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Submitted for Review May 7th, 2019
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Abstract:

Northern Tanzania has experienced several anthrax outbreaks in the recent past. In Monduli district, an outbreak in 2016 prompted an organization of district officials to create an updated outbreak response action plan. The pastoralist community is often affected by these outbreaks due to their frequent direct contact with cattle and herds’ proximity to wild species potentially affected by the disease. This characterization of the existing systems of reporting and mitigating anthrax outbreaks was accomplished through structured interviews with ward and village officers, local veterinarians, and members of the pastoralist community in Monduli district near Mto wa Mbu. The purpose of this study was to identify the main successes and challenges of anthrax biosecurity implementation are in the area. The resulting record of recognizable similarities and differences in knowledge about anthrax and its reporting contributes to the body of knowledge that can be drawn upon for future decisions on resource and time distribution in designing biosecurity in Monduli district. The main challenges identified included lack of exchange between livestock professionals (read: livestock officers and veterinarians) and rural pastoralist communities, cultural practices related to livestock consumption, and lack of awareness of annual vaccination.
Introduction

Background

*Bacillus anthracis* is a gram-positive spore-forming bacterium in the Bacillaceae family, which causes the disease known in English as anthrax, in Swahili as *kimeta*, and in Maasai as *emboroto* (Mock Fouet 2001; Mangesho et al. 2017). Human infection can proceed by three clinical routes: cutaneous, gastrointestinal, and pulmonary, dependent on route of infection. Case fatality rates for the three are 20% without antibiotics, 25-60%, and 75% even with appropriate treatment, respectively (“Anthrax: Gateway to Health…” 2017). Cutaneous infection is most common, comprising about 95% of human infections. In animals, symptoms are highly variable, and diagnosis is extremely difficult. Most prominently, sudden death of the animal occurs, after possible symptoms including but not limited to swellings in the head and neck region, convulsions, digestive ailments (including colic and cessation of rumination), fever, wounds on the skin, lethargy, and lack of appetite. Generally, death can occur within 48 hours, though this is dependent on the species and clinical presentation, which can be peracute, acute, subacute, or chronic (“Anthrax facts,” 2001). Upon post-mortem inspection of a carcass, clinical signs of the disease can include bleeding from orifices, lack of clotting of the blood, dark, tarry color to the blood and spleen, rapid bloating, and lack of rigor mortis. A suspected case of anthrax can be generally defined as sudden death of an animal with one of the above signs in the carcass. Without the laboratory capability to definitively identify the bacterium in samples, such as exists at the Tanzania Veterinary Laboratory Agency, it is difficult to confirm the diagnosis (Mwakapeje et al. 2017). Modes of transmission and infection of anthrax are generally understood to include inhalation of spores, contact with an infected individual, and ingestion of
meat or products of an infected animal (Mock Fouet 2001). Transmission and infection are complicated by the zoonotic pathology of anthrax. Typically affecting herbivores, a large number of species have been recorded as infected with the bacteria, including carnivores (Hampson et al. 2011). Wild species such as wildebeest, hippos, gazelles, and rabbits have been observed with the disease, which spreads to cattle and other livestock when herds graze on land these animals have previously defecated or died on. Further, there is evidence of anthrax transmission through vectors; flies feed on the carcasses of infected wild animals and spread the bacteria to livestock-available vegetation, or bite livestock and directly introduce the bacterium, resulting in transmission to the animals (“Anthrax facts,” 2001). Notably, in northern Tanzania, anthrax is an endemic disease which causes outbreaks in humans and both wild and domestic animals around the myriad of protected land areas.

The *B. anthracis* bacteria can survive in the soil for up to 60 years in its sporulated form, causing outbreaks when optimal environmental conditions arise. Carcasses of any animal which remain undisposed of or untreated thus increase the potential of infection of livestock. Outbreaks generally begin in a period of heavy rain following a drought (“Anthrax facts,” 2001). Once domestic herds are infected, the potential for human infection rises, as contact is so frequent and extensive.

The pastoralist communities of northern Tanzania face perhaps the greatest risk of infection. As people who maintain large herds of cattle and small ruminants, meat, raw milk, and blood are three staples of the Maasai diet. The Maasai also consume the products of animals in the herd which have died from disease if the carcass has not decayed visibly (Mangesho et al. 2017). This, alongside the extensive contact between Maasai and their cattle daily, unfortunately creates an environment conducive to the spread of the *B. anthracis* bacteria without extensive
and proactive controls. Further, 20% of income to rural households in Tanzania comes from livestock; a 2017 census reported 30.5 million cows in Tanzania (Covarrubia et al. 2014; “Tanzania has 30.5ml…” 2018). This enormously significant sector thus extends the socioeconomic threat of anthrax through many communities.

Currently, a vaccination is available for cattle, which contains a strain with “reduced virulence” (“Vaccines and Therapeutic Sera”). Though government programs now subsidize the cost of the vaccination and its administration, it can be costly for some farmers, especially those with large herds. In 2015, only 38% of rural farmers vaccinated their herds and only 20% “made use of extension services” (Tanzania Livestock Modernization Initiative 2015). A 2017 study in Monduli district found that all cattle owned by Maasai interviewed for the study were unvaccinated (Mwakapeje et al. 2017).

Anthrax is a notifiable disease, meaning that information on cases observed must be reported by health care, livestock, and wildlife workers to regional governance systems. Nationally, this information is then required to be reported to WHO. However, this system relies on the community’s knowledge of the disease’s symptoms as well as the ability of government at multiple levels to respond quickly and efficiently (Mwakapeje et al. 2018).

Tanzania has experienced several anthrax outbreaks in the recent past, including in 1998, 2003, 2006, 2009, and 2016. In response, the government of Tanzania created a “National One Health Strategic Plan” for 2015-2020, which entails “collaboration between livestock, wildlife, and human health” officials at a national level (Mwakapeje et al. 2017). However, its implementation requires participation of many levels of government. Another outbreak occurred shortly prior to this study, in January and February of 2019, in the Rombo, Songwe, and Longido
districts. Over its course, around 77 cases in people were confirmed, and 7 died from the disease ("Anthrax outbreak in northern Tanzania…" 2019; "Anthrax outbreak in Songwe…" 2019). This study took place during a consequent vaccination campaign in the neighboring Monduli district, which was also the district affected by the 2016 outbreak. Located between Ngorongoro Conservation Area and Lake Manyara National Park, the area is home to many Maasai communities. The villages within which interviews were conducted are along wildlife corridors between Lake Manyara National Park and Ngorongoro Conservation Area.

A previous study in Selela ward, within Monduli district, identified a shortage of experts, decomposition as the deciding factor in whether or not to consume carcasses, cultural practices around consumption of raw animal products, the presence of parks and the movement of wildlife, and the cost of vaccinations as some of the main challenges to anthrax prevention and control (Mwakapeje et al. 2017). Traditional medicines taken in place of hospital treatment can also complicate reporting and response. Livestock vaccination campaigns which also incorporate human prophylactic distribution to area health providers and targeted education to populations most at risk have been suggested as seasonally important, as well as working with traditional community leaders more socially significant than government officials, such as Laigwanan in Maasai communities (Mwakapeje et al. 2018; Mwakapeje et al. 2017).

The purpose of this study is to first, understand the local systems in place for preventing and controlling anthrax; and second, identify the current specific challenges to implementation of anthrax biosecurity in Monduli District. It can therefore be seen as a continuation of previous studies in the area. This is significant in that it will add to the body of knowledge officials can access in updating outbreak response and mitigation systems in the future, or in addressing possible prevention or containment strategies at the times of year in which there is higher
prevalence of anthrax. Anthrax has high costs for communities economically, with the burden of carcass disposal and response measures, the loss of livestock, and the reduced ability of infected people to work. Ultimately, it can also be lethal, and therefore the systems of prevention, response, and outbreak mitigation are crucial. This project does not fully characterize the system but will contribute to knowledge of which aspects require additional attention and resources. To accomplish this it answers the question: “what are the main challenges and successes to anthrax biosecurity implementation by ward and village officials, veterinarians, and pastoralist community members near Mto wa Mbu?”

**Objectives:**

The main objective of this study is to compare what the well-suited and more challenging components of the implementation of biosecurity (vaccine campaigns, reporting of suspected cases, disposal of carcasses, information dispersal etc.) against anthrax are for each group named (veterinarians, district officials, and pastoralist community members) in the Monduli District of Tanzania. Within this objective, the subobjectives include characterizing what current methods and measures of biosecurity exist in the Monduli district; acquiring a basic picture of what the knowledge of these measures is in each group; identifying the challenges faced by pastoralist community members, those faced by veterinarians, and those by ward and village officials in anthrax biosecurity; and identifying the biosecurity implementation measures members of each group consistently take.

**Methods:**
Data for this study was collected through interviews with individuals in the Monduli District. The main method of sampling for these was snowball sampling, relying on the translator provided by Cultural Tourism Program (CTP) of Mto wa Mbu to identify the initial individuals and asking for any additional contacts participants thought relevant after each interview.

Interviews were conducted with Ward Livestock Officers, Ward and Village Officers which the translator can contact, veterinarians suggested by the Ward Veterinary Officers, other village officials, and the translator. Convenience Sampling was important in conducting interviews with Pastoralist community members; within the neighborhoods suggested by officials and veterinarians, community members were asked for interviews as we passed by their homes, at which point the translator began explaining the project and the procedure. The characteristics specifically qualifying pastoralist community members as study participants were an age of over 18 years, residence within the Monduli District, and ownership of three or more cattle and/or small ruminants, which are not kept exclusively within a structure or fenced area. The consent procedure involved describing the project and contents of the consent form to each participant in Swahili or English, giving them the form to review, and asking for their consent verbally and as a written signature. If consent was given, the interview commenced; if it was not, the interview participant was thanked for their time and the process was terminated. The participants were informed that all participation was completely voluntary and could be terminated by them at any time. If at any time once the interview had commenced the participant indicated their desire to exit the study procedure, the process was terminated for that participant and all data collected from that participant was formally excluded from the study. Participants were informed of their ability to skip any questions they did not want to answer or did not feel comfortable asking.

Interviews took place with a translator familiar with the language the study participant felt most
comfortable conversing in; if this was not possible, the process was terminated for that participant so as not to risk misunderstandings. All participants are anonymous to the degree possible within the study; this degree of anonymity is limited for those who hold public office, as their position determines the group they are placed in for data analysis. In this paper, however, these offices are not specifically connected to interview responses; instead, these responses are reported as being from a "public official" or "veterinarian" or "livestock official." Those who do not hold public office are not identified in any capacity except as a member of a specific pastoralist community; their names and other identifiable components of personal data are not included in study documents.

The structured interview questions for each group were as attached in Appendix A.

The variables collected for pastoralist community members were knowledge of the disease, source of knowledge, known transmission routes to humans, recognizable symptoms, believed cause, known species infected, prior experience with the disease, actions that need to be taken with infected carcasses, perceived threat, prevention methods, how the disease would be reported, environmental conditions that increase risk, frequency of interaction with livestock officers, other diseases humans can get from livestock, and any preventative medication given in general.

The variables collected for non-livestock officials were: knowledge of the disease, source of knowledge, known transmission routes to humans, recognizable symptoms, believed cause, known species infected, prior experience with the disease, actions that need to be taken with infected carcasses, perceived threat, prevention methods, availability of resources, how the disease would be reported, involvement with education, and perceived public awareness.
The variables collected for livestock officers and veterinarians were: cause of the disease, prior experience with the disease, symptoms in livestock, known species infected, known transmission routes to humans, actions that need to be taken with infected carcasses, how disease would be reported, perceived threat, perceived public awareness, methods of prevention, environmental conditions that increase risk, availability of resources, resources needed, consistency of vaccination administration, and encountered hesitations towards vaccination.

Additional comments made by participants were recorded as well.

Interview notes were taken at the time of the interview in a notebook and typed later into an excel sheet based on the population the participant(s) interviewed belonged to. From these notes, responses were grouped into response categories for further analysis and comparison within and between groups. Conclusions are based on these categorical comparisons and general qualitative data, and analysis conducted using SPSS software.

*Study Site:*
This study took place mainly in and near Mto wa Mbu, a ward within Monduli District. This was the base location for the study, and other sites were selected on the advice of the translator and livestock officers and veterinarians in the area. All sites were reachable by tuktuk and were thus also chosen for their accessibility from the center of town. Nine villages outside of Mto wa Mbu were visited, to remain specifically unidentified to protect the anonymity of the officials connected to these areas. Pastoralist community members were classified as living “in” or “out” of town based on the proximity of their homes to roads and commercial businesses. All villages were between Lake Manyara National Park and Ngorongoro Conservation Area, many directly adjacent to wildlife corridors between the two, as shown in Figure A. In the areas included in the study, wildlife therefore often graze on land also utilized for grazing of herds by pastoralists in the area.

Figure A: Mto wa Mbu, the central study site, is located between Ngorongoro Conservation Area and Lake Manyara National Park

Limitations and Biases

There are a number of limitations which undermine the scope and application of this study. Primarily, the study period was extremely short, owing to the time constraints of the program on which it was conducted as well as days on which interviews could not be conducted due to...
holidays and unforeseen circumstances. Additionally, transportation options were limited due to budget and program rules to bajaji or tuktus, three-wheeled covered motor vehicles. These run as taxis near town, but to go more than about 15 minutes outside of town is largely impractical except on certain market days, on which multiple can be taken in sequence to more remote areas. This limited the range of study, and thus biases the data to areas more reachable from town, though walking from these drop-off sites to more remote neighborhoods also comprised a large part of the study. Further, my lack of experience in approaching the study limited the depth of questions and the flow of interviews, possibly excluding more important data. Language barriers were also an issue; the only language I am fluent in is English, and though a translator was present for all interviews, and I do speak very basic Swahili, the translations may not have been exact or extremely consistent in their interpretation, though I did trust fully in the abilities of the translator.

Due to these limitations, there are a number of possible biases in the data. Only 58 interviews were included in the study, due to time constraints and exclusions of some participants after conducting interviews. This is an extremely small sample size, especially considering that, for data analysis, this was broken down into 35 community member interviews, 16 veterinarian and livestock officer interviews, and 7 non-livestock official interviews. The limitation on transportation also meant that geographic convenience sampling at sites near town and accessible by tuktuk was relied on heavily. This created locational bias in the data and further reduced its ability to represent the district. Some villages were visited during market days, on which the people most involved in livestock keeping were absent from most households. This may have resulted in data less representative of the knowledge present in the community as a whole. Conversely, a vaccination campaign was in progress throughout the
study period, which may have artificially inflated the number of people aware of both the disease and the correct actions to take in responding to it. Since this campaign was happening, a number of officials from the district and region visited the wards around Mto wa Mbu during the study period, and many officials were involved in meetings and tasks with them in the last two weeks of the study. Therefore, some of the officials I did interview may have been those least involved with anthrax prevention and control, and the data may exclude those most involved.

Ethics

Upon initiation of this study, I was unaware that vaccination of livestock against anthrax was legally mandated in Tanzania. This complicated interviews and could be seen as a large ethical dilemma in the reporting of this study; potentially reflecting poorly on officials or livestock keepers in some areas which are not completely compliant. To reflect this, no study sites are specifically indicated within this document, and no personal or identifiable information was collected in any part of the study excepting the consent procedure. The group perhaps most at risk of identification and consequences, the livestock officers, are protected as their data is grouped with data from veterinarians and randomized in terms of order.

Another ethical dilemma, which creates considerable controversy, is the lack of information about the disease offered to community member participants. The authority and necessary skill in distributing information I considered outside of my abilities; fact sheets or listing of information on the disease translated into languages I do not speak might have generated confusion or mistrust of actual authorities or systems and would likely not have been ultimately helpful to people receiving the information. However, in cases where a lack of knowledge which could pose significant risk was encountered and no attempt was made to correct it, it may seem ethically wrong. I recommend that in future studies of similar content
authors arrange a meeting with livestock officers early in the study period to discuss how to best offer information to community members in accordance with existing educational programs and what specific information to offer.

The consent procedure involved describing the project to individuals and summarizing the consent form in the language used in the interview, obtaining verbal consent, and asking for a signature on the consent form, provided to the participant at the end of the interview. While the translator was available to answer any and all questions on the form, and while no participant was compelled to sign the form, the form was in English, and many participants could not read the form for themselves. This could be seen as complicating consent, though everything was voluntary, and all participants were informed as such, and signatures were collected at the end of the interview so that participants could withdraw their information completely in refusing consent if they were uncomfortable with the questions.

Results

In total, 58 interviews were conducted over the study period. Thirty-five interviews were conducted with members of the pastoralist community, nine with ward livestock officers, seven with veterinarians, and seven with non-livestock ward and village officials. Selected data can be found in Appendices B, C, and D.

Using information from Ward Livestock Officers, Non-livestock officials, and Veterinarians, the following systems are described. These descriptions reflect the ideal functionality of the prevention and control systems for anthrax outbreaks as understood from 23 interviews with individuals in these positions.
The system for prevention of anthrax in Monduli district involves annual vaccination campaigns. Livestock officials and veterinarians administer the vaccine, traveling to each village on predetermined dates. Prior to these dates, village chairmen inform residents in their area that the vaccination will take place, and briefly summarize its purpose, its cost, and the time and location residents should bring livestock to. The time window between this announcement and the actual date of vaccination allows residents to prepare the necessary funds to vaccinate their entire herd. On the date of vaccine administration, livestock officers or veterinarians arrive at the location, provide additional education about the disease, including its recognizable symptoms and how to report it, and vaccinate livestock in the area, collecting the fee of 500 to 1000Tsh per head. If community members refuse to vaccinate their livestock, they are summoned to the ward or village offices, where they are given a seminar with more information about the necessity of vaccination and the severity of the disease. If they continue to refuse, they are compelled by law enforcement to vaccinate their livestock and can be fined additionally for their non-compliance. This ensures that all livestock keepers vaccinate all livestock every time.

The system for control of outbreaks involves a chain of reporting and response measures at multiple levels. When an animal dies from anthrax, community members report the incident promptly to the chairman of the village, a veterinarian, or a livestock officer. Livestock officers then arrive quickly in personal protective equipment, including gloves and masks, and ensure that the carcass is buried in a hole over 6 meters deep, burned, and that lime or another disinfectant is spread in the area. Immediately after disposal of the carcass, animals within the same herd as the infected animal are treated with antibiotics, nearby herds are vaccinated, and the case is reported to the district office, more specifically to the District Veterinary Officer. The district office has the authority to initiate appropriate quarantine, vaccination, and information
dispersal campaigns, and additionally communicates with the regional offices and other district offices to notify them. These campaigns then begin in other districts nearby.

A number of important successes of these systems became apparent in the responses collected in this study. All participants said they were aware of the disease, and 82.9% of pastoralist community members interviewed have knowledge of the vaccination as a means of prevention. Additionally, 57.1% of pastoralist community members indicated that they would report a suspected case of anthrax to either a veterinarian, village chairman, or livestock officer. A 77.1% majority of pastoralist community members perceive anthrax as a serious threat to public health. Learning about anthrax from a veterinarian or livestock officer was positively associated with indicating the correct actions to take when an animal dies from anthrax (p=0.001). This association suggests that education programs have been successful, though the small sample size means associations in the data lack statistical significance.

While the above descriptions represent the ideal functionalities as compiled from interviews, many challenges to these systems were also expressed, creating a difference between these ideals and the reality of implementation. A 31.4% minority of community members said that the vaccination should be administered at an interval (although this interval also varied), while 51.4% said that the vaccination is administered only during outbreaks. Figure 1 represents the responses of community members when asked what methods of prevention existed for anthrax.
This is particularly note-worthy as 15/16 veterinarians and livestock officers said that vaccination is annual. Of community members interviewed 45.7% said that they would consume the products of an animal that had died from anthrax, with 30.3% indicating that they would

Figure 1: Pastoralist community member responses when asked about existing methods of preventing anthrax. No participants provided answers in more than one category. The vaccination should be administered annually, though not all participants in the ‘vaccination at an interval’ category said that it should be administered specifically once a year.

Figure 2: Pastoralist community member responses when asked what action should be taken when an animal dies from anthrax. To ensure that no spores survive in the soil, carcasses must be buried and burned, and lime or another disinfectant should be spread around the area.
dispose of “visibly affected” portions of the carcass first. Figure 2 shows the responses of community members as to what action should be taken when an animal dies from anthrax.

Additionally, 13 out of 16 livestock officers and veterinarians said that they had encountered hesitations towards the vaccination. These included beliefs by community members that the vaccination makes animals sterile or abort pregnancies; that it brings other diseases to animals; that anthrax will not harm the herd; and that the cost of the vaccination is too high. Community members indicated several other concerns as well in their own answers, including a general mistrust in the abilities of livestock officers and veterinarians due to observations of procedures previously and a lack of availability of education about the disease.

Knowledge of potential hosts is also critical to containing diseases in the event of an outbreak; Figure 3 depicts the responses from community members as to which animals can potentially contract the disease. As shown, 23.5% of community members stated that only cattle and humans could have the disease, while another 23.5% correctly responded that all livestock can contract the disease, as well as wild animals and humans.
Ten out of the 16 veterinarians and livestock officers interviewed said that they did not believe that the community understands the diseases and the threat it poses, while 4 of them said that vaccination does not always happen even when announced due to refusals of the vaccination and inability to compel livestock keepers with the law due to geographic constraints and the continuous movement of people. Only 3 of 7 non-livestock officials interviewed said they are involved with anthrax education for the community, and only 2 of 7 said they themselves had learned about the disease from livestock officers or veterinarians. Twelve out of the 16 livestock professionals said that there are not enough resources available for anthrax control and prevention, and 6 of these participants specifically listed transportation as lacking. Figure 4 depicts the resources veterinarians, livestock officers and non-livestock officials mentioned as lacking in relation to anthrax prevention and control.
Though learning about anthrax from a livestock officer or veterinarian was associated with indicating the correct actions to take in carcass disposal, it was also associated with
proximity to town (p=0.009). As shown in Figure 5, only 34.3% of community members interviewed said that they had learned about the disease from livestock officers or veterinarians. In fact, 71.4% of community members said that they only saw livestock officers in shops in town or when called for a specific problem. Forty percent of community members said that they would not report an animal dying from anthrax to anyone, and 54.3% of community members said that ingesting the products of an infected animal was the only route of transmission of the disease, that no other routes of transmission exist.

Discussion and Implications

While the systems in place for prevention and control of anthrax in Monduli district are extensive and functional on many levels of government, they face significant challenges in implementation.

The results indicate a lack of information exchange regarding anthrax between livestock professionals and keepers, likely related to a lack of transportation which limits access to more rural areas, and a general lack of routine interaction, and, therefore, of significant relationships between livestock officers and pastoralist community members. The mistrust of livestock professionals may be related to this lack of interaction, and the low number of community members that have learned about the disease from livestock professionals. The specific hesitations stemming from the belief that the vaccination will make animals sterile were attributed by both livestock professionals and keepers to a government campaign to “reduce livestock numbers.” The campaign, as described by several participants, is to make livestock
keepers aware of more preventative health practices necessary to the continued welfare of livestock, and advocates for keepers to have fewer animals so that more resources can be spent on each. However, this has been taken by some communities to mean that the government wants to reduce the number of livestock they own as part of their agenda. This has created further mistrust and will likely require emphasis in education efforts and proof that the vaccination cannot sterilize cattle or other livestock.

The critical point of control, when livestock keepers report an animal dying of anthrax to authorities, is still far from ubiquitous, though a majority of community members did say they would report the disease. The actions community members would take to dispose of a carcass are also highly varied, and the minority who indicated that they would take the full range of necessary action is small. However, this disease is particularly challenging to address because of its lack of consistent symptoms, and because of how quickly it progresses. One community member explained her reluctance to report the disease as an absolute uncertainty of whether or not the animal had truly died from anthrax; in the absence of definitive diagnosis, the reluctance to waste the products of the animal took priority over potential risk. Wasting meat, several Maasai community members expressed, is seen as abhorrent. One participant phrased it as “losing the animal twice,” that it is already devastating to lose an apparently healthy animal, and that to lose its products is doubly so. As all participants knew of the disease, a majority expressed that it is a threat to public health, and all participants indicated that eating the products of an infected animal can result in human infection, it is possible that the participants who indicated that they would not report it and would eat the meat prioritize lack of waste and accept the potential risk. Another comment which a few participants made was that Maasai are “not afraid of anything,” and therefore do not fear anthrax. These comments taken in combination
with the results indicate a challenge to reporting and control which may be related to cultural practices of some communities, and which will require thorough consideration in education about the disease and the systems in place.

All participants were asked to list all recognizable symptoms of the disease. This was included in an attempt to ensure that participants who recognized the name of the disease were speaking about anthrax. However, responses to this question mirrored the enormous range and inconsistencies in clinical presentations of the disease. All participants either named at least one symptom within the symptoms they listed that can be a sign of the disease, or stated that there are rarely any recognizable symptoms, which can also be characteristic of the disease. This data and similar comments made by livestock officers in interviews also indicates another issue, however, which is that, in many cases, anthrax can present symptoms which overlap with those of other diseases, and other diseases can resemble anthrax. This further complicates education about and reporting of the disease. A cheap and effective field test for anthrax could simplify diagnosis and control. However, successful education programs will likely have to address the inevitable uncertainty around whether or not an animal has died from anthrax and insist that reporting all sudden deaths of livestock is of paramount importance.

The results also indicate that vaccination does not take place annually in communities of many of the participants. Many participants from all groups emphasized separately, in defining anthrax, that it is an “outbreak disease,” meaning that it is not consistent in terms of timing and prevalence. Thus, it may seem economically unwise or unfeasible to vaccinate every year when it has not been a problem for several years, an interpretation supported by the number of livestock professionals who said that the cost of the vaccination was a major hesitation they faced from community members. However, this seriously undermines the prevention system, as
lack of annual vaccination creates large numbers of animals susceptible to the disease and necessitates a reactionary rather than proactive course of action.

The range of answers community members gave when asked to name known hosts of the disease has a number of possible interpretations. The cumulative 29.4% who responded that either anthrax was limited to “cows and humans, only” or “one species of livestock… wild animals, humans” are perhaps the most important category. The belief that anthrax can only spread to one species of livestock increases risk in an outbreak scenario, as quarantines and bans on slaughter carried out by livestock keepers themselves may fail if they are only applied to one species. Most of the community members interviewed had more than one species of livestock, though numbers and species owned by participant were not recorded. However, the respondents that did not respond with any wildlife species may have only been naming those animals in which the disease can be controlled or in which it is frequently confronted by people. Some of the respondents which did not list any wild species as hosts still referenced their role in spreading the disease in speaking about the risk in grazing livestock on land also occupied by animals from the National Park.

Finally, the resources officials from different areas and veterinarians reported as lacking seem related to the main challenges identified. The three most common resources mentioned as lacking were transportation, educational seminars and materials, and personnel. It seems likely that an insufficient number of personnel with limited transportation would provide inadequate education and have limited interactions with livestock keepers, especially with rural communities who are harder to reach. While this may be a funding issue, there are perhaps other ways of circumventing the problem, including contacting specific, influential community leaders and incorporating them into these systems as community liaisons, as suggested in previous literature,
or educating village chairmen more extensively and thoroughly involving them in this process. As village chairmen are already essential in vaccination campaigns, this may create more efficient dispersal of knowledge about control and reporting of the disease over larger areas.

Conclusion

The findings of this study suggest that the existing systems of anthrax prevention and control in Monduli district ideally include annual vaccination and education campaigns, and reporting through local officials, alongside thorough carcass disposal methods and quarantines. However, education about reporting and responding to anthrax is limited in rural communities, and preventative vaccinations are not administered annually in many places included in the study. A lack of transportation and routine interaction between livestock officers and pastoralist community members in rural neighborhoods compound these issues and create gaps in reporting structures. While this may be related to funding and personnel, it could potentially be corrected for with programs that systematically educate village chairmen and involve them more meaningfully in vaccination and community education campaigns. Though the sample size diminishes the applicability of these conclusions, these findings present possible areas of interest for local government to reexamine and address in designing future biosecurity measures.

Future Research

A number of potentially impactful directions for future research are suggested by the findings of this study. Primarily, repeating this study with a much larger sample size over a longer period would create more significant findings and more productively add to existing knowledge. Conducting similar interviews in a year without a vaccination campaign might yield
different results and help indicate the longer-term effects of education programs, or lack thereof. An in-depth analysis of existing education programs about anthrax could identify more specific areas for resource redistribution in prevention strategies. Additionally, it could further characterize the consistency of education techniques and distribution throughout the district. A study focusing on the involvement of non-governmental leaders in the success of vaccination programs could help identify key influences within communities who are not named or included in this study, but who could have significant impact on community acceptance of vaccinations. Further, expanding on the involvement of park officials in anthrax prevention and control efforts and funding could elucidate how parks subsidize community measures for battling diseases which originate, in large part, within populations of wild animals on park land.

Appendix A: Interview Questions
Community Members:
1. Have you heard of anthrax?
   a. How did you learn about anthrax?
   b. What do you believe causes anthrax?
   c. What are the symptoms of anthrax?
   d. Do you know what can cause anthrax in people?
2. What species do you know of that can be infected with anthrax?
3. Have you ever seen a case of anthrax?
4. Are you aware of any environmental conditions that increase the risk of anthrax?
5. In the case of anthrax, what action should be taken?
   a. Would you report it to anyone?
6. Do you believe anthrax is a serious threat to peoples’ health?
7. What are some methods of preventing anthrax?
8. How frequently do you interact with livestock officers?
9. Are you aware of any other diseases people can get from livestock?
10. Do you practice any other preventative medicine?

Ward Livestock Officers/Veterinarians:
1. How would you define Anthrax (symptoms, hosts, transmission)?
2. Have you ever seen or treated a case of anthrax?
3. When an animal dies from anthrax, what action should be taken? Can you describe the steps in the process of anthrax reporting to me?
4. If you see or treat a case of anthrax, do you report that information to anyone?
5. Do you think anthrax is a serious threat to public health?
6. Do you believe that anthrax is understood and recognized as a threat by the community?
7. Do you feel as though anthrax reporting is consistent and efficient?
   a. If not, what are some challenges that the community faces in anthrax reporting?
8. What are some methods of preventing anthrax?
9. Have you seen any hesitations towards or misunderstandings of the vaccination in the community?
10. In your experience, does everyone vaccinate their cattle every time vaccination is announced?
11. Are you aware of any environmental conditions that increase the risk of anthrax?
12. Do you believe there are enough resources provided in the district for anthrax control?
   a. If not, what resources are lacking?

Ward and Village officials other than livestock:
1. Have you heard of anthrax?
   a. How did you learn about anthrax?
   b. What are the symptoms of anthrax?
   c. What do you believe causes anthrax?
   d. What animals can be infected with anthrax?
   e. Do you know what can cause anthrax in people?
2. Have you ever seen a case of anthrax?
3. If an animal dies from anthrax, what action should be taken?
4. Are you involved in anthrax education or are you aware of any programs regarding anthrax information dispersal?
5. Do you believe anthrax is a serious threat to public health?
6. Do you believe the community understands anthrax and the threat it poses?
7. What are some methods of preventing anthrax?
8. Are you aware of any environmental conditions that increase the risk of anthrax?
9. Do you believe there are enough resources provided in the district for anthrax control?
   a. If not, which are lacking?

Appendix B: Selected Pastoralist Community Member Data
## Appendix C: Selected Livestock Officer and Veterinarian Data

<table>
<thead>
<tr>
<th>Animal</th>
<th>Disease</th>
<th>Clinical Signs</th>
<th>Pathogen</th>
<th>Transmission Routes to Humans</th>
<th>Sources of Infection</th>
<th>Method of Prevention</th>
<th>Effect of Prevention</th>
<th>Is there another community or household affected?</th>
<th>What specific resources are necessary?</th>
<th>Do vaccination strategies work?</th>
<th>Do antibiotic treatments work?</th>
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</thead>
<tbody>
<tr>
<td>Bovine</td>
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### Appendix D: Selected Non-Livestock Official Data

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<th>Have you heard of anthrax?</th>
<th>How did you hear about anthrax?</th>
<th>What causes anthrax?</th>
<th>Do you know how a person can be infected with anthrax?</th>
<th>What are the symptoms of anthrax?</th>
<th>What species do you believe can be infected with anthrax?</th>
<th>Have you ever seen a case of anthrax?</th>
<th>Do you believe that anthrax is a serious threat to public health?</th>
<th>What are some methods of preventing anthrax?</th>
<th>Are there enough resources for controlling/preventing?</th>
<th>Which resources are lacking?</th>
<th>Who would you report a case of anthrax to?</th>
<th>Are you married?</th>
<th>Do you believe the public understands anthrax and the threat it poses?</th>
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<td>yes</td>
<td>experience</td>
<td>unsure</td>
<td>eating</td>
<td>unsure</td>
<td>cows, goats, pigs, sheep, humans</td>
<td>no</td>
<td>yes</td>
<td>vaccination biannually</td>
<td>no</td>
<td>cost of vaccination; education</td>
<td>livestock officer; official executive officer</td>
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<td>yes</td>
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<tr>
<td>yes</td>
<td>experience</td>
<td>unsure</td>
<td>eating; touching</td>
<td>crashes on mouth and hooves; wounds into the skin</td>
<td>cows, goats, sheep, wild animals, people</td>
<td>unsure; but livestock officers would be called</td>
<td>yes</td>
<td>vaccination when there is an outbreak</td>
<td>no</td>
<td>education; cost of vaccination</td>
<td>livestock officer</td>
<td>no</td>
<td>yes</td>
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<tr>
<td>yes</td>
<td>experience</td>
<td>unsure</td>
<td>eating; touching</td>
<td>hair looks different; scratching</td>
<td>cows; wild animals, people</td>
<td>yes</td>
<td>buy the carcass</td>
<td>vaccination annually</td>
<td>no</td>
<td>transportation; education</td>
<td>livestock officer</td>
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<td>bacteria</td>
<td>eating; touching</td>
<td>sudden death</td>
<td>livestock; wild animals, people</td>
<td>unsure; but livestock officers would be called</td>
<td>yes</td>
<td>vaccination when there is an outbreak</td>
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<td>livestock officer</td>
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<td>eating; touching; inhaling</td>
<td>(didn't ask)</td>
<td>cows, people</td>
<td>unsure; but livestock officers would be called</td>
<td>yes</td>
<td>vaccination annually</td>
<td>no</td>
<td>not enough personnel; transportation</td>
<td>livestock officer</td>
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<td>yes</td>
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<td>eating</td>
<td>unsure</td>
<td>unsure which animal; humans</td>
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<td>buy the carcass</td>
<td>vaccination annually</td>
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<td>livestock officer</td>
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<td>schooling</td>
<td>bacteria</td>
<td>eating</td>
<td>(didn't ask)</td>
<td>goats; sheep, cattle, people</td>
<td>no</td>
<td>buy the carcass; bury, disinfect area</td>
<td>vaccination when there is an outbreak</td>
<td>yes</td>
<td>education; cost of vaccination</td>
<td>livestock officer</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
References


Tanzania has 30.5ml cows: NBS. (2018, May 16). Retrieved from https://www.thecitizen.co.tz/News/Tanzania-has-30-5ml-cows-NBS/1840340-4565204-14f3m1mz/index.html


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