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Article

Entomological, Epidemiological, and Climatological Investigation of the 2019 Dengue Fever Outbreak in Gewane District, Afar Region, North-East Ethiopia

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Simple Summary: Dengue Fever (DF) is a viral disease transmitted by mosquitoes throughout tropical and sub-tropical climates worldwide. DF ranges in severity from mild flu-like symptoms to severe joint and muscle pain, and even death from severe dengue, In the past 50 years, DF incidence has increased 30-fold, with 3.9 billion people in 129 countries currently considered at-risk annually. DF has been circulating on the African sub-continent for decades, but actual cases are highly unreported, due to their non-specific symptomology and overlapping distributions with other febrile illnesses, notably malaria and pneumonia. Ethiopia has been experiencing annual DF outbreaks since 2013. This study describes key epidemiological, entomological and climatological features of the first DF outbreak in Gewane District, Afar Region, Ethiopia in 2019. A total of 1185 DF cases were identified, mostly among individuals aged 15-49, experiencing fever, headache, and joint pain; there were no recorded deaths. Mosquito species which transmit DF (*Aedes*) were found breeding in buckets/bowls, clay jars, plastic tanks, and tires in and around DF patients' homes. High rainfall in July 2019 and long-term storage of uncovered, stagnant drinking water by community members, were implicated in this outbreak. Study results emphasize the need for vector control activities and improved entomological surveillance to prevent future DF outbreaks in this endemic part of Ethiopia.

Abstract: Dengue Fever (DF) is an important arthropod-borne viral infection, which has repeatedly occurred as outbreaks in eastern and northeastern Ethiopia since 2013. A cross-sectional epidemiological outbreak investigation was carried out from September - November 2019 on febrile patients (confirmed malaria negative) who presented with suspected and confirmed DF at both public and private health facilities in Gewane District, Afar Region, northeastern Ethiopia. Entomological investigation of containers found in randomly selected houses belonging to DF positive patients was undertaken, to survey for the presence of *Aedes* larvae or pupae. A total of 1185 DF

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cases was recorded from six heath facilities during the 3-month study period. The mean age of DF cases was 27.2 years and 42.7% of the cases were female. The most affected age group was 15-49 years (78.98%). However, the attack rate (AR) was highest in the 49+ age group (134.2). A total of 162 artificial containers were inspected from 62 houses, with 49.4% found positive for *Aedes* larva/pupae. *Aedes* mosquitoes were mostly found breeding in buckets/bowls, clay jars, plastic tanks, and tires. World Health Organization entomological indices classified the study site as high risk for dengue outbreaks (House Index=45.2%, Container Index=49.4% and Breteau Index=129). Study findings highlight the importance of vector control to prevent future DF outbreaks in the region. The scarcity of drinking water and changing climactic conditions may have also contributed to the occurrence of this outbreak.

Keywords: Dengue Fever; Arbovirus; *Aedes aegypti*; Ethiopia; Climate

1. Introduction

Dengue Fever (DF) is an important arthropod-borne viral infection (arboviral), which has repeatedly occurred as outbreaks in eastern and northeastern Ethiopia since 2013 [1,2]. This infection causes flu-like symptoms, and occasionally develops into a potentially lethal complication called severe dengue, especially following repeated infections with different viral serotypes. In the last two decades, dengue cases reported to the World Health Organization (WHO) have risen by more than eightfold, from 505,430 cases in 2000 to over 2.4 million in 2010, and 4.2 million in 2019; reported deaths between 2000 and 2015 also increased from 960 to 4032, respectively [3]. Furthermore, the geographical range of dengue has expanded to new countries, as well as from urban to rural settings, largely due to climate change [4-6].

The actual number of dengue cases is underreported, and many cases are misclassified. A recent estimate indicated that 390 million (95% credible interval 284–528 million) dengue infections occur per year, of which 96 million (67–136 million) manifest clinically (with any severity of disease) [7]. Approximately 22,000 die from severe dengue annually [8]. The WHO have estimated that 3.9 billion people in 129 countries are at risk of dengue infection each year [3]. With early diagnosis and proper management, the case-fatality rate (CFR) of dengue hemorrhagic fever (DHF) is generally under 1%, but the CFR may be over 10% once shock develops [9].

DF is transmitted by the bite of female *Aedes* mosquitoes. *Aedes aegypti* is the principal vector of DF and DHF in almost all countries [10,11]; this vector species prefers to rest indoors and feed on human blood during daylight hours [12], particularly during the early morning and evening [13]. Eggs of this mosquito are able to withstand dry weather conditions for a month and hatch when exposed to water [12,14,15]. Once emerged, adult *Aedes* mosquitoes can bite multiple times before oviposition [16]. *Ae. africanus, Ae. albopictus* [17] and *Ae. luteocephalus* also act as potential arbovirus vectors in Africa [11].

The extrinsic incubation period of the virus in the gut of mosquitoes is highly dependent on ambient air temperature; viral development takes ~8-12 days when the ambient air temperature is between 25-28^{o}C [18,19]. Once bitten by an infectious mosquito, the incubation period of DF is ~4-10 days [20]. High temperature, humidity and extended rainfall are significantly associated with increased incidence of DF [21]. Other notable risk factors for dengue infection include those that facilitate mosquito breeding, such as having uncovered, stagnant water in containers (e.g. buckets,

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drums, tires, pots etc.), and those that increase vector-human contact, for example, a lack of door and window screens and personal protective measures (e.g. repellents) [22-24].

In Ethiopia, DF was diagnosed among returning travelers but was never reported as an outbreak locally until September 2013 [25]. The first major outbreak occurred in Dire Dawa city (East Ethiopia), with a total of 11,409 cases [2]. The following year, in 2014, another outbreak was reported in Dire Dawa, as well as in Godey Town, Somali Region (South-East Ethiopia) and in Ada'ar Woreda, Afar Region (North Ethiopia) [24,26]. Subsequently, annual outbreaks have been observed in Godey Town and Dire Dawa [27,28]. Circulating dengue infection has also been identified in Humera, Tigray Region, Metema, Amhara Region, Arba Minch, Southern Nations, Nationalities, and People Region, Gondar, Amhara Region, and Borena Zone, Oromia Region, by the presence of anti-DENV IgG/IgM antibodies in febrile patients [29-32], indicating that the true distribution of DF in Ethiopia is highly underestimated. More recently, in 2017, DF emerged in Kabridahar Town, Korahey Zone (Eastern Ethiopia), affecting more than 100 individuals [24], and in 2019, for the first time in Gewane District, Afar Region (North-East Ethiopia).

To date, there is still a severe paucity of data on the epidemiology of DF and its association with climatic factors in Ethiopia. Moreover, DF incidence is likely severely underreported in Ethiopia due to the lack of Integrated Disease Surveillance and Response (IDSR) reporting requirements for DF, limited regional and national laboratory capability to confirm cases and the remoteness of many endemic areas. The aim of the present study was to investigate entomological, epidemiological, and climatological parameters associated with the 2019 DF epidemic in northeastern Ethiopia.

2. Materials and Methods

2.1 Study area

This study was conducted in Gewane District (10.1496 N, 40.66894 E), which is administratively located in Zone 3, Afar Region, Ethiopia. Gewane District is found along the highway from Addis Ababa to Djibouti, 372km North-East of Addis Ababa and 226 km from Semera, the capital of Afar Regional State (Figure 1). The district is located at a low-lying elevation, 618 meters above sea level. Gewane District has a total of 22,322 inhabitants, of which 11.3 % (n=2522) are children under five years of age. The district has a pipeline water source; however, the water was available once per week.

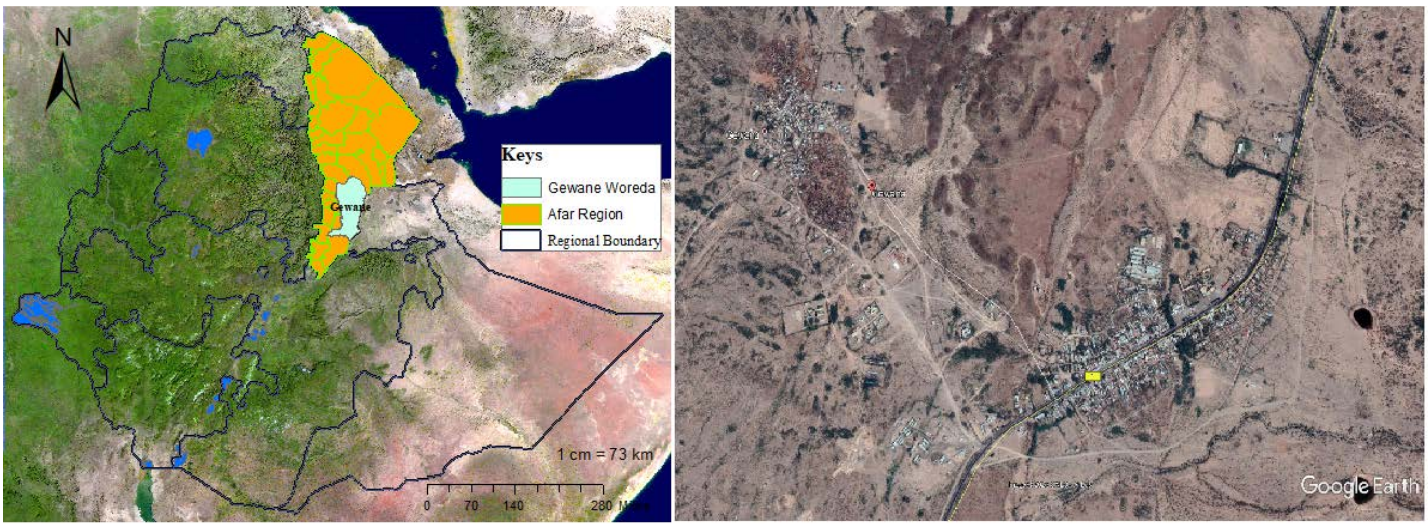

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Figure 1. Map of the study area (Left) and of Gewane District Town (Right).

2.2. Study design, period and population

The present study employed a cross-sectional design and was performed between September and November 2019. All study participants were confirmed free of malaria infection using either microscopy or rapid diagnostic test (RDT). Confirmed and epidemiologically-linked DF cases at both public and private health care facilities in Gewane District were considered for this study. A line list of every case identified during the study period was collected. Demographic information including age and sex, as well as other data, including place of residence and date of onset of signs and symptoms, were carefully retrieved from records. In addition, data on period of admission, admission status, laboratory results, and final patient outcome were collated.

2.3 Entomological investigation

Entomological investigation of containers for the presence of *Aedes* larvae and pupae was conducted in randomly selected houses and their premises, belonging to DF patients and family members. Samples were collected from infested containers with a plastic cup, pipette, and dipper, and larvae/pupae were reared to the adult stage for identification using morphological identification keys [33]. Entomological indices were interpreted according to WHO guidelines; high risk of dengue virus transmission when House Index (percentage of houses found positive for mosquito larvae or pupae; HI) > 35%, Breteau Index (number of containers found positive for mosquito larvae or pupae; BI) > 50, or Container Index (percentage of containers found positive for mosquito larvae or pupae; CI) > 20%. Low risk was when HI < 4%, BI < 5, or CI < 3%.

2.4 Laboratory investigation

Blood specimens (3-5ml) were collected from 12 suspected DF cases and transported to the National Influenza and Arbovirus Laboratory at the Ethiopian Public Health Institute (EPHI), Addis Ababa. Extraction of viral RNA was performed from serum using the QIAamp Viral RNA Mini Kit (Qiagen) and tested for dengue virus by quantitative real-time PCR (qRT-PCR). A dengue virus-specific primer and the Agpath-ID™ one-step qRT-PCR kit was used to detect dengue virus. Appropriate negative and positive controls were tested in parallel. Reaction conditions for the qRT-PCR were reverse transcription at 45˚C for 10 minutes, denaturation at 95˚C for 10 minutes, followed by 45 cycles of denaturation at 95˚C for 15 seconds and annealing/extension at 55˚C for 1 minute. Fluorescence was measured at the annealing/extension step and recorded as the cycle threshold (CT) value. Specimens were considered positive if the CT value-was <40, indeterminate if the CT was ≥ 40, and negative if the CT value was undetermined. Similar laboratory procedures were used for testing the blood specimens for other arboviruses (Chikungunya, Yellow Fever, Rift Valley Fever, and West Nile Virus) using viral-specific primers and appropriate negative and positive controls.

2.5 Climatological data

Quality-controlled climate data for Gewane District was obtained from the National Meteorological Agency (NMA) of Ethiopia. Three-year rainfall, temperature, and relative humidity were analyzed for the study area.

2.6 Data analysis

Entomological and epidemiological data was entered, cleaned, and analyzed descriptively using Microsoft excel. The risk of DF in the study district was interpreted according to entomological indices set by the WHO [34]. Population

 doi:10.20944/preprints202208.0359.v1

projections for Afar Region, determined by the central statistics agency, were used to compute the population at-risk in each age group [35].

3. Results

3.1 Epidemiological investigation

A total of 1185 DF cases was recorded between September and November 2019. Of these cases, twelve had serum samples taken and six tested positive for DF by qRT-PCR at EPHI, with the remaining 1179 defined through epi-link. DF patients originated from ten kebeles: Bida (n=2; 0.17%), Bireforo (n=41; 3.5%), Gebayabora (n=60; 5.1%), Geliladora (n=239; 20.2%), Gewane (n=736; 62.1%), Kedabada (n=6; 0.51%), Keroma (n=2; 0.17%), Meteka (n=72; 6.08%), Ourafita (n=4; 0.34%) and Yigilla (n=23; 1.9%); and presented at six health facilities: Bireforo health center (n=42), Geliladorahospital (n=246), Gewane health center (n=416), Meteka hospital (n=4), Yigilla hospital (n=15) and private clinics (n=462). The index case was reported from Bireforo health center, with the onset of symptoms on 13th September 2019. The initial peak of the outbreak occurred from 16th – 29th September 2019, with a secondary peak between 28th October – 10th November 2019 (Figure 2).

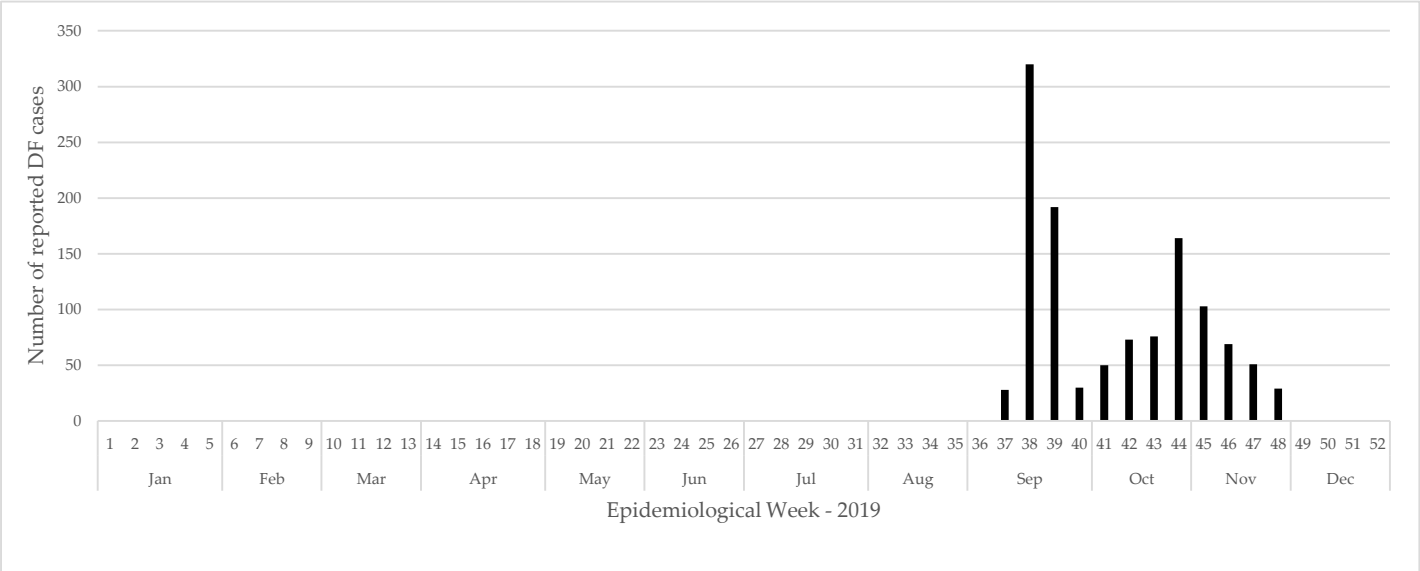

Figure 2. Distribution of reported DF cases by their date of onset, from September – November 2019 in Gewane District, Afar Region, Ethiopia (n=1185).

The mean age of DF cases was 27.2 years and 42.7% of the cases were female. The most affected age group was 15-49 years (78.98%). However, the attack rate (AR) was highest in the 49+ age group (134.2), followed by 15-49 years old (65.7) per thousand populations (Table 1). All suspected cases (n=1185) reported experiencing fever, headache, and joint pain. No patients had a travel history to a dengue-endemic area. There were no recorded deaths associated with DF in Gewane District during the study period. Of the 12 blood specimens collected for laboratory confirmation, 50% (n=6) were positive for DF by qRT-PCR.

Table 1. Age-specific DF attack rates in Gewane District, Afar Region, Ethiopia (n=1185).

Age Category	Female	Male	Total Cases	Population (2019)	Attack Rate (per 1000)

 doi:10.20944/preprints202208.0359.v1

<5	12	21	33	2522	13.08
5-14	60	70	130	4920	26.4
15-49	394	542	936	14239	65.7
49+	39	47	86	641	134.2
Total	505	680	1185	22322	53.08

3.2 Entomological investigation

A total of 162 artificial containers were inspected from 62 houses from Gubi Gewane, and Gewane Town-01 kebele. Of these, 80 containers from 28 houses were positive for *Aedes* larva/pupae (49.4%). *Aedes* mosquitoes were most commonly observed breeding in buckets/bowls, clay jars, plastic tanks and tires (Figure 3).

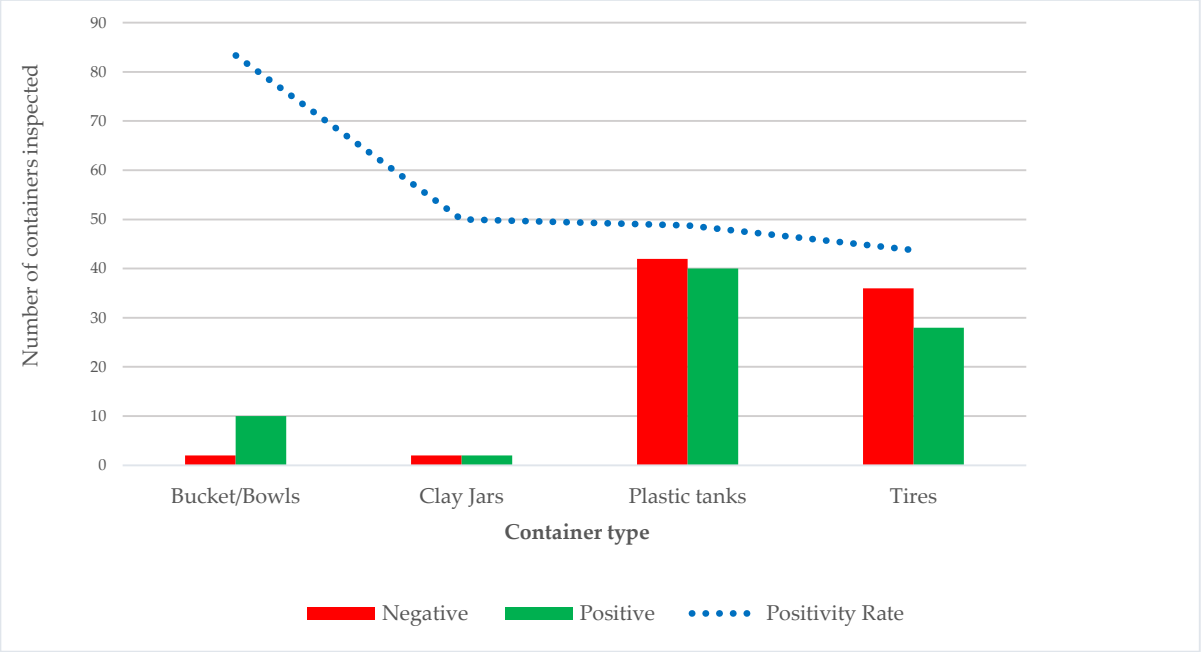

Figure 3. Proportions of containers found positive with either *Aedes* larvae or pupae in Gewane District, Ethiopia, 2019.

Of the total inspected containers, 50.6% (82/162) were plastic tanks and 39.5% (64/162) were tires; the remaining were buckets/bowls (7.4%; 12/162) and clay jars (2.5%; 4/162). However, buckets/bowls (83.3%) were the major breeding habitats that yielded *Aedes* larvae and clay jars (50%) constituted the second most productive breeding sites (Figure 4).

 doi:10.20944/preprints202208.0359.v1

Figure 4. Typical *Aedes* breeding sites identified in Gewane District, Ethiopia, 2019: (a) plastic buckets/bowls; (b) rubber tires; (c) metal drum; (d) pots; (e) plastic water jar; and (f) plastic containers.

To estimate the potential dengue outbreak risk, WHO entomological indices (house index; HI, container index; CI and Breteau index; BI) were calculated. During this investigation, the entomological indices were very high, with a HI of 45.2% (WHO high-risk threshold = HI >35%), a CI of 49.4% (WHO high-risk threshold = CI >20%), and a BI of 129 (WHO high-risk threshold = HI >50).

3.3 Climatological data

The mean monthly temperatures in 2018 and 2019 was similar in Gewane District (Figure 5). However, the mean monthly temperature of the district in 2017 was lower than in 2018 and 2019. In 2017 there was high rainfall in May and July – September; by comparison there was low rainfall in 2019 for the same period (May and July – September). In 2019, the highest weekly cumulative rainfall was recorded in WHO Epi-week 29. The present DF outbreak emerged in Epi - week 37, indicating a lag phase of 8 weeks.

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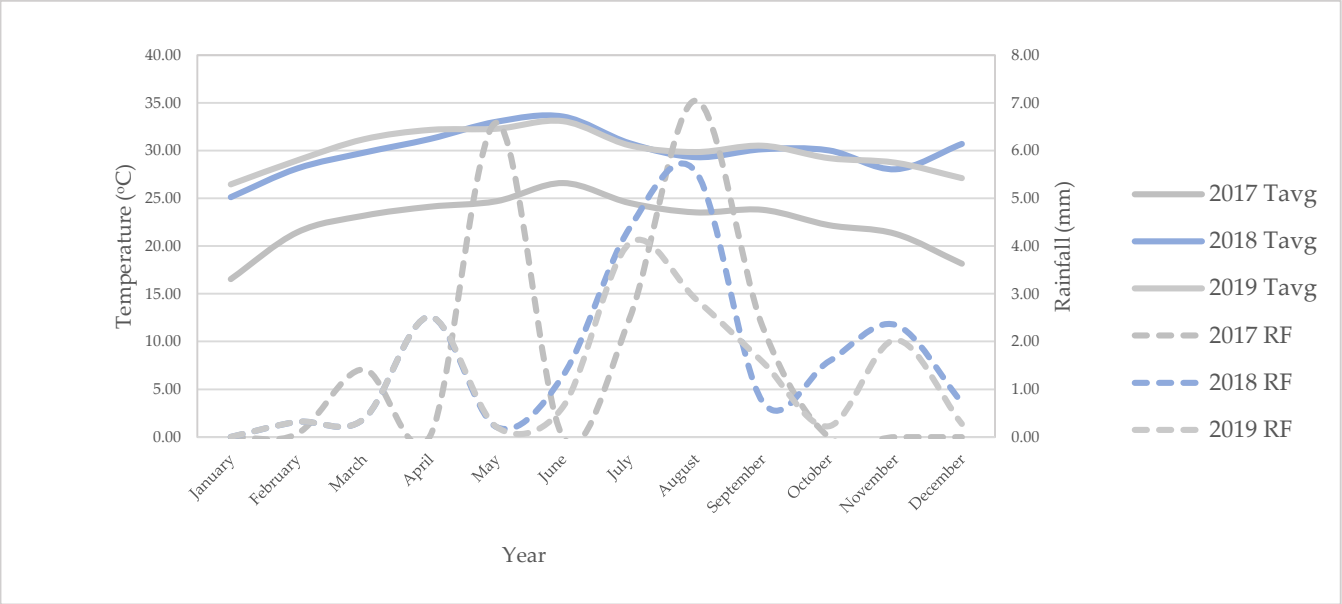

Figure 5. Monthly average temperature (Tavg) and rainfall (RF) in Gewane District from 2017-2019.

3.4 Outbreak response activities

Gewane District community members regularly collect water in many plastic containers to use over several weeks. Most of the containers were old and did not have covers, thus providing ample sites for mosquito oviposition. There were a number of old, discarded tires, which formed another source of stagnant water. As part of the outbreak response, social mobilization and awareness of disease control strategies, particularly environmental manipulation (removing, altering or recycling non-essential containers, which were serving as vector habitats), was undertaken using megaphones, leaflets and during house-to-house active case searches.

4. Discussion

To reduce the risk of future DF and other arboviral disease outbreaks in Ethiopia through appropriate policy recommendations, it is crucial to understand key epidemiological, entomological, and climatological features of previous outbreaks. This study reports the first DF outbreak in Gewane District, Afar Region, Ethiopia, affecting more than one thousand individuals, over a 3-month period in 2019. Epidemiological characteristics of this outbreak were consistent with previous studies, which also documented more DF cases among the male population (57.3%) due to gender cultural and behavioural differences [24,27,29,36]. *Aedes* mosquitos bite during the daytime when many female community members are commonly inside the house and/or may have their entire body covered according to Islamic Law, providing a defensive layer from mosquito bites. Other reports from Ethiopia have confirmed that daily wearing of short sleeve T-shirts was strongly associated with a higher likelihood of DF infection, compared to those in full dress [24]. The median age of DF cases in Gewane District was 26 years old, which also aligns with other DF outbreaks in Ethiopia [27], where younger age groups spent more time outdoors due to economic or leisure pursuits, and were therefore at higher risk of vector contact. While not directly assessed during this study, poor knowledge of DF prevention in other parts of Ethiopia, among both community members and healthcare providers, has been identified as a significant barrier to the prevention of future outbreaks, particularly awareness of the importance of emptying containers that can be used as *Aedes* breeding sites [26,28,30]. It can be assumed that in areas like Gewane District, where DF has emerged for the first time, community education may be especially low; and initiatives to increase nationwide knowledge of DF and other arbovirus control are needed. Since this present study, further DF outbreaks have occurred in Somali Region Ethiopia (Warder Woreda of Dolo Zone and Dolo Ado Woreda of Liban Zone) during 2021[37].

Study entomological findings classified Gewane District as high risk for DF transmission, with HI=45.2%, CI=49.4% and BI=129; entomological indices were similar to those reported from other recent DF outbreaks in Kabridahar District, Somali Region in 2017 [24]. These results strongly emphasize the need for regional vector control activities, improved entomological surveillance and strengthening of laboratory capacity to prevent future DF outbreaks. As part of this outbreak response, the study team undertook removal of potential *Aedes* breeding sites within the community and increased awareness of DF control strategies. High rainfall in July 2019, lack of pipped water and therefore long-term storage of uncovered, stagnant drinking water by community members, likely contributed to this outbreak [38]. To improve prospective DF vector control, during other DF outbreaks in Ethiopia, distribution of long-lasting insecticidal nets (LLINs) has been shown to be protective because some residents slept under nets early in the morning and during the daytime, in response to harsh weather conditions [24,26,29]. Furthermore, use of LLIN material as window curtains has shown contrasting evidence to reduce DF transmission in parts of Latin America, but efficacy of these tools has yet to be established for DF control in sub-Saharan Africa [39-41].

This study had several limitations. Community-level serological diagnosis was not possible to confirm all suspected cases or to screen for asymptomatic carriers. Because the epidemiological investigation was based on clinical data and not all laboratory specimens were confirmed as DF positive, it is possible that some patients were infected with other acute non-malarial febrile illnesses. This study lacked the resources to identify which DENV serotype(s) was responsible for this outbreak; however, the low CFR (no deaths reported during the outbreak) may either indicate a recent introduction of DF into this area, with few prior infections in the population, or re-emergence of the same circulating DENV serotypes, which would not elicit severe dengue symptoms. Given the geographical proximity of Gewane District to other DF outbreaks (Dire Dawa: 376 km) it is quite probable that human movement also played a role in the occurrence of this outbreak. Finally, entomological collections were only identified to genera-level (*Aedes* spp.) but were suspected to be a mix of *Ae. aegypti* and *Ae. africanus*.

5. Conclusions

DF is an important arthropod-borne viral infection, which has repeatedly occurred as outbreaks in eastern and north-eastern Ethiopia since 2013. A cross-sectional epidemiological outbreak investigation was carried out from September - November 2019 on febrile patients (confirmed malaria negative) who presented with suspected and confirmed DF at six health facilities in Gewane District, Afar Region, northeastern Ethiopia, identifying a total of 1185 DF cases. The mean age of DF cases was 27.2 years and 42.7% of the cases were female. The most affected age group was 15-49 years (78.98%). However, the attack rate (AR) was highest in the 49+ age group (134.2). A total of 162 artificial containers were inspected from 62 houses, with 49.4% found positive for *Aedes* larva/pupae, mainly breeding in buckets/bowls, clay jars, plastic tanks, and tires. High rainfall in July 2019, lack of pipped water and therefore long-term storage of uncovered, stagnant drinking water by community members, were implicated in this outbreak. Study results emphasize the need for vector control activities and improved entomological surveillance to prevent future DF outbreaks in this endemic part of Ethiopia.

Author Contributions: Conceptualization, W.M., M.W., C.S.; methodology, W.M., M.W., C.S.; formal analysis, W.M., L.A.M.; investigation, W.M., S.K., B.K., Y.M., G.H.; resources, F.B.; data curation, W.M., L.A.M.; writing—original draft preparation, W.M., A.G., A.W., L.A.M.; writing—review and editing, L.A.M.; visualization, W.M., L.A.M.; supervision, A.G., A.W. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Ethical clearance was not required by EPHI for this work because it was a rapid outbreak investigation. However, oral informed consent was obtained from household heads during home-to-home entomological collections.

Data Availability Statement: The data sets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Degife, L.H.; Worku, Y.; Belay, D.; Bekele, A.; Hailemariam, Z. Factors associated with dengue fever outbreak in Dire Dawa administration city, October, 2015, Ethiopia-case control study. *BMC public health* **2019**, *19*, 650.
2. Woyessa, A.B.; Mengesha, M.; Kassa, W.; Kifle, E.; Wondabeku, M.; Girmay, A.; Kebede, A.; Jima, D. The first acute febrile illness investigation associated with dengue fever in Ethiopia, 2013: a descriptive analysis. *The Ethiopian Journal of Health Development (EJHD)* **2014**, *28*, PDF-PDF.
3. WHO. Dengue and severe dengue:Global burden of dengue. Availabe online: https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue (accessed on July 15).
4. Campbell, L.P.; Luther, C.; Moo-Llanes, D.; Ramsey, J.M.; Danis-Lozano, R.; Peterson, A.T. Climate change influences on global distributions of dengue and chikungunya virus vectors. *Philos Trans R Soc Lond B Biol Sci* **2015**, *370*, 20140135.
5. Messina, J.P.; Brady, O.J.; Golding, N.; Kraemer, M.U.G.; Wint, G.R.W.; Ray, S.E.; Pigott, D.M.; Shearer, F.M.; Johnson, K.; Earl, L., et al. The current and future global distribution and population at risk of dengue. *Nature Microbiology* **2019**, *4*, 1508-1515.
6. Kulkarni, M.A.; Duguay, C.; Ost, K. Charting the evidence for climate change impacts on the global spread of malaria and dengue and adaptive responses: a scoping review of reviews. *Global Health* **2022**, *18*, 1.
7. Organization, W.H. Dengue and severe dengue. Availabe online: https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue (accessed on
8. CDC. About Dengue: What You Need to Know. Availabe online: https://www.cdc.gov/dengue/about/index.html (accessed on
9. Rigau-Perez, J.G.; Vorndam, A.V.; Clark, G.G. The dengue and dengue hemorrhagic fever epidemic in Puerto Rico, 1994-1995. *The American journal of tropical medicine and hygiene* **2001**, *64*, 67-74.
10. Guillena, J.B.; Opena, E.L.; Baguio, M. Prevalence of dengue fever (DF) and dengue hemorrhagic fever (DHF): a description and forecasting. In Proceedings of Proceedings of the 11th National Convention on Statistics (NCS'10).
11. Were, F. The dengue situation in Africa. *Paediatrics and international child health* **2012**, *32*, 18-21.
12. Gubler, D.J. Dengue and dengue hemorrhagic fever. *Clinical microbiology reviews* **1998**, *11*, 480-496.
13. Narayanan, M.; Aravind, M.; Thilothammal, N.; Prema, R.; Sargunam, C.R.; Ramamurty, N. Dengue fever epidemic in Chennai-a study of clinical profile and outcome. *Indian pediatrics* **2002**, *39*, 1027-1033.
14. Baba, M.; Talle, M. The effect of climate on dengue virus infections in Nigeria. *New York Science Journal* **2011**, *4*, 28-33.
15. WHO. Dengue control:The mosquito. Availabe online: https://www.who.int/denguecontrol/mosquito/en/ (accessed on 8/5/2020).
16. Pancharoen, C.; Mekmullica, J.; Thisyakorn, U. Primary dengue infection: what are the clinical distinctions from secondary infection? *The Southeast Asian journal of tropical medicine and public health* **2001**, *32*, 476-480.
17. Ngoagouni, C.; Kamgang, B.; Nakouné, E.; Paupy, C.; Kazanji, M. Invasion of Aedes albopictus (Diptera: Culicidae) into central Africa: what consequences for emerging diseases? *Parasites & Vectors* **2015**, *8*, 1-7.

18. Srivastava, V.; Suri, S.; Bhasin, A.; Srivastava, L.; Bharadwaj, M. An epidemic of dengue haemorrhagic fever and dengue shock syndrome in Delhi: a clinical study. *Annals of tropical paediatrics* **1990**, *10*, 329-334.
19. WHO. *Dengue haemorrhagic fever: diagnosis, treatment, prevention and control*; World Health Organization: 1997.
20. Kabra, S.; Verma, I.; Arora, N.; Jain, Y.; Kalra, V. Dengue haemorrhagic fever in children in Delhi. *Bulletin of the World Health Organization* **1992**, *70*, 105.
21. Choi, Y.; Tang, C.S.; McIver, L.; Hashizume, M.; Chan, V.; Abeyasinghe, R.R.; Iddings, S.; Huy, R. Effects of weather factors on dengue fever incidence and implications for interventions in Cambodia. *BMC public health* **2016**, *16*, 1-7.
22. Kolawole, O.M.; Seriki, A.A.; Irekeola, A.A.; Ogah, J.I. The neglect and fast spread of some arboviruses: a note for healthcare providers in Nigeria. *Diseases* **2018**, *6*, 99.
23. Lalani, T.; Yun, H.; Tribble, D.; Ganesan, A.; Kunz, A.; Fairchok, M.; Schnaubelt, E.; Fraser, J.; Mitra, I.; Kronmann, K.C., et al. A comparison of compliance rates with anti-vectorial protective measures during travel to regions with dengue or chikungunya activity, and regions endemic for Plasmodium falciparum malaria,. *Journal of Travel Medicine* **2016**, *23*, taw043.
24. Gutu, M.A.; Bekele, A.; Seid, Y.; Mohammed, Y.; Gemechu, F.; Woyessa, A.B.; Tayachew, A.; Dugasa, Y.; Gizachew, L.; Idosa, M., et al. Another dengue fever outbreak in Eastern Ethiopia-An emerging public health threat. *PLoS Neglected Tropical Diseases* **2021**, *15*, e0008992.
25. Amarasinghe, A.; Kuritsky, J.N.; Letson, G.W.; Margolis, H.S. Dengue virus infection in Africa. *Emerging infectious diseases* **2011**, *17*, 1349.
26. Degife, L.H.; Worku, Y.; Belay, D.; Bekele, A.; Hailemariam, Z. Factors associated with dengue fever outbreak in Dire Dawa administration city, October, 2015, Ethiopia - case control study. *BMC Public Health* **2019**, *19*, 650.
27. Ahmed, Y.M.; Salah, A.A. Epidemiology of dengue fever in Ethiopian Somali region: retrospective health facility based study. *Cent Afr J Public Health* **2016**, *2*, 51-56.
28. Yusuf, A.M.; Ibrahim, A.M. Knowledge, attitude and practice towards dengue fever prevention and associated factors among public health sector health-care professionals: in Dire Dawa, eastern Ethiopia. *Risk Manag Healthc Policy* **2019**, *12*, 91-104.
29. Ferede, G.; Tiruneh, M.; Abate, E.; Wondimeneh, Y.; Damtie, D.; Gadisa, E.; Howe, R.; Aseffa, A.; Tessema, B. A serologic study of dengue in northwest Ethiopia: Suggesting preventive and control measures. *PLoS Neglected Tropical Diseases* **2018**, *12*, 0006430.
30. Geleta, E.N. Serological evidence of dengue fever and its associated factors in health facilities in the Borena Zone, South Ethiopia. *Res Rep Trop Med* **2019**, *10*, 129-136.
31. Eshetu, D.; Shimelis, T.; Nigussie, E.; Shumie, G.; Chali, W.; Yeshitela, B.; Assefa, A.; Gadisa, E. Seropositivity to dengue and associated risk factors among non-malarias acute febrile patients in Arba Minch districts, southern Ethiopia. *BMC Infectious Diseases* **2020**, *20*, 639.
32. Akelew, Y.; Pareyn, M.; Lemma, M.; Negash, M.; Bewket, G.; Derbew, A.; Belay, G.; Pollmann, J.; Adriaensen, W.; Peeters, M., et al. Aetiologies of acute undifferentiated febrile illness at the emergency ward of the University of Gondar Hospital, Ethiopia. *Tropical Medicine & International Health* **2022**, *27*, 271-279.
33. Huang, Y.-M.; Rueda, L.M. Pictorial keys to the sections, groups, and species of the Aedes (Finlaya) in the Afrotropical Region (Diptera: Culicidae). *Zootaxa* **2017**, *4221*, 131-141.
34. Rozendaal, J.A. *Vector control: methods for use by individuals and communities*; World Health Organization: 1997.
35. CSA. *Population projection for Ethiopia 2007–2037. The 2012 inter-censual population survey*; Central Statistics Agency Adddis Ababa, 2013.
36. Getachew, D.; Tekie, H.; Gebre-Michael, T.; Balkew, M.; Mesfin, A. Breeding Sites of Aedes aegypti: Potential Dengue Vectors in Dire Dawa, East Ethiopia. *Interdiscip Perspect Infect Dis* **2015**, *2015:706276*.

37. Mohan, A.; Fakhor, H.; Nimavat, N.; Wara, U.U.; Lal, P.M.; Costa, A.C.D.S.; Ahmad, S.; Essar, M.Y. Dengue and COVID-19: A risk of coepidemic in Ethiopia. *Journal of Medical Virology* **2021**, *93*, 5680-5681.
38. Schmidt, W.-P.; Suzuki, M.; Thiem, V.D.; White, R.G.; Tsuzuki, A.; Yoshida, L.-M.; Yanai, H.; Haque, U.; Anh, D.D.; Ariyoshi, K. Population density, water supply, and the risk of dengue fever in Vietnam: cohort study and spatial analysis. *PLoS Med* **2011**, *8*, e1001082.
39. Loroño-Pino, M.A.; García-Rejón, J.E.; Machain-Williams, C.; Gomez-Carro, S.; Nuñez-Ayala, G.; Nájera-Vázquez Mdel, R.; Losoya A, A., L., ; Saavedra-Rodriguez, K.; Lozano-Fuentes, S.; Beaty, M.K., et al. Towards a Casa Segura: a consumer product study of the effect of insecticide-treated curtains on Aedes aegypti and dengue virus infections in the home. *American Journal of Tropical Medicine & Hygiene* **2013**, *89*, 385-397.
40. Lenhart, A.; Orelus, N.; Maskill, R.; Alexander, N.; Streit, T.; McCall, P.J. Insecticide-treated bednets to control dengue vectors: preliminary evidence from a controlled trial in Haiti. *Tropical Medicine & International Health* **2008**, *13*, 56-67.
41. Lenhart, A.; Morrison, A.C.; Paz-Soldan, V.A.; Forshey, B.M.; Cordova-Lopez, J.J.; Astete, H.; Elder, J.P.; Sihuincha, M.; Gotlieb, E.E.; Halsey, E.S., et al. The impact of insecticide treated curtains on dengue virus transmission: A cluster randomized trial in Iquitos, Peru. *PLoS Neglected Tropical Diseases* **2020**, *14*, e0008097.