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Characterization of population connectivity for enhanced cross-border surveillance of yellow fever at Mutukula and Namanga borders in Tanzania

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ABSTRACT

Objectives: Yellow fever (YF) remains a public health threat in Sub-Saharan Africa and South America, with an estimated 200,000 cases and 30,000 deaths annually. Although the World Health Organization considers Tanzania to be at low risk for YF because no YF cases have been reported, the country remains at alert to importation of the virus due to ecological factors and high connectivity to high-risk YF areas in other countries. This study aimed to identify points of interest with connectivity to high-risk YF areas to guide preparedness efforts in Tanzania.
Methods: Using the Population Connectivity Across Borders (PopCAB) toolkit, the Nelson Mandela African Institution of Science and Technology (Department of Health and Biomedical Sciences), in collaboration with the Tanzania Ministry of Health and the Centers for Disease Control and Prevention, implemented 12 focus group discussions with participatory mapping in two high-risk borders of Mutukula and Namanga.
Results: Participants identified 147 and 90 points of interest with connectivity to YF risk areas in Kenya and Uganda, respectively. The identified locations are important for trade, fishing, pastoralism, tourism, health-seeking, agriculture, mining, religious activities, education, and cross-border marriages.
Conclusions: The Tanzania Ministry of Health used the results to update cross-border surveillance and risk communication strategies and vaccination guidelines to prevent the importation of YF into Tanzania.

Introduction

Yellow fever (YF) is an acute viral hemorrhagic disease transmitted primarily by *Aedes spp.* mosquitoes. YF epidemics occur when the virus is introduced to a population with low vaccination rates and insufficient vector control. There are an estimated 200,000 cases of YF annually, with more than 90% of the cases occurring in Africa [1]. Recently, the disease has resurged in both Africa and South America [1]. A large epidemic in 2016 affected Angola and the Democratic Republic of the Congo (DRC), with 965 cases leading to more than 400 deaths. Exported cases to China and Kenya highlighted the potential for the international spread of the virus [2].

Kenya and Uganda have experienced repeated YF outbreaks. After the first outbreak in 1992 in Rift Valley Province, Kenya, the government identified additional cases in 1993-1995 [3,4]. Kenya also recorded two imported cases from Angola in 2016 [5]. Most recently, Kenya reported a YF outbreak in March 2022 in Isiolo and Garissa counties, resulting in 111 cases and 12 deaths [6]. Uganda recorded outbreaks in 2010, 2016, 2019, and 2020 [7]. Similarly, in March 2022, Uganda reported an outbreak in Wakiso, Masaka, and Kasese districts.

The World Health Organization classifies Tanzania as a low-risk country for YF because no human cases have been reported in the country. Because of this status, the country has not included YF as one of the mandatory routine vaccinations at 9 months of age [8]. However, the

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country shares a border with YF high-risk countries, DRC, Kenya, and Uganda, and previous studies have shown the presence of the mosquito vector (*Aedes aegypti*) in various parts of Tanzania, including Dar es Salaam, Mbeya, Mwanza, Kagera, Morogoro, Arusha, Coast, and Kilimanjaro [9–13]. To help prevent YF introduction into Tanzania, the government implements enhanced traveler screening involving inspection of the international certificate of vaccination for travelers from or who transited through YF risk areas, visual inspection for signs and symptoms of the disease, and mosquito vector control at official points of entry (PoE).

Although YF control measures are implemented at the official PoE, human mobility and connectivity between Tanzania and YF risk areas in neighboring countries, including across unofficial borders, pose a risk of importation of YF and other public health threats to Tanzania. The connectivity is rooted in movement among similar ethnic groups living across the region and for economic systems networked across multiple countries. To address this risk of importation, the Tanzania Ministry of Health (MoH) conducted this study to characterize population movement patterns and describe areas with strong population connectivity and apply the results to enhance YF surveillance and preventive measures.

Material and methods

Study design and population

The study team conducted a cross-sectional study between July and September 2023, integrating both qualitative and participatory mapping (PM) methods to better understand the risk of importing YF through cross-border population movement with Kenya and Uganda using the Centers for Disease Control and Prevention's Population Connectivity Across Border (PopCAB) toolkit. We invited individuals with a deep understanding of population mobility across the borders to participate in this study. Eligibility criteria included Tanzanian citizens, based on self-report, who had resided in the border area for more than 5 years or who engaged in formal or informal cross-border activities. The local authorities at the sub-district ward level, including ward health officers, ward executive officers, and village executive officers, assisted in the identification of participants.

Study area

The study team selected the Namanga border with Kenya in the Longido district, Arusha region, and the Mutukula border with Uganda in the Misenyi district, Kagera region, for PopCAB implementation due to the high volume of cross-border movement. An average of 12,000 and 33,000 travelers and cross-border community members per month cross the Mutukula and Namanga borders, respectively [14]. Both borders have numerous unofficial borders that border community members, and travelers use to cross the border without being subjected to screening by health authorities.

Data collection toolkit

The study team collected data using an adapted version of the standard PopCAB toolkit developed by the Centers for Disease Control and Prevention. The publicly accessible toolkit, described in detail elsewhere, integrates focus group discussions (FGD) with PM to facilitate gathering qualitative, quantitative, and spatial data on population mobility patterns through community engagement [15]. Tanzania's Government, in collaboration with other countries, has previously used this novel toolkit to design public health programs to mitigate the spread of communicable diseases across borders [16]. The data collection exercises involved two steps: training of data collectors and data collection.

Training of data collectors

A total of eight data collectors were trained for 1 week on the PopCAB toolkit. The trainees were drawn from the regional, district, and local levels, and individuals with a background in public health, epidemiology, and disease control were prioritized. The training included skills on how to conduct FGDs, how to document the discussions accurately, how to facilitate map annotation during the discussions, how to apply consistent point and travel route of interest unique identifiers on the maps and in the FGD notes, and roles and responsibilities of all implementing team members.

Data collection

The trained data collectors were divided into two groups, each comprising four individuals (one facilitator, one team lead, and two notetakers). Each group implemented six FGDs with PM across the two study areas of Namanga and Mutukula borders. Focus groups included 6 to 10 key informants grouped together based on shared occupational or demographic characteristics, e.g., border, ward, and district leaders (agriculture, planning, health, animal and plant health, administration, social and community development officers), border cargo handlers, border officials, motorcycle (*boda boda*), businessmen, and truck drivers. The discussion with border cargo handlers included a total of 21 participants as more individuals joined during the FGD. Each FGD lasted 1-2 hours and was conducted in Kiswahili. The facilitators used the PopCAB FGD guide and a printed, spatially accurate map of the area, including areas in the neighboring country, to gather information about locations and routes of interest for local and cross-border community members. Notetakers recorded the discussion and facilitators guided FGD participants to annotate the map with points and routes of interest. When possible, the facilitators also created an audio recording.

After each FGD, the facilitators compared the annotated map and discussion notes to ensure all mentioned locations and routes were captured through both media and were assigned concordant unique identifiers. Facilitators submitted the latitude and longitude coordinates for the FGD location and photos of the annotated maps and key informant registration forms to a Kobo Toolbox account for safe storage and management. Facilitators saved the annotated map and registration forms for use later by the study team. After each FGD, the implementation teams typed the verbatim qualitative discussion notes in English.

Data analysis and visualization phase

Data analysis started with creating a summary table of the spatial data of points of interest containing location names for specific locations and for waypoints along described travel routes, unique identification (ID) number for each location and route that matched the ID number in the notes and on the map, descriptions of the locations and routes, and GIS coordinates of locations. Then, qualitative data analysts analyzed the FGD notes using the thematic analysis method to generate information on who, where, why, and how of population mobility. Cartographers and spatial analysts used the summary tables to create digital maps of the population movement data using ArcGIS. The study team used the results to identify areas and populations with elevated risk of YF exposure or importation based on connectivity to recent outbreak areas. They developed recommendations to improve public health measures to address the identified risks with the goal of reducing the risk of YF importation and improving public health support to those with an elevated risk of exposure to YF.

Ethical considerations

The study team obtained permission to undertake the study from the Permanent Secretary of the MoH and the Office of the President, Regional Administration and Local Government. Before initiating the FGDs, facilitators gathered written informed consent from key informants and emphasized to key informants that they could withdraw at any time. This study was part of a larger study on estimating the risk of YF and other selected arboviruses at PoE and capacity for detection

Table 1
Distribution of focus group discussions in Misenyi and Longido districts in Tanzania, July 2023.

Location	Focus group discussions categories	No. of participants
Mutukula border	Border cargo handlers	21
	Motorcycle taxi drivers (*boda boda)*	6
	Cleaners	8
	Truck drivers	6
	Border officials	10
Misenyi district headquarters	District leaders	8
Namanga border	Truck drivers	6
	Border officials	6
	Motorcycle taxi drivers (*boda boda)*	6
	Bus operator agents	6
Kimokoua ward	Ward leaders	6
Longido district headquarters	District leaders	6

and containment in the context of the COVID-19 pandemic with ethical clearance (NIMR/HQ/R.8a/Vol.IX/4325) from the National Institute of Medical Research. The collected data was secured in password-protected computers.

Results

The study team conducted 12 FGDs across the two study areas in Tanzania along the border with Kenya and Uganda (Table 1). Key informants identified 147 and 90 points of interest visited by cross-border community members and travelers with connectivity between Tanzania and Kenya and between Tanzania and Uganda, respectively (Figure 1). The farthest distance from a YF high-risk area in Kenya, such as Wajir, to the Mbeya region in Tanzania, is approximately 1,933 km (with an estimated travel time of 30 hours), and from Kasese in Uganda to Dar es Salaam in Tanzania is approximately 1,733 km (estimated travel time of 28 hours).

Main reasons for population movement and connectivity

Participants described eight main reasons for population movement and connectivity between Tanzania and Kenya and six reasons between Tanzania and Uganda (Figures 2, 3, and 4).

Livestock markets and pastoralist connectivity

Tanzanians, especially the Maasai community in Arusha, interact frequently with Kenyan counterparts while grazing animals and visiting livestock markets (Figure 3). Kenyan pastoralists use grazing areas in Tanzania, including Loitoktok, Mbilikani, Lengesimu, Shompole, Meto, Naisenyi, Msitu wa Tembo, Ngorika, Kamwanga Town, Engarenaibo, and Gelailumbwa during the dry season. There are several livestock markets used by both Tanzanians and Kenyans for buying and selling livestock and livestock products. The markets in Kenya include Bisili, Mairua, Lengesimu, Maili-Tisa, Taveta, Kariobangi, Dagoretti Nairobi, Matapato North, and Longursua. Tanzanian livestock markets frequented by Kenyans include Magugu, Eworendeke, Kimookuwa, and Sokolambuzi. Hybrid goats from Isiolo, a YF risk area, are also sold in these markets. This was not the main reason for connectivity between Tanzania and Uganda.

Business, trade, and city center

Participants reported business, trade, and visiting city centers as reasons for travel and connectivity between Tanzania and Kenya as well as Tanzania and Uganda (Figure 3). Traders from Tanzania sell sunflower oil and byproducts from Babati, Tanzania, in Nairobi, Kenya. Traders from Kikuyu, Kenya, sell matchboxes in Tanzania and Malawi. In addition, traders from Moshi, Tanzania, sell vegetables in Kenya. Traders from Tanzania and Malawi transport ground nuts to Nairobi, Kenya, passing through Baringo and Isiolo counties in Kenya, which are YF risk zones, before returning to their home countries. Participants described that community members from Arusha, Moshi, Dar es Salaam, Babati, and Tanga in Tanzania have elevated connectivity with Kenya, especially the cities of Nairobi, Kikuyu, and Thika, for business purposes. Business and trade interactions also involve cities in other neighboring countries, including Malawi (Blantyre, Chipata, and Lilongwe) and Goma, DRC.

Notably, the main locations in Tanzania frequented for business purposes between Tanzania and Uganda include Bukoba Urban, Mwanza City, Kibondo, and Uvinza in Kigoma, Buseresere in Geita, Mutukula town, and Dar es Salaam (Figure 4). Locations in Uganda include Jinja, Kampala, Kyotela, Masaka, Mukono, Mbarara, and Busia. Business activities include buying and selling of clothes, shoes, utensils, and bicycle spare parts from Uganda. Dar es Salaam is mainly used by truck drivers to transport goods received via Dar es Salaam Port to Uganda or DRC. There is a big market for clothes and other commercial products on the Ugandan side of the Mutukula border. Some Tanzanians shop on the Uganda side instead of continuing to Kampala because similar quality goods are available at a cheaper price in Mutukula.

Tourism and recreation

Participants also described the population connectivity between Tanzania and Kenya associated with tourism and recreation (Figure 3). They described extensive tourism travel involving arrival at Jomo Kenyatta International Airport, Kenya, or entering Tanzania through other airports and road transportation routes. Travelers often visited Arusha National Parks, including Lake Manyara, Ngorongoro, Tarangire, Kilimanjaro Mountain, Lengai Mountain, and Tingatinga. People from Kenya, including those from YF risk areas, also visit Namanga nightclubs for recreation. This was not among the reasons for the connectivity between Tanzania and Uganda.

Health-seeking and traditional healers

Visiting biomedical and traditional healer services are the other reasons for cross-border connectivity (Figures 3 and 4). Health facilities located in Tanzania frequented by Kenyans include Oworendeke Health Center and Namanga Dispensary (Figure 3). In Kenya, the health facilities frequented by Tanzanians include Namanga Hospital, Amboseli Pharmacy, Loitoktok District Hospital, Meto Dispensary, and Shompole Dispensary. Community members engage in cross-border movement to these health facilities to seek more privacy for care associated with diseases with stigma, such as sexually transmitted infections and human immunodeficiency virus, and due to proximity to their border communities. Some patients in Kenya visit traditional healers in Tanzania, mainly at Olesambau and Lekulule.

People from Kyotera and Mutukula, Uganda, visit the Mutukula Dispensary and Bunazi Health Center in Tanzania for health services (Figure 4). Kakuto, Mulago, and Masaka Hospitals in Uganda provide health services to Tanzanians, mainly for residents around Bunazi and

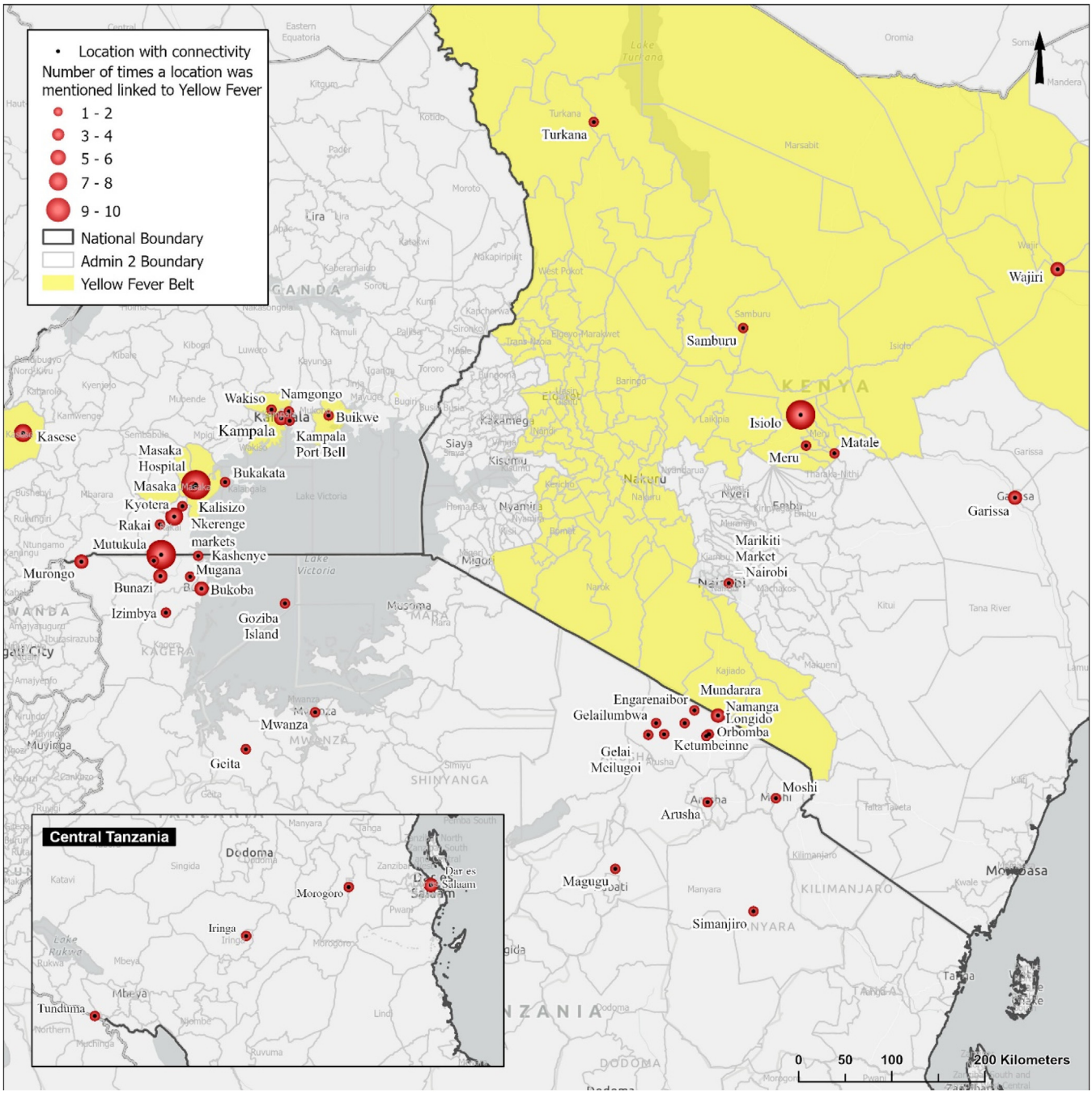

Figure 1. Locations visited by cross-border travelers across Kenya, Tanzania, and Uganda mentioned by participants during focus group discussions in Tanzania.

Mutukula cross-border areas. Participants mentioned that Tanzanians travel to Kalisizo in Kyotera, Uganda, to visit a famous traditional healer.

Fishing and fishing markets

Business people and fishermen sell fish and fish products, including sardines, from Bumbire and Goziba Islands, Kabindi, Ukerewe, and Sangabuye lakeshore in Tanzania to various places in Uganda, including Kampala and Kasensero (Figure 4). People from places across Tanzania and Uganda frequent sardine markets on the Goziba Islands in Lake Victoria. This was not mentioned in discussions on the Kenya border.

Agricultural produce and timber

Business people and traders move from Tanzania and Kenya, selling agricultural products such as carrots, green peppers, onions, and other vegetables (Figure 3). The main areas in Tanzania for the production of agricultural products include Lushoto in Tanga region and Karatu and Ngarenanyuki in the Arusha region. Timber is sold from Mafinga in Iringa, Tanzania, to Somalia through Isiolo and Garissa, which are both YF risk areas in Kenya.

Similarly, traders sell most of the agricultural produce from Bugango, Karagwe, Murongo, Isingiro, and Kyerwa in Tanzania, such as bananas, beans, salt, and coffee, at Mbarara and Mubende in the western part of Uganda (Figure 4). Participants described Tanzanian traders and people

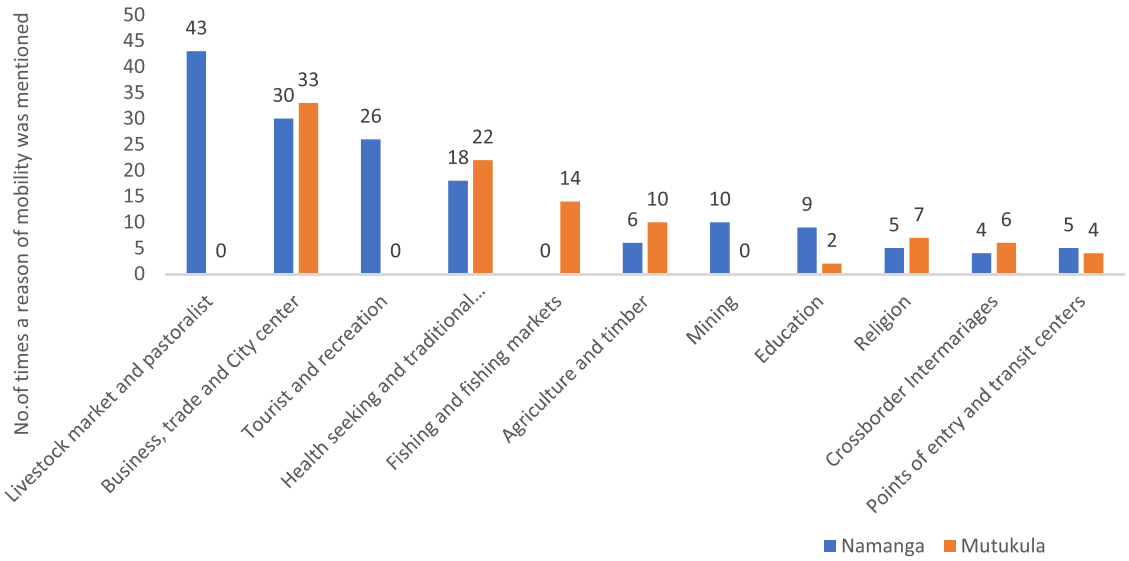

Figure 2. Reasons for population connectivity across Kenya, Tanzania, and Uganda through Namanga and Mutukula border areas in Tanzania mentioned by participants during focus group discussions in Tanzania.

from Wakiso and Buikwe (Uganda YF risk areas) converging in Mukono, Uganda, for the main, popular crop market.

Mining

Mining activities in Tanzania for ruby and tanzanite minerals encourage population movement from Kenya to Tanzania, including travelers from YF risk areas (Figure 3). The main mining centers located in Tanzania include Mundarara, Mererani, Matale in Longido, and Engarenaibor.

Education

People cross the border between Kenya and Tanzania for educational purposes. The prominent schools believed to have quality education and that are easily accessible from the border districts are in Namanga and Nairobi, Kenya. Similarly, some Kenyans send their children to school in Arusha, Tanzania. Tanzanians, especially from the Kagera region, prefer to further their education at Makerere University in Kampala, Uganda, due to its historic reputation as one of the oldest and best universities in East Africa (Figure 4).

Religion

Religious activities are another key reason for connectivity between Tanzania and Kenya (Figure 3). Congregants from both sides of the border often frequent open spaces at the Namanga border for religious worship. Both Kenyans and Tanzanians use churches at the border. Similarly, there are various religious congregations involving people from Tanzania and Uganda (Figure 4). Community members from both countries travel to Mutukula and Mugana, Tanzania, for religious congregations. Tanzanians from Mugana and Bunazi visit Namugongo in Uganda for pilgrimage.

Cross-border marriages

Intermarriages are common among people of the same tribe who live on either side of the Tanzania-Uganda border, speak the same language, and share a marriage culture. Key informants mentioned that intermarriages facilitate cross-border interaction through established marriage ties and regular visits for attending social events such as marriage and funeral ceremonies.

PoE and transit centers

Key informants described that people traveling between Kenya and Tanzania through the Namanga border area use 11 unofficial PoEs and two official PoEs, where people can lawfully enter Tanzania (Figure 5). The unofficial PoE are Kimwati, Engarenaibor, Sinya, Kamwanga, Kikerelwa, Lerang'wa, Meto, Milangosaba, Wosiwosi, Torosei, and Shompole. The official PoEs include Namanga and Loitoktok. The five main transit hubs connecting Tanzania and YF areas in Kenya are Kitui, Kajiado, Mbeya, Isiolo, and Wajir. The latter two are YF risk areas in Kenya, with linkages to Somalia. Most travelers from Somalia travel to South Africa through Tanzania via Namanga and Tunduma borders. In addition, people travel to and from the major airports of Kilimanjaro and Arusha in Tanzania, and Jomo Kenyatta in Kenya through the Namanga border.

Participants mentioned that people travel between Tanzania and Uganda through five official PoEs and 11 unofficial PoEs (Figure 5). They described that people travel between the YF risk areas in Uganda and Tanzania through official PoEs of Mutukula, Bugango, Kashenye, Minziro, and Murongo. Community members use the unofficial PoE of Kanyigo, Kisakara, Kabindi, Kabasesa, Kakiri, Kirashwa, Bandama, Karora, Lyabatura, Nyakasinga, and Nyakalinzi. The six main transit hubs connecting Tanzania and Uganda are Bunazi, Muleba, Biharamulo, Nyakanazi, Isaka, and Buseresere.

Discussion

The Tanzania MoH, in partnership with NM-AIST (Health and Biomedical Sciences) and the Centers for Disease Control and Prevention, characterized the risk of cross-border importation of YF by conducting FGDs with PM in border areas along the Kenya and Uganda borders and applying the results to tailor public health programming. Although there are ongoing efforts among YF high-risk neighboring countries to control YF, including preventive and reactive vaccination campaigns during outbreaks, vector control, and public awareness, the risk of exportation to Tanzania remains high due to repeated outbreaks and existing cross-border interactions [17–19]. The FGD participants reported high connectivity between locations in Tanzania and YF risk areas in Kenya and Uganda. Notably, the study has shown the likelihood for a YF-infected traveler to spread disease to an unaffected location due to the incubation period of YF that ranges between 3 and 6 days and shorter travel distance and duration between identified points

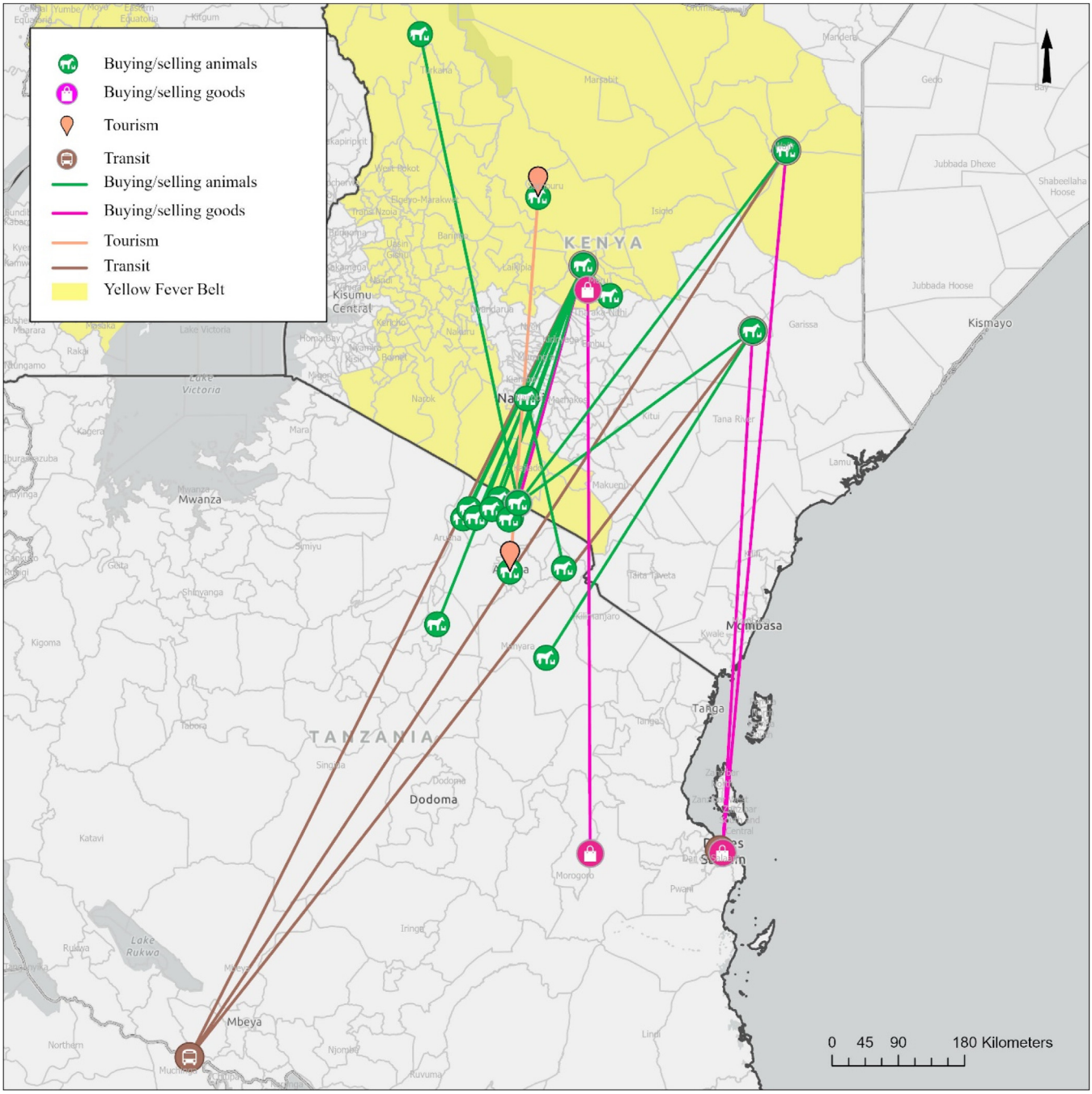

Figure 3. Points of interest and between-location population connectivity between Tanzania and Kenya based on focus group discussions in the Namanga border area, Tanzania, July 2023.

of interest with connectivity to YF high-risk areas. This highlights the possibility that a YF infected individual can travel to these destinations within the incubation period [20]. In addition, conveyances may transport infected mosquito vectors from YF high-risk areas to unaffected areas in Tanzania [21].

This high connectivity increases the risk of YF transboundary transmission into Tanzania and requires the MoH to consider opportunities to adapt programs to better accommodate cross-border connectivity dynamics. The findings of this study highlighted several reasons for population mobility, which underscore the intricate web of connectivity between Tanzania and Kenya and Uganda.

Business and trade emerged as predominant reasons for population connectivity between Tanzania and Kenya and Uganda. The movement of traders and goods, including mining, between rural and urban centers contributes to regional economic integration [14]. Nonetheless, efforts to enhance trade should be accompanied by effective health surveillance and vaccination programs to mitigate the risk of YF transmission, including implementing vaccination requirements and health screenings at PoE [17,19].

More specifically, participants reported connectivity between Tanzania and Uganda related to fishing along Lake Victoria and the associated fish and fish product market between the islands and urban areas in the countries. This interconnectivity raises concerns about the introduction of YF into the island and lakeshore communities, underscoring the importance of ensuring disease surveillance activities in the rural islands. In addition, YF serologic assessments among the populations with

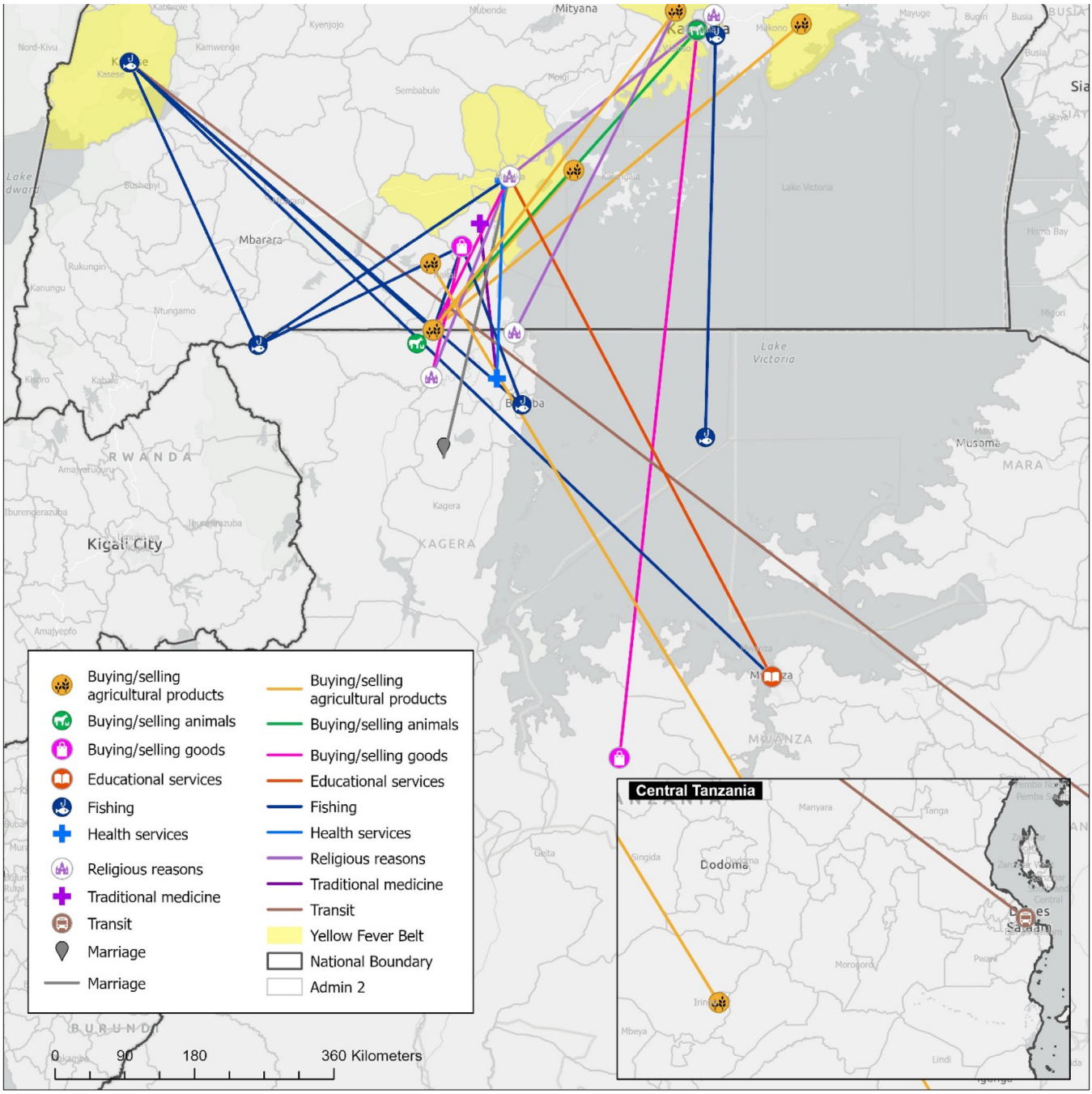

Figure 4. Points of interest and between-location population connectivity between Tanzania and Uganda based on focus group discussions in the Mutukula border area, Tanzania, July 2023.

strong connectivity with YF areas could help inform estimates of YF risk in these locations.

Livestock markets and pastoralist connectivity also emerged as significant factors driving population movement between Tanzania and Kenya, particularly among the Maasai community in Arusha. The exchange of livestock and products through various markets highlights the deep-rooted ties between these countries, especially in rural areas where pastoralism is a primary livelihood [15]. However, amidst fostering this connectivity, it is imperative to monitor and prevent the spread of YF from high-risk areas visited by these populations [16].

This study highlighted instances of cross-border movement for health services, with Tanzanians seeking medical attention in Kenyan and Ugandan health facilities and vice versa [20]. This movement raises the possibility of disease transmission if individuals from YF-risk areas access health services where Tanzanians visit and subsequently return home. Education, religious activities, and cross-border marriages further drive population movement and cultural exchange [15,22]. Strengthening health and disease surveillance systems, data sharing between countries, and collective adherence to international health regulations is critically important.

Finally, participants noted the routine use of unofficial PoE to cross the border. Individuals passing through these informal crossings are not subjected to the same public health protocols and screenings as those using official PoE, facilitating the undetected movement of individuals who could be infected with YF. There is a need to engage local leaders,

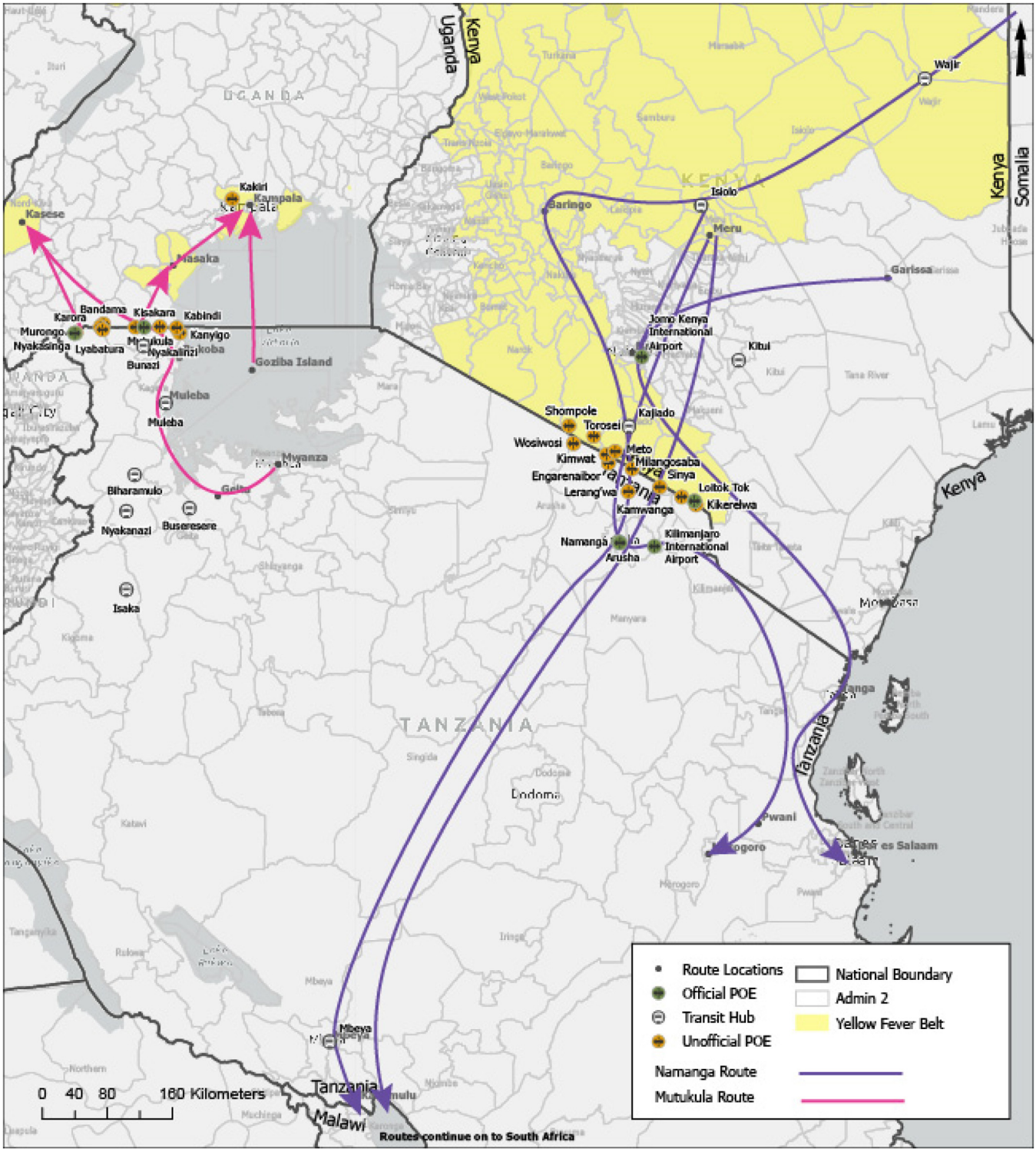

Figure 5. Points of entry and main travel routes used for cross-border movement between Tanzania and Kenya and Uganda, based on focus group discussions in Namanga and Mutukula border areas in Tanzania, July 2023.
PoE, points of entry.

community health workers, and security authorities to enhance the prevention of YF importation through informal PoE. Notably, the existence of unofficial PoEs and transit centers underscores the need for strengthened surveillance and vaccination efforts at these locations to prevent the importation of YF cases.

The results from this study were shared with the district, regional-, and national-level surveillance committees to help inform YF interventions, including where to strengthen active YF surveillance. In addition, tailored risk communication messages to religious and educational institutions and high-risk communities were recommended. Furthermore,

the MoH recommended using the results to strengthen existing cross-border initiatives with neighboring countries through the development of a multinational memorandum of understanding and cross-border operational guidelines and meetings, with an emphasis on applying a One Health approach.

Understanding community-level population mobility and connectivity patterns is crucial for understanding the avenues of potential risk of YF transmission across borders and for developing programming tailored to unique population dynamics. This study builds on other examples of PopCAB implementation during COVID-19, Ebola, and Lassa fever outbreaks. Beginning in 2016, the MoHs in Benin and Togo used PopCAB to understand the seasonal movement and health care-seeking locations of migrant agricultural workers between Benin, Nigeria, and Togo to support cross-border Lassa fever preparedness and response measures [15,23]. In 2018, the Uganda MoH used PopCAB during an Ebola outbreak in DRC to enhance Ebola preparedness and response measures in areas in Uganda with elevated connectivity with the outbreak zones [22]. During COVID-19, Tanzania, Uganda, and DRC governments generated PopCAB information to identify points of interest for COVID-19 mitigation measures and to enhance cross-border collaboration [16].

This study acknowledges certain limitations, including the generalizability of results and the subjective nature of interpreting data. Future research should focus on more extensive and joint PopCAB implementation, incorporating data from all three countries to provide a comprehensive understanding of population mobility.

Conclusion and recommendations

Understanding the multifaceted reasons for population movement and connectivity between Tanzania and its neighboring countries is crucial to inform effective cross-border YF prevention and control strategies. Although these reasons promote social and economic integration between countries, they also pose risks, including transboundary transmission of YF. Strengthening health surveillance and vaccination programs, implementing robust public health measures at PoE and transit centers to screen travelers and ensure vaccination compliance, enhancing cross-border cooperation and communication to facilitate information sharing and collaborative efforts in disease control, promoting sustainable socioeconomic development initiatives that consider public health implications and prioritize community well-being and infrastructure development to improve health care access and disease prevention measures in border regions are all highly recommended. Other countries with similar considerations can implement community-level PopCAB activities to guide the development of public health programs that more accurately accommodate the dynamics of population mobility to reduce the risk of communicable disease spread.

Declarations of competing interest

The authors have no competing interests to declare.

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Ethics approval and consent to participants

Ethical clearance was obtained from the National Institute of Medical Research, and written informed consent was sought from key informants.

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Author contributions

RK drafted the manuscript. RK, MM, SW, SM, AL, JK, NM, KM, EM, AB, GL, MM, WG, RM, SW, AS, KM, EK and EM read, reviewed and updated the drafted manuscript. All authors checked and approved the final manuscript.

Consent for publication

Permission to publish was obtained from the National Institute of Medical Research (NIMR).

Availability of data and materials

Data collected during this study are sensitive and, therefore, not publicly available, but data sets and reports can be provided upon reasonable request with permission from the responsible institutions.

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention/the Agency for Toxic Substances and Disease Registry.

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