	Enclosures	6.52446	<0.0001
Back	Blood	6.63673	<0.0001
Entrance	Shops	6.62842	<0.0001
Back	Grazing	6.05336	<0.0001
Entrance	Blood	6.297	<0.0001
Building	Horns/bones	6.3641	<0.0001
Building	Blood	6.28751	<0.0001
Building	Enclosures	6.03444	<0.0001
Roof	Horns/bones	5.97512	<0.0001
Back	Grazing	5.35757	<0.0001
Building	Horns/bones	6.76204	<0.0001
Roof	Enclosures	5.5238	<0.0001
Roof	Blood	5.62446	<0.0001
Grazing	Horns/bones	5.57841	<0.0001
Entrance	Grazing	4.83034	<0.0001
Grazing	Blood	5.07883	<0.0001
Entrance	Legs	4.38514	0.0005
Grazing	Enclosures	4.40592	0.0004
Roof	Grazing	3.6225	0.0109
Building	Back	2.1429	0.4968
Enclosures	Horns/bones	2.30658	0.3845
Legs	Horns/bones	2.30571	0.3851
Legs	Blood	1.68092	0.8066
Enclosures	Blood	1.61801	0.8397
Entrance	Roof	0.31319	1
Blood	Horns/bones	0.96296	0.9942
Shops	Horns/bones	0.96296	0.9942
Legs	Enclosures	0.30657	1
Shops	Blood	0	1
Shops	Enclosures	-1.61801	0.8397
Shops	Legs	-1.77607	0.7506
Legs	Grazing	-3.15474	0.0514
Legs	Roof	-3.9583	0.003
Roof	Building	-4.49199	0.0003
Shops	Back	-5.13721	<0.0001
Entrance	Back	4.82494	<0.0001
Roof	Back	-4.84245	<0.0001
Entrance	Building	-4.87268	<0.0001
Shops	Roof	-5.70073	<0.0001
Legs	Back	-5.39801	<0.0001
Legs	Building	-5.52493	<0.0001
Shops	Building	-6.28751	<0.0001
Shops	Back	-6.69204	<0.0001

Table 3 8.2 Appendix B: Steel-Dwass Test Results

Species of Bird	Chi-square Statistic	P-value
Cattle Egret	0.032	0.8569
Piapiac	0.218	0.6408
Pied Crow	0.411	0.5235
Spur-winged Lapwing	0.023	0.8800

Table 4 8.3 Appendix C: Chi-Square Results (df =1, n = 90, α=0.01) for Occupancy of Marabou Storks and Other Bird Species

Date	Start Time	End Time	Temperature (F)	Abattoir
22-Nov	7:40 AM	8:30 AM	70	Jinja City Cattle Association
23-Nov	7:45 AM	8:45 AM	70	Jinja City Cattle Association
24-Nov	8:00 AM	8:45 AM	71	Jinja City Cattle Association
25-Nov	7:40 AM	8:40 AM	70	Jinja City Cattle Association
27-Nov	7:50 AM	8:30 AM	68	Jinja City Cattle Association
29-Nov	7:20 AM	7:40 AM	68	Bugembe Slaughter Slab
29-Nov	7:50 AM	8:20 AM	71	Jinja City Cattle Association
30-Nov	8:15 AM	8:30 AM	68	Bugembe Slaughter Slab
30-Nov	8:45 AM	9:30 AM	71	Jinja City Cattle Association
1-Dec	7:30 AM	8:00 AM	70	Njeru Abattoir
1-Dec	8:15 AM	8:45 AM	71	Jinja City Cattle Association
2-Dec	7:30 AM	7:50 AM	71	Njeru Abattoir
2-Dec	8:10 AM	9:00 AM	71	Jinja City Cattle Association

Table 5 8.4 Appendix D: Metadata about Data Collection Days