

Original article

***Aedes* Mosquitoes distribution and risk of Yellow Fever transmission in Gurage Zone, Southwest Ethiopia**

Abate Waldetensai^{1*}, Wondatir Nigatu¹, Yosef Asrat¹, Chalachew Sisay¹, Mesay Gunta², Desalegn Belay¹ and Geremew Tasew¹

¹Ethiopian Public Health Institute, Addis Ababa, Ethiopia

²Wolayta Zonal Health Department, Wolayta, Ethiopia

*Corresponding author: abyw.res31@gmail.com

Cell phone: +251910850181

Abstract

Introduction: Yellow fever is a serious arboviral disease present with a variety of clinical signs and outcomes ranging from mild to severe fatal cases transmitted by *Aedes* mosquito.

Objective: To determine the distribution and specific species of *Aedes* mosquitoes present in the Gurage zone, Southwest Ethiopia, following the yellow fever outbreak in the area.

Methods: An entomological cross-sectional study design was used with simple random sampling techniques following the yellow fever outbreak report starting from February to April, 2020 for two months.

Results: A total of 748 houses were investigated, of these 621 (83%) houses were found to be positive for larvae/pupae. From a total of 168 water containers inspected, 78 (46%) were productive for larvae/pupae collections. The highest house index was recorded in Doba (95.7%) and Shumuro (95.3%) followed by Wodesha (89.5%), Woyera (89%), Terbieishikure (75%), Genideterbe (67%) and Lankatore (65%) Kebeles. The most preferred breeding sites of *Aedes* were found Enset (*Ensete ventricosum*) with Container Index (CI), Breteau index (BI) of (65.5%, 19), (54.8%, 13.7), (46.7%, 6.5), (45.7%, 13.7), (42.9%, 3), (44.4%, 12) and (19%, 4) in Genideterbe, Wodesha, Shumuro, Doba, Terbieishukure, Woyera and Lankatore Kebeles, respectively. From a total of 293 *Aedes* mosquito, 209 (71.3%) were collected from false banana. The mosquito species of *Ae. simpsoni* complex 199 (67.9%), *Ae. africanus* 40 (13.7%), *Ae. aegypti* 27 (9.2%) and *Ae. vittatus* 27 (9.2%) were collected from all types of breeding sites.

Conclusion: This study reveals that *Aedes* mosquitoes are abundant and widely distributed across the study sites. Larval indices were significantly associated with yellow fever transmission. The study found that *Aedes* larval indices were above the critical level which strongly suggests that there is high risk of yellow fever transmission. The abundance of *Aedes simpsoni* complex was found higher than *Ae. aegypti*, *Ae. africanus* and *Ae. vittatus*. Sustained surveillance must be standardized for adequate comparisons within and among regions.

Keywords: *Aedes*, Yellow Fever, Larval Indices, houses, containers, Gurage

Introduction

Aedes mosquitoes are usually black with white or silver markings on their bodies and nuisance species. They are the potential transmitters of human and animal infections, and are found distributing throughout the world by occupying many biotopes (Patrick et al. 2018). They are found to be spread to all continents excluding Antarctica primarily and hugely aided by man-made activities. The abundant distribution of different arboviral vectors is dependent on climate, topography, and anthropogenic changes in environments (Chimaeze et al. 2018). Temperature, rainfall, and relative humidity can influence the density of *Aedes* mosquito's population to cause a severe and potentially fatal illness in humans and are a cause of serious epidemics and pandemics (Lutomiah et al. 2013). In West Africa and parts of East Africa, during the rainy and early

dry seasons, tree-hole breeding anthropophilic *Aedes* reach high densities (Torres et al. 2018) and linked closely to the forest-savanna ecotone (Monath and Vasconcelos 2015). *Aedes* mosquito is considered one of the most relevant groups of mosquito in public health and got interested because of their role in the transmission of many arboviral diseases (Mint et al. 2017) causing large-scale outbreaks throughout the world (Chimaeze et al. 2018). The female *Aedes* acquires blood meals by simply extracting from people, birds, and other animals to obtain proteins needed to develop her eggs (Morris and Soule 2016). Dynamics interest in the mosquitoes of Africa has been derived from their ability to thrive mostly in the tropics and act as the vectors of the most debilitating human diseases caused by bio-agents (Cornel et al. 2018a; Das et al. 2018). The role of the mosquito in the transmission of disease to humans and animals

increased research interest on mosquitoes especially in Africa (Leta et al. 2018).

Because of the outbreaks of arboviral disease, the rapid spread and increasing challenge in Africa is posed by mosquito-borne viruses resulted in high public health problems (Cornel et al. 2018). This constitutes serious health, economic and social problems (Raphaelle et al. 2018). Yellow fever (YF) is a serious viral disease including mild illness and severe with fever, jaundice or hemorrhage and cause death that transmitted by *Aedes* mosquito. YF is known to be endemic in tropical and subtropical areas of South America and Africa. Annually, YF continues to occur in epidemic situations, and it is estimated to result in 130,000 human cases and 78,000 deaths in Africa (Mulchandani et al. 2019). In Ethiopia, the first YF epidemic occurred between 1960 and 1962 caused 100,000 cases with 30,000 deaths followed by the second YF outbreak between 2012 and 2013 (Legesse et al. 2018). In 2016, Ethiopia reported 22 suspected yellow fever cases, including five deaths in the South Omo zone (African Union Permanent Representatives Committee (PRC) 2016). More recently, in October 2018 and March 2020, an outbreak of YF has been confirmed in Southwest Ethiopia leads to the death of 4 peoples (Ministry of Health (MoH) 2020). Rapid urbanization, population movement and human activities are the main factors for expanding the geographical range of the YF virus and creating a high density of vectors at the unvaccinated population (Mulchandani et al. 2019).

High densities of mosquito vectors closer to human dwellings and reservoir hosts within unvaccinated and highly populated areas are the major factors expanding the geographical spread of this virus (World Health Organization (WHO) 2014). The capacity of disease transmission will be determined by the degree of anthropophilic (Nnanna et al. 2016). The YF virus and the vectors live together adopting one another to maintain the transmission cycles. *Aedes* and *Haemagogus* mosquitoes are the responsible vectors of the YF virus in many endemic areas (Samaroo 2015). Sporadic yellow fever infection occurs almost exclusively in forestry and agricultural workers because of occupational exposure (Eni et al. 2014). For instance, across regions of Africa, the vectors and associated ecological patterns of YFV transmission is different (Monath and Vasconcelos 2015). The transmission of YFV is characterized by three and two types of cycles in Africa and South America respectively (WHO 2014). The amplification of the YF virus involved a variety of vector species, including *Ae.*

aegypti, *Ae. simpsoni* complex, *Ae. furcifer-taylori*, *Ae. luteocephalus*, *Ae. metallicus*, *Ae. Africanus* and *Ae. vittatus* (Couto-lima et al. 2017; Monath and Vasconcelos 2015; Tomor 2002; Zettel and Kaufman 2016). In parts of Africa (East Africa), during yellow fever epidemic, the current most important vector is *Aedes simpsoni sensu lato* (s.l.), likely *Ae. bromeliae* and *Ae. africanus*, were the principal vectors during the largest recorded epidemic of yellow fever in between 1960 and 1962 (Ellis et al. 2012), and 2012 in Ethiopia (Lilay et al. 2017).

Various fruitful approaches have been attempted to prevent and control the spread of YF virus. YF vaccine linked with vector control is proving to be the best approach until YF specific drugs are developed (Basker and Kannan 2013).

Disease surveillance, vector surveillance, and monitoring of environmental and social risks are among the YF surveillance program (Sitepu et al. 2018). From these surveillances, entomological surveillance is used to establish changes in the environmental provision and density of the vectors to evaluate control programs, obtain comparative measurements of the vector population over time. This is also can be used to decide and facilitate appropriate interventions on time. In general, the objectives of *Aedes* mosquitoes investigation methods are to obtain baseline information on infestation and re-infestation, evaluate and recommend control methods through larval and adult mosquito surveys (Basker and Kannan 2013).

Though YFV is well known in Ethiopia, there is no complete information documented with regards to vector species involved in transmission according to geographic distribution because of under-reported infections due to lack of laboratory facilities and inaccessibility of some of the endemic areas (Getachew et al. 2015). As a result, YF prevention and control requires strong and continuous collection and collation of data on *Aedes* species. The present study is therefore sought to determine the diversity and distribution of *Aedes* mosquitoes in Gurage Zone, Southwest Ethiopia, during the time of YF outbreak.

Methods and Materials

Study area: The Gurage Zone is 155 kilo meters far from Addis Ababa, the capital city of Ethiopia. Geographically, Gurage zone is located to the southwest direction between 7.8°C - 8.5°C N and 37.5°C- 38.7°C E with altitude ranging from 1,001 to 3,500 meters above sea level (m.a.s.l) (Aduna and Ayalew 2019). It comprises three agro-climatic zones: Dega (28.3%) with high altitude (25000-

3662m ASL), Woina Dega (64.9%) with mid-altitude (1500 – 2500 m ASL) and Kolla (6.8%) with lowland altitude (1000 – 1500m ASL). It is known with bimodal rainfall pattern Kiremt (with 80% of rainfall from June to August) and Belg (with 20% of rainfall from February to May). The annual temperature and mean annual rainfall of the area is 13-30°C and 600-

1600 mm in range, respectively. According to the land utilization data of the region 298,369 hectares (ha) cultivated land (mostly with Enset), 70,249.31 ha grazing land, 67,678 ha forest, bushes and shrub-covered land, and 14,234 ha of land is covered by others (Hailemariam et al. 2018) (Figure 1).

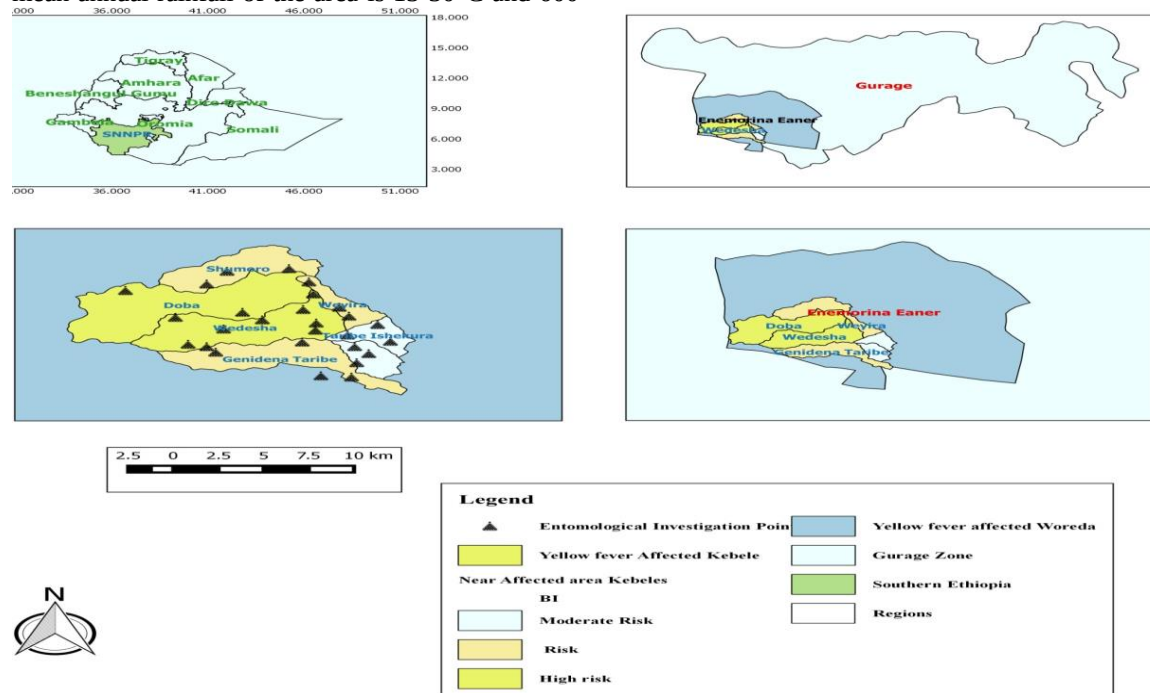


Figure 1: Entomological investigation maps for yellow fever risk assessment in Gurage Zone, South Western Ethiopia

Study design, sampling, and sample collection techniques: An entomological cross-sectional study was conducted in the Gurage zone, southwest Ethiopia following a yellow fever outbreak report starting from February to April, 2020 for two months. Simple random sampling techniques was applied to select the hundred meters (100m) transect households using the cases reported households as a start point. Due to time shortage and some sites were hard to reach, only seven lowest administrative Kebeles namely, Wodesha, Woyra, Shumoro, Lankatore, Genideteribe, Doba, and Teribeishekure were selected. To conduct this investigation, the outbreak point and distributions of forests with non-human primates were considered due to the condition that YF may spread from jungle to rural or urban. This means nearby villages to forest environments were selected at relatively high human population densities and large-scale land alterations due to human involved activities. Discussions were undergone with the area authorities and house owners before sampling to assure their involvement in the study. Next, to check the presence of immature stages of mosquitoes, appropriate environmental variables

for breeding sites of mosquitoes were determined through community's recommendations and observation

All preferred resting places of *Aedes* mosquito and breeding sites were identified before sample collection employment. Following the WHO (2016) guideline, at least 100 houses were selected from each identified Kebeles. The mosquito collection was undertaken focusing only on immature stages with dipper and pipetting techniques (WHO 2014). Each identified household and its vicinity have been investigated for possible mosquito vectors. Artificial and natural mosquitoes breeding sites were inspected. Since only aquatic habitats harboring at least one larva or pupae of *Aedes* spp. were considered positive, samples were collected from infested containers. Larvae/pupae were sampled from various water storage containers (Jerycans, Barrels, Clay Pots, Plastic Pans, and Rotoes) (Figure 2). The collections were entered into well-labeled plastic laboratory (insectary) for rearing to the adult stage to identify the species level. All count of larvae or pupae with inspected containers were recorded by

types and localities. The presence of *Aedes* larvae in natural breeding habitats was also recorded. While larval indices were used to quantify vector breeding

potential in each cluster, the pupae counts were also taken as a proxy for adult vector abundance.

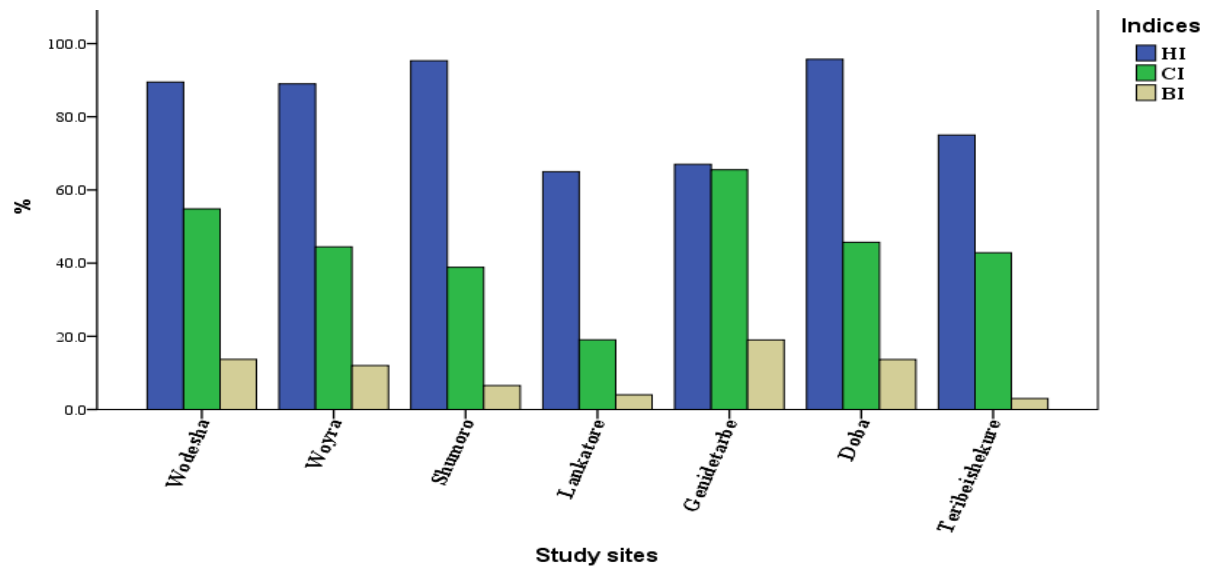


Figure 2: The distribution pattern of *Aedes* larvae with indicative larvae indices

Mosquito identification: This was done at frozen and sorted on a chill table adult stage emerged immature stages using the morphological identification keys and by reference to morphological descriptions (Huang 1990 and 2004); Huang and Rueda 2017) under light compound microscope. The identified *Aedes* species were pooled based on collection sites and preserved in 96% ethanol for farther arboviruses screening.

Data management and Analysis: All information about *Aedes* mosquitoes was entered into the excel spreadsheet and imported to SPSS (version 20) for statistical analysis. Descriptive statistics were used to determine the most preferred breeding sites, density, and abundances of *Aedes* mosquitoes. ANOVA was used to compare the different habitat types of these vectors at 95% confidence intervals (P value, 0.05). House index (i.e. percentage (%) number of positive house per 100 houses inspected), Breteau (i.e. the total number of containers with larvae or pupae per 100 houses) and container (i.e. percentage (%) number of positive containers divided by the number of containers inspected) index risks were estimated with collected databased on the WHO protocol. Entomological indices were interpreted according to the WHO guideline (WHO 2016).

Results

YF outbreak case investigation: On March 2020 three yellow fever cases were reported from the same households (father, mother and son) from Wodesha

rural Kebele located in Enor Ener District of Gurage zone, Southern Nation and Nationalities Peoples Region. Serum samples were collected from these patients and transported to the Ethiopian Public Health Institute (EPHI) laboratory. Two of the three samples tested by reverse transcriptase polymerase chain reaction (RT-PCR) were found positive for yellow fever virus acute infections. As of 6 April 2020, a total of 4 deaths and 85 suspected cases have been notified from 6 Kebeles, of which 54 were from Wodesha Kebele. Among the total suspected cases, 6 samples tested positive at EPHI national laboratory. In response to the problem, EPHI and MoH preformed an in-depth investigation and response, supported by partners including WHO. Accordingly, this study made entomological investigation and active case search on 1275 households and schools. At the same time vaccination on 27,178 individuals were done.

Immature Stage (Larvae and Pupae) Surveys: A total of 748 houses were investigated in the Enomorenor district in Guraghe Zone (South Western Ethiopia) to detect the existence of *Aedes* mosquito breeding sites after checkup of mosquito's larvae/pupae presences. Potential breeding sites such as artificial and natural breeding places which include Enset (*Ensete ventricosum*) or false banana and containers were found in the study sites. Of the total, 621 (83%) houses were found to be larvae/pupae positive. Within this scenario, about 168 water containers, suspected or expected to be best for

mosquito breeding were inspected. Of these, 78 (46%) containers or water storages were found positive for larvae/pupae collection. Out of the identified containers contain immature stages, 468

larvae and 138 pupae were collected and reared to the next adult stage. The overall inspection results were tabulated for the study sites and presented in Table 1.

Table 1: Distribution of houses, containers inspected for positivity of immature stage across the study sites, Gurage zonea, March 2020

Sites	# house inspected	# houses +ve	# container inspected	#containers +ve	# larvae	# pupae
Wodesha	124	111 (89.5)	31	17 (54.8)	200	139
Woyra	100	89(89)	27	12 (44.4)	75	36
Shumoro	107	102 (95.3)	18	7 (46.7)	29	22
Lanka Tore	100	65 (65)	21	4 (19)	20	17
Genidetaribe	100	67 (67)	29	19 (65.5)	17	10
Doba	117	112 (95.7)	35	16 (45.7)	96	58
Teribeishekure	100	75 (75)	7	3 (42.9)	31	17
Total	748	621 (83)	168	78 (46.4)	468	299

The result confirmed that there were big positivity differences in number of houses, containers and larvae/pupae across all the study sites. Among the listed and inspected water holding containers, *Aedes* mosquito larval/pupae positive breeding's were found on containers placed outside the homes. Clay pots with the highest rate of positivity for *Aedes* mosquito larvae (n = 272 and mean = 39) followed by Barrel (n = 97 and mean = 14), Gerycan, (n = 38 and mean =

5), Plastic Pan (n = 25 and mean = 4) and Roto (n = 22 and mean = 4). In regards of Pupae positive containers, Barrel was found with highest pupae (n = 82 and mean = 12) followed by Clay Pot (n = 24 and mean = 3), and Roto (n = 27 and mean = 4). It has been found that there is a difference in all types of containers between larvae and pupae positivity; that may be due to different factors associated on the impacting of developmental stages (Figure 3).

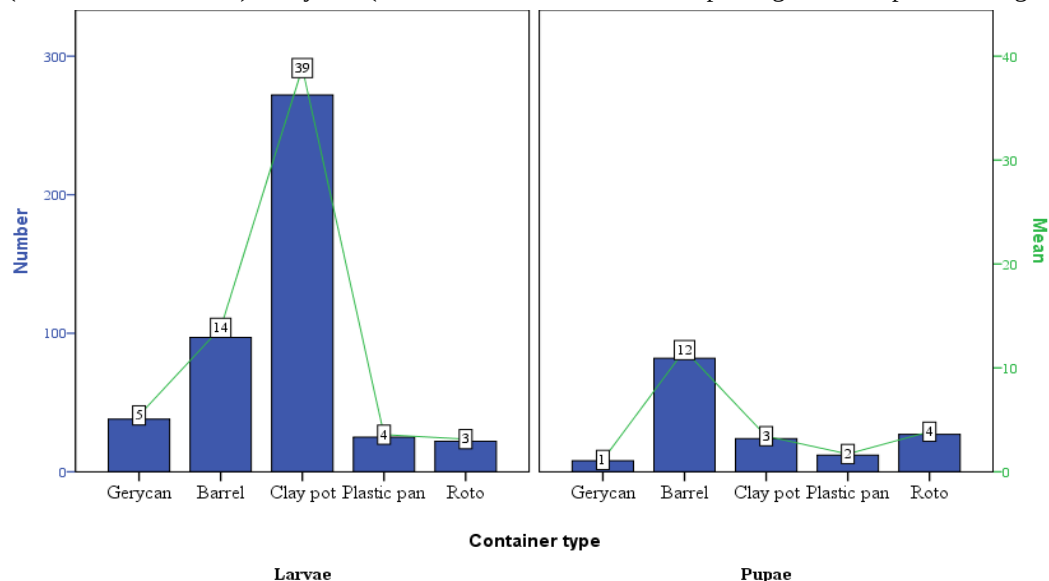


Figure 3: Distribution of larvae and pupae by water holding container types, Gurage Zone South Western Ethiopia, March 2020

Aedes mosquito immature stage indices: The numbers of *Aedes* mosquitoes were calculated as *Aedes* mosquito larval indices (HI, CI, and BI) from all study areas to determine if they were associated with YF transmission (Figure 3). The proportion of houses infested with *Aedes* mosquito larvae can be expressed as the HI by study sites. High proportional infestation of *Aedes* mosquitoes were observed in Doba (95.7%) and Shumoro (95.3%) followed by Wodesha (89.5%), Woyera (89%), Terbieishikure (75%), Genideterbe (67%) and Lankatore (65%). In specific breeding habitats (containers) BI were found

to be higher in Genideterbe 19 (CI, 65.5%; BI, 19) and Wodesha 17 (CI, 54.8%; BI, 13.7) ranged above 50% and followed by Shumoro 7 (CI, 46.7%; BI, 6.5), Doba 3 (CI, 45.7%; BI, 13.7), Terbieishikure 16 (CI, 42.9%; BI, 3), Woyera 12 (CI, 44.4%; BI, 12) being below 50 % of breeding habitats. Low infestation level was observed at Lankatore with BI 4 (CI, 19%; BI, 4). In total, 767 water stage mosquitoes were collected from 7 study sites across Guraghe Zone. Among these, 293 (38.2%) were *Aedes* mosquitoes. The rest 437 (57%) and 37 (4.8%) were found *Culex* and *Anopheles* mosquitoes respectively.

The *Aedes* mosquito larvae were identified to species level found to be *Ae. Aedes simpsoni* complex (199 (67.9%)), *Ae. aegypti* (27 (9.2%)), *Ae. africanus* (40

(13.7%)), and *Ae. vittatus* (27 (9.2%)). Though small number of *Aedes* mosquito recorded, all member species were abundant in all the study sites (Table 2).

Table 2: Distribution and abundance of *Aedes* mosquito species across study sites, March 2020

	Wodesha	Woyra	Shumoro	Study sites (%)		Doba	Teribeish ekure	Total
				Lanka Tore	Genidet aribe			
<i>Ae.simpsoni</i> complex	47 (16)	37 (12.6)	39 (13.3)	4 (1.4)	6 (2)	63 (21.5)	3 (1)	199 (67.9)
<i>Ae. aegypti</i>	3 (1)	10 (3.4)	9 (3.1)			5 (1.7)		27 (9.2)
<i>Ae. africanus</i>	13 (4.4)	6 (2)	5 (1.7)	1 (0.3)		15 (5.1)		40 (13.7)
<i>Ae. vittatus</i>	10 (3.4)	4 (1.4)	6 (2)			7 (2.4)		27 (9.2)
Total	73 (24.9)	57 (19.5)	59 (20.1)	5 (1.7)	6 (2)	90 (30.7)	3 (1)	293 (100)
<i>Culex</i>	150 (31.6)	68 (14.3)	32 (6.8)	51 (10.8)	39 (8.2)	44 (9.3)	53 (11.2)	437 (92.2)
<i>Anopheles</i>	9 (1.9)	12 (2.5)	5 (1.1)			11 (2.3)		37 (7.8)
Total	159 (335)	80 (16.9)	37 (7.8)	51 (10.8)	39 (8.2)	55 (11.6)	53 (11.2)	474 (100)

Of all (293) *Aedes* mosquitos collected from all types of breeding habitats, 209 (71.3%) were collected from Enset which was the most preferred breeding site and dominantly found in the study areas. The abundance of *Ae. simpsoni* complex were recorded high from all breeding types (199 (67.9%)), followed by Enset (*Ensete ventricosum*) (153 (52.2%)), Barrel (13 (4.4%)), Gery can (7 (2.4%)), Clay pots (16 (5.5%)), Roto (6 (2%)), Plastic Pan (4 (1.4%)). The species of *Ae. africanus* (40 (13.7%)), *Ae. aegypti* (27 (9.2%)) and *Ae. vittatus* (27 (9.2%)) were collected

from all breeding types. The collection of *Ae. aegypti* from Enset (false banana), Clay Pots, Gerycan, Roto and Barrel were found to be 10 (10%), 9 (3.1%), 4 (1.4%) and 1 (0.3%) respectively. *Ae. aegypti* were not found from Plastic Pan. Relatively the abundance of *Ae. africanus* was found to be the second following *Ae. simpsoni* complex. In the decreasing order of 29 (10%), 8 (2.7%) and 3 (1%) numbers, *Ae. africanus* were collected from Enset, Clay Pots and Roto respectively.

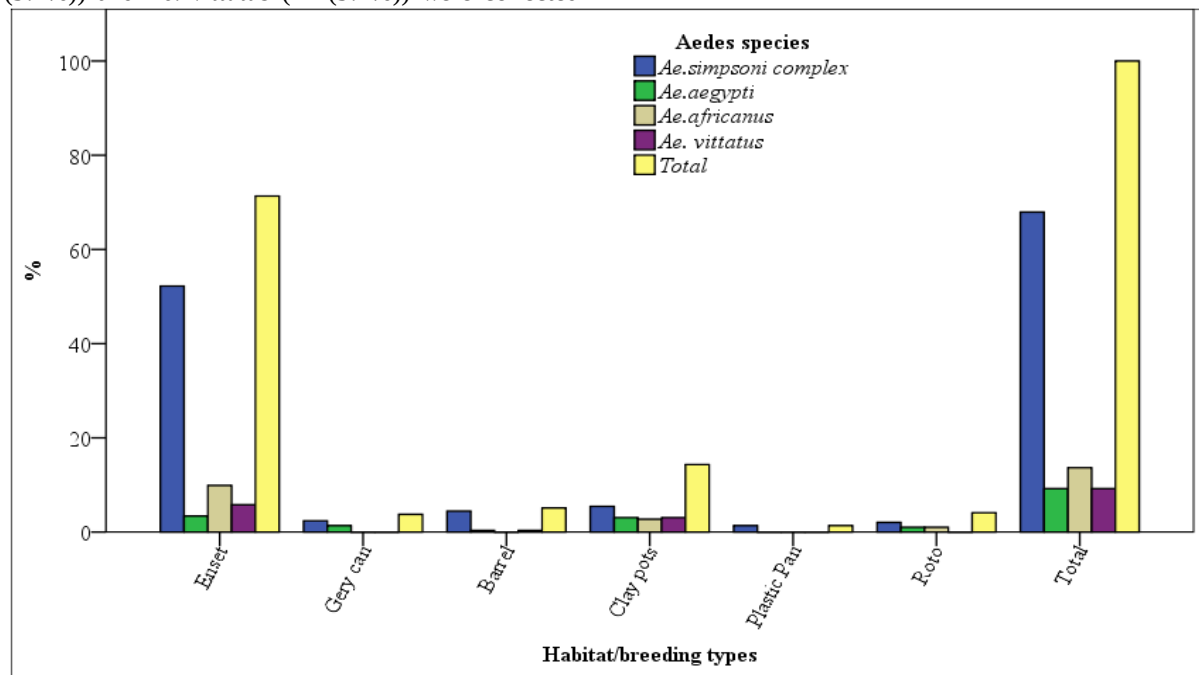


Figure 2: *Aedes* mosquito species distribution by container habitat/breeding type, Gurage Zone South Western Ethiopia, March 2020

Ae. africanus was not observed from Gerycan, Barrel and Plastic pans. The *Ae. vittatus* collected from Enset, Clay Pots and Barrel was found 17 (5.8%) 9 (3.1%) and 1 (0.1%) correspondingly. Totally, next to Enset collection, 42 (14%) *Aedes* were collected from

Clay Pots followed by 15 (5.1%), 12 (4.1%), 11 (3.8%), 4 (1.4%) from Barrel, Roto, Gerycan and Plastic pan consecutively. Clay Pot was found the second preferred breeding types of *Aedes* mosquitoes in the study areas which are followed by Roto and Gerycan (Figure 4).

Discussion

Though an outbreak of arboviral infections has always been associated with *Aedes* mosquitoes, there is still a lack of adequate information on the ecological distribution of *Aedes* species and the diseases they transmit in different parts of Ethiopia. Since the transmission of yellow fever is directly related to its vectors, information on density, species identification, and breeding places are essential for effective vector control (Chimaeze et al. 2018). This is because, in a place where relatively little is known about mosquito populations, or the presence of arboviruses, understanding the potential for arbovirus transmission is dependent on species occurrence and their abundances and variation of species in time and space (Cornel et al. 2018).

In the present study, both artificial and natural sites were found the potential breeding places for mosquitoes. This is consistent with another study (Simard et al. 2005) in which Enset (*Ensete ventricosum*) and containers play a major role in *Aedes* breeding (Lilay et al. 2017). Though there was sample size difference in the number of houses inspected, the houses and containers infested with larvae/pupae were high across all study sites compared to the study conducted in Dire Dawa, Eastern Ethiopia (Getachew et al. 2015).

In this study, the most common breeding habitats observed were false banana (*Ensete ventricosum*), Barrels, Clay Pots, Jerrycan, Plastic drums/pans, and Roto. Similar to a study carried out in Ethiopia (Lilay et al. 2017), this investigation found that the average number of larvae per breeding place was higher in the natural than in the artificial breeding sites. According to this study, a false-banana (*Ensete ventricosum*) which is traditionally cultivated close to the residential home was found to be a highly preferred breeding site of *Aedes* species followed by Clay pots. The property of Ensete with large plant stem resists evaporation making mosquito breeding possible all year round. Regarding this, the current study is in agreement with another study which conducted in Southern Ethiopia (Mulchandani et al. 2019). In the study area due to the absence of piped water, the community used the ground, rain, and spring water sources that may be contributed to the factor of mosquito water preferences for breeding (Getachew et al. 2015). Discarded containers (like Barrel Jerrycan, Plastic Pans, and Roto) may also differently

favorable to the proliferation of mosquitoes in this study, which is in parallel with the study performed in Cote d'Ivoire (Konan et al. 2013). All containers inspected for the *Aedes* larvae/pupae were found positive outside of the home which is similar to a study conducted in Kenya (Agha et al. 2017). This information might have important implications in the design of arbovirus vector control strategies. The population of YF vectors can be greatly reduced by reducing their sources such as small containers on the premises of human dwellings. These activities can also be supported by advocacy, social mobilization and legislation, collaboration within different sectors, integrated approach to disease control, evidence-based decision making, and capacity building (Basker and Kannan 2013). The habitats of *Aedes* mosquitoes can also be eliminated by preventing access to these containers through frequently emptying and cleaning them (WHO 2019).

In this study, efforts have been made to understand the significance of entomological surveillance using the HI, CI, and BI. These indices help to design the implementation of the outbreak prevention and control measures. The meaning of using *Aedes* indices has been proven an effective tool for the rapid prevention and control of YF (Basker and Kannan 2013). The larval indices of HI and CI found in this study are relatively comparable with the study conducted in Dire Dawa (Ferede et al. 2018; Getachew et al. 2015). The larval indices were also significantly associated with yellow fever transmission, which is in parallel with the study conducted in Indonesia (Siregar and Makmur 2018). The presence of suitable containers for larvae breeding can increase the *Aedes* mosquito population, associated with the risk of YF virus transmission (Lutomiah et al. 2013).

In the current study, all the investigated sites had high *Aedes* larval indices that indicate the fact of high risk of YF possible transmission, when arboviral cases become established (Sharma et al. 2015). This is in contrast to the study results found elsewhere (Huang et al. 2014). The variability of mosquito abundance depends on ecological and climatic factors (temperatures and rainfall), and chemical composition of the water for the development and the distribution of mosquito species (Patrick et al. 2018).

The current population growth, demographic shifts to urban areas, and its prominence with the presence of competent vectors linked with imported cases of arboviruses infections pose continuous outbreaks in different places (Hasty et al. 2020).

In this study, the dominant *Aedes* mosquito species that emerged from the collected larvae were *Ae. simpsoni* complex followed by *Ae. Africanus* with the vectors of sylvatic yellow fever which is consistent with the study conducted in southern Ethiopia (Lilay et al., 2017). But, this is in contrast with the study conducted in North West Ethiopia (Ferede et al. 2018). *Ae. vittatus*, which is known as a vector of chikungunya and yellow fever around the forest, and *Ae. aegypti*, the urban vector (Ali et al. 2014) found to be less dominant in all of the current study areas which is opposite to the study carried out in North West Ethiopia (Ferede et al. 2018). It is worthy to note that the members of the *Ae. simpsoni* complex collected from study Zone suggesting that the species may be *Ae. bromeliae*, as observed in Nigeria (Chimaeze et al. 2018), the widely distributed anthropophilic member of the complex in Ethiopia (Mulchandani et al. 2019). This indicated that *Ae. simpsoni* complex and *Ae. africanus* were involved in the transmission of YF more dominantly in the study area which makes the transmission may be rural/sylvatic (Lilay et al. 2017). The sylvatic cycles involves the circulation of the YF virus between non-human primates and tree-dwelling mosquitoes in which the risk the virus transmission tends to be higher toward the end of the rainy season and at the beginning of the dry season, due to increased vector density (Young et al. 2017). This study provides a valuable clue on *Aedes* mosquitoes distribution in YF virus outbreak reported in rural areas. The result therefore suggest that the urban and sylvan areas also need to be considered for the implementation of arbovirus vector surveillance and control strategies.

Conclusion

This study reveals that *Aedes* mosquitoes are abundant and widely distributed across the study sites in Gurage Zone. The habitats preference of *Aedes* species has found to be both natural (false banana) and artificial containers (Clay Pots, Gerycan, Roto, Barrel, and Plastic Pan). The most preferred *Aedes* mosquito breeding habitat was a false banana (*Ensete ventricosum*) followed by Clay Pots. Larval indices were significantly associated with YF transmission.

Larval indices tabulated for all the current study sites shows that there is a potential of high-risk YF transmission in the areas. *Aedes simpsoni* complex immature stages were higher than *Ae. aegypti*, *Ae. africanus* and *Ae. vittatus* but all of them are found co-existed that may again facilitate for high risk of YF transmission. The presence of diverse habitats and water availability and the progressing history of disease outbreak by *Aedes* species in the study area may inspire an intensification of the vector surveillance activities. Variation in mosquito abundances is the highest important epidemiological risk parameters that may impacts differentially on transmission risk of YFV in the Zone. This study provides the first baseline data on the presence of *Aedes* species, the potential for the emergence of viral diseases in the vulnerable populations and high risk areas based on densities of mosquitoes. It may also suggest establishing a continuous and systematic surveillance program across the different geopolitical and ecozones of the country. Monitoring vector density is essential as a basis for health professionals in designing more effective prevention strategies. Such sustained surveillance must be standardized for adequate comparisons within and among regions. All important breeding containers should be subjected to appropriate control measures (source reduction via the removal of these containers) around the premises of living and working areas. Routine activities for eliminating mosquito breeding sites such as managing the natural and artificial water-filled containers should be required. Managing the breeding habitat of *Aedes* mosquito on Enset/false banana (*Ensete ventricosum*) should be established and strengthened through cooperative work plans with agricultural sectors. The distribution of the vectors of YFV in the study areas indicates relatively a wide diversity of vector species, suggesting that surveillance and vector control programmers should take into account the ecological specificity of each species. Finally, similar studies are recommended to be carried out on different geopolitical, hydrological, and agricultural development corridors and ecological zones of the country that have conducive habitats for the breeding of *Aedes* species.

Acknowledgments

The authors would like to thank for the support provided by colleagues from Ethiopian Public Health Institutes, Guraghe Zone Health Departments, Enomoenor Health Offices, facility staff, Health Centers, and Kebele Administration Offices. All technical personnel involved in this study from EPHI are highly appreciated for their excellent technical support in field mosquito collection.

Competing interests: The authors declare that they do not have competing interests.

References

- Afuna TF & Ayalew W (2019). Assessment of Dairy cattle management in Gurage Zone , Southern Nation Nationalities and Peoples Region , Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, 5(4):1–10.
- African Union Permanent Representatives Committee (PRC) (2016). *Briefing on the outbreaks of communicable diseases of 2016 in different parts of Africa*. Addis Ababa.
- Agha SB, Tchouassi DP, Bastos ADS & Sang R (2017). Dengue and yellow fever virus vectors: seasonal abundance , diversity and resting preferences in three Kenyan cities. *Journal of Parasite and Vector*, 10(628):1–10.
- Ali KM, Asha AV & Aneesh EM (2014). Bioecology and vectorial capacity of Aedes mosquitoes (Diptera: Culicidae) in Irinjalakuda Municipality , Kerala , India in Relation to Disease Transmission. *International Journal of Current Research and Academic Review*, 2(4):43–49.
- Basker P & Kannan P (2013). Study on Entomological surveillance and its significance during a Dengue outbreak in the District of Tirunelveli in Tamil Nadu , India. *Osong Public Health and Research Perspectives*, 4(3):152–158.
- Chimaize CO, Kechukwu NE, Okechukwu NE & Chimaize CO (2018). Diversity and distribution of Aedes mosquitoes in Nigeria. *New York Science Journal*, 11(2).
- Cornel AJ, Lee Y, Paulo A, Almeida G, Johnson T, Mouatcho J, et al. (2018a). Mosquito community composition in South Africa and some neighboring countries. *Parasite and Vector*, 11(331):1–12.
- Couto-lima D, Madec Y, Bersot MI, Campos SS, Motta DA, Barreto F, et al. (2017). Potential risk of re-emergence of urban transmission of Yellow Fever virus in Brazil facilitated by competent Aedes populations. *Scientific Reports*, 7(4848).
- Das Biswadeep G, Sayam Mohanty S (2018). Aedes: What do we know about them and what can they transmit? *Vectors and Vector-Borne Zoonotic Diseases*, 1–22. DOI: 10.5772/intechopen.81363.
- Ellis BR, Sang RC, Mcelroy K, Higgs S & Wesson DM (2012). Yellow fever virus susceptibility of two mosquito vectors from Kenya , East Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 106(6):387–389.
- Eni EG, Andem AB, Effanga EO, Umoh CJ, Oku EE & Ogbeche EO (2014). Prevalence of yellow fever vectors in forested area of Bekwarra , South prevalence of Yellow Fever vectors in the forested area of Bekwarra , Southern Nigeria. *Journal of Academia and Industrial Research*, 2(8):472–475.
- Ferede G, Tiruneh M, Abate E, Kassa WJ, Wondimeneh Y, Damtie D, et al. (2018). Distribution and larval breeding habitats of Aedes mosquito species in residential areas of northwest Ethiopia. *Epidemiolog and Health*, 40(e2018015):1–7.
- Getachew D, Tekie H, Gebre-michael T, Balkew M & Mesfin A (2015). Breeding sites of Aedes aegypti: Potential Dengue vectors in Dire Dawa , East Ethiopia. *Hindawi*, <http://dx.doi.org/10.1155/2015/706276>.
- Hailemariam T, Belete T, Hailu T, Ayele D & Ligani S (2018). Analytical & bioanalytical techniques analytical & bioanalytical techniques quantification of organochlorine pesticide residues in chewable part of Chata edulis in Gurage Zone , SNNPR , Ethiopia. *Journal of Analytical & Bioanalytical Techniques*, 9(1). DOI: 10.4172/2155-9872.1000395
- Hasty JM, Felix GE, Amador M, Barrera R, Santiago GS, Nakasone L, et al. (2020). Entomological investigation detects Dengue virus Type 1 in Aedes (Stegomyia) albopictus (Skuse) during the 2015 – 16 Outbreak in Hawaii. *American Journal of Tropical Medicine and Hygiene*, 102(4): 869–875.
- Huang Y-JS, Higgs S, Horne KMCE & Vanlandingham DL (2014). Flavivirus-Mosquito Interactions. *Viruses*, 6(11):4703–4730.
- Huang Y & Rueda LM (2017). Pictorial keys to the sections, groups, and species of the

- Aedes* (Finlaya) in the Afrotropical Region (Diptera: Culicidae). *Zootaxa*, 4221(1): 131–141.
- Huang YM (1990). The subgenus *Stegomyia* of *Aedes* in the Afrotropical Region. Contributions of the American Entomological Institute. pp 90.
- Huang YM. (2004). *Zootaxa*, *Diptera*, *Culicidae*, *Aedes* (*Stegomyia*). pp 120.
- Klitting R (2018). What does the future hold for Yellow Fever virus? (I). *Genes*, 9(291):12–16.
- Konan YL, Coulibaly ZI, Kone AB, Ekra KD, Doannio JM, Dosso M, et al. (2013). Species composition and population dynamics of *Aedes* mosquitoes, potential vectors of arboviruses, at the container terminal of the autonomous port of Abidjan, Co. *Parasite*, 20(13).
- Legesse M, Endale A, Erku W, Tilahun G & Medhin G (2018). Community knowledge, attitudes and practices on Yellow fever in South Omo area, Southern Ethiopia. *PLoS Neglected Tropical Diseases*, 1–13.
- Leta S, Jibat T, Clercq EM De, Amenu K, Kraemer MUG & Revie CW (2018). Global risk mapping for major diseases transmitted by *Aedes aegypti* and *Aedes albopictus*. *International Journal of Infectious Diseases*, 67:25–35.
- Lilay A, Asamene N, Bekele A, Mengesha M, Wendabeku M, Tareke I, et al. (2017). Reemergence of yellow fever in Ethiopia after 50 years, 2013: epidemiological and entomological investigations. *BMC Infectious Diseases*, 2–7.
- Lutomiah J, Bast J, Clark J, Richardson J, Yalwala S, Oullo D, et al. (2013). Abundance, diversity, and distribution of mosquito vectors in selected ecological regions of Kenya: public health implications. *Journal of Vector Ecology*, 38(1):134–142.
- Ministry of Health (MoH) (2020). *Yellow Fever outbreak in gura zone, southwestern Ethiopia*. Addis Ababa, Ethiopia.
- Mint A, Lemine M, Aly M, Lemrabott O, Ebou MH, Lekweiry K, et al. (2017). Mosquitoes (Diptera: Culicidae) in Mauritania: A review of their biodiversity, distribution and medical importance. *Parasites & Vectors*, 1–13.
- Monath TP & Vasconcelos PFC (2015). Yellow fever. *Journal of Clinical Virology*, 64(2015):160–173.
- Morris R & Soule BM (2016). *Aedes* Mosquitoes: A Force in human history. *American Journal of Public Health*, 106(4):596–75.
- Mulchandani R, Massebo F, Bocho F, Jeffries CL, Walker T & Messenger LA (2019). A community-level investigation following a yellow fever virus outbreak in South Omo. *PeerJ-the Journal of Life and Environmental Sciences* 7(e6466):22.
- Nnanna AD, Nwabueze OG, Kosisochukwu UI, Benedicta AO & Amauche IE (2016). Species composition and infection rate of mosquito vectors following the indoor species composition and infection rate of mosquito vectors following the indoor residual spraying exercise in three communities in Awka North L.G.A of Anambra State, Nige. *Annual Research & Review in Biology (ARRB)*, 10(2):1–8.
- Patrick BN, Kinimi E, Shayo MJ, Ang SO, Weyer J, Vuren PJVan, et al. (2018). Distribution and diversity of mosquitoes and the role of *Aedes* in the transmission of arboviruses in selected districts of Tanzania, 5(1):53–60.
- Samaroo SK (2015). *Aedes aegypti* (Yellow Fever Mosquito). *The Online Guide to the Animals of Trinidad and Tobago: Ecology*, pp 5.
- Sharma AK, Kumar K, Singh S & Sharma AK (2015). Entomological surveillance for the vector of yellow fever/dengue/chikungunya in and around ports of Goa, India. *International Journal of Pure and Applied Zoology*, 3(3):204–209.
- Simard F, Nchoutpouen E, Toto JC & Fontenille D (2005). Geographic distribution and breeding site preference of *Aedes albopictus* and *Aedes aegypti* (Diptera: Culicidae) in Cameroon, Central Africa. *Entomological Society of America*, 42(5):726–731.
- Siregar FA & Makmur T (2018). Survey on *Aedes* mosquito density and pattern distribution of *Aedes aegypti* and *Aedes albopictus* in high and low incidence

- districts in north sumatera province *IOP Conference Series: Earth and Environmental Science*, 130(1).
- Sitepu FY, Nasution H, Supriyadi T & Depari E (2018). Epidemiological and entomological investigation of Dengue Fever outbreak in South Nias District. *Outbreak, Surveillance, Investigation and Response Journal*, 11(3):8-12.
- Tomor O (2002). Yellow fever in Africa: public health impact and prospects for control in the 21st century. *Biomédica*, 22(2):178-193.
- Moreira-Soto A, Torres MC, de Mendonça MCL, Rodrigues C, Fabri A, de Santos C, et al. (2018). Evidence for multiple sylvatic transmission cycles during the 2016 e 2017 yellow fever virus outbreak, Brazil. *Clinical Microbiology and Infection*, 24(9):1019e1-1019e4.
- WHO (2014). Yellow fever. In B. P. Ltd (Ed.). Rapid field entomological assessment during yellow fever outbreaks in Africa : *Methodological field approaches for scientists with a basic background in entomology* (3rd ed). pp 48.
- WHO (2016). Entomological surveillance for Aedes spp. in the context of Zika virus: Interim guidance for entomologists. pp 10. WHO/ZIKV/VC/16.2
- WHO (2019). Framework for the implementation of the global vector control response in the WHO Africa region. Brazzaville, Republic of Cong.
- Young KI, Mundis S, Widen SG, Wood T G, Tesh RB, Cardoso J, et al. (2017). Abundance and distribution of sylvatic dengue virus vectors in three different land cover types in Sarawak, Malaysian Borneo. *Parasites & Vectors*, 10(406).
- Zettel C & Kaufman P (2016). Yellow fever mosquito *Aedes aegypti* (Linnaeus) (Insecta : Diptera : Culicidae). Introduction - Synonymy - Distribution - Description - Life cycle - Medical importance - Management. 1. IFAS Extension. featured creatures. FDACS/DPI. *Entomology and Nematology*, 1–8.