

The first record of the invasive mosquito species *Aedes albopictus* in Yemen

Alia Zayed^{a,*}, Yasser Baheshm^b, Mohammed Al Amoudi^b, Salim Bin Shabiz^b,
Matthew Jensen Montgomery^c

^a US Naval Medical Research Unit EURAFCENT, Cairo, Egypt

^b National Malaria Control Programme (NMPC), Aden, Yemen

^c US Naval Medical Research Unit EURAFCENT, Sigonella, Italy

ARTICLE INFO

Keywords:

First record
Aedes albopictus
Invasive species
Al Mahrah
Yemen

ABSTRACT

The invasive mosquito *Aedes albopictus* is regarded as a public health threat due to its ability to transmit pathogens such as dengue and chikungunya viruses, its wide range of hosts, and its ecological plasticity. *Aedes albopictus* has already invaded parts of the Middle East region and further expansion is expected. Twenty-two sites in three districts of Yemen (Al Ghaydha, Hawf, and Sayhouth) were screened for the presence of mosquitoes. We surveyed water bodies and containers, and deployed Centers for Disease Control and Prevention (CDC) and Biogents Sentinel (BG) traps, spray catches, and aspiration for adult collection. *Aedes albopictus* was recorded for the first time in Yemen in September 2023, during routine surveillance in Al Mahrah Governorate. Adults and immature stages of *Ae. albopictus* were identified in Hawf, a city 17 m above sea level in the easternmost part of the Governorate of Al Mahrah, which is located less than 8 km from the border with Oman. Our findings showed that *Ae. albopictus* adults were coexisting with both *Aedes aegypti* and *Anopheles stephensi* in the same location and occupying the same containers with *Ae. aegypti* with a ratio of 1:2. This is the first report on the presence of *Ae. albopictus* in Yemen. The proximity, ongoing human activity and transportation exchanges between Al Mahrah and Oman may have played a role in the introduction of this species. Intensive efforts should be undertaken to monitor and manage *Ae. albopictus* spread in the country, in addition to coordinating cross-border surveillance with Oman. The presence of both *Aedes* spp. vectors together highlights the need for surveillance for associated diseases and consideration of countermeasures.

1. Background

Yemen borders Saudi Arabia and Oman to the north and northeast, respectively. It neighbors Djibouti, Eritrea and Somalia along the Red Sea and Gulf of Aden Maritime borders. The climate is semiarid and arid-tropical with different ecozones (USAID, 2016). Yemen is one of the most water-constrained countries in the Middle East and North Africa, facing a significant risk of drought (USAID, 2016). This risk will in turn reinforce water storage practices among the population, creating suitable habitats for mosquitoes.

Al Mahrah, the easternmost Governorate of Yemen, borders Oman to the east and Hadramout Governorate to the north and west. Hawf District, located in Al Mahrah, harbors a nature reserve that is considered one of the largest forests in the Arabian Peninsula (UNESCO, 2002), with foggy weather and an ascending altitude reaching 1400 m above sea level.

Yemen has a long history of dengue and chikungunya outbreaks (Bin Ghouth et al., 2012; Zayed et al., 2012; Madani et al., 2013; Malik et al., 2014; Rezza et al., 2014; Al-Garadi, 2015; Saied et al., 2015; Saghir et al., 2022), in addition to several unpublished reports. Unrest in the country and successive civil wars amplified the frequency and spread of dengue (Saghir et al., 2022), with overall challenges in the required surveillance and health services (Saied et al., 2015). The main dengue vector in Yemen is *Aedes aegypti* (Bin Ghouth et al., 2012; Zayed et al., 2012), as well as in the rest of neighboring Saudi Arabia (Naeem et al., 2016; Alahmed et al., 2019). Recently, the introduction of *Aedes albopictus* in Oman has been announced (Al-Abri et al., 2020; Al Awaidy et al., 2022). According to a recent review, *Ae. albopictus* has not been recorded in Saudi Arabia (Dawah et al., 2023). A similar species, *Aedes unilineatus*, which can be misidentified as *Ae. albopictus* has been reported in Saudi Arabia (Godsey et al., 2003) and Iran (Yaghoobi-Ershadi et al., 2017). Closeness, continuous traffic between Al Mahrah

* Corresponding author.

E-mail addresses: aliazayed@yahoo.com, alia.m.zayed.ln@health.mil (A. Zayed).

<https://doi.org/10.1016/j.crpvbd.2024.100233>

Received 17 October 2024; Accepted 21 November 2024

Available online 23 November 2024

2667-114X/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>).

Governorate and Oman, and the transportation of goods may facilitate vector movements and distribution.

Here, we report the first record of *Ae. albopictus* in Yemen and discuss the factors that may contribute to an increased risk of further spread in the country.

2. Materials and methods

As part of the routine surveillance in 9 southern governorates in Yemen, we conducted mosquito surveillance in Al Mahrah Governorate in 2023. We inspected 22 sites in Al Mahrah: 9 in Al Ghaydha, 6 in Hawf, and 7 in Sayhout districts, with the respective average elevation of 17 m, 17 m, and 8 m above sea level, respectively. We ran 5-day indoor inspections, outdoor field surveillance, and checked the surrounding water bodies and containers in each site. For adult collections, Centers

for Disease Control and Prevention (CDC) and Biogents Sentinel (BG) traps, spray catches and aspiration were employed (Fig. 1). Larvae were collected and reared to the adult stage in emergence chambers for confirmatory identification according to the key of Rueda (2004). To avoid misidentification between *Ae. albopictus* and *Ae. unilineatus*, we used the keys of Huang (2004) and Dawah et al. (2023).

3. Results

Water bodies and containers were inspected for larvae in Al Mahrah Governorate in 18 out of the 22 sites. A total of 1390 *Aedes* spp. larvae were collected, 800 of which were from Sayhout, 540 from Hawf, and 50 from Al Ghaydha sites (Table 1). Females without scutal round pale spots and having dark mid-femora with pale apical patches were identified as *Ae. albopictus*. Emerged adults identified as *Ae. albopictus* were



Fig. 1. Indoor and outdoor mosquito collections in Al Mahrah Governorate. **A** Cement basin. **B** Plastic barrel. **C, D** Spray catches. **E** BG traps. **F** Rearing field-collected larvae to adults.

Table 1
Number of mosquito specimens collected in the inspected districts of Al Mahrah Governorate, Yemen, in 2023–2024 with the confirmed positive sites for *Aedes albopictus*.

| District | Site ID | Collection | <i>Aedes</i> spp. larvae | Emerg ed adults | | Indoor adults | | <i>An. stephensi</i> larvae |
|------------|---------|------------|--------------------------|-----------------------|--------------------|-----------------------|--------------------|-----------------------------|
| | | | | <i>Ae. albopictus</i> | <i>Ae. aegypti</i> | <i>Ae. albopictus</i> | <i>Ae. aegypti</i> | |
| Hawf | H1 | I & O | 40–49 | | | | | |
| | H2 | I & O | 150–159 | | 74 (35♀) | | 1 | 50–59 |
| | H3 | I & O | 80–89 | | 38 (17♀) | | | 30–39 |
| | H4 | I & O | 70–79 | | 29 (13♀) | | | 50–59 |
| | H5 | I & O | | | | 2 | 5 | 80–85 |
| | H6 | I & O | 200–209 | 16 (7♀) | 32 (15♀) | | | |
| Al Ghaydha | Gh1 | I | | | | | | |
| | Gh2 | I | | | | | | |
| | Gh3 | I | | | | | | |
| | Gh4 | I & O | | | | | | 30–39 |
| | Gh5 | I & O | | | | | | 180–189 |
| | Gh6 | O | 50–59 | | 10 (8♀) | | | 130–139 |
| | Gh7 | O | | | | | | 150–159 |
| | Gh8 | O | | | | | | 90–99 |
| | Gh9 | O | | | | | | 60–69 |
| Sayhut | S1 | I & O | | | | 2 | | 20–29 |
| | S2 | I & O | | | | | | 25 |
| | S3 | I & O | | | | | | 22 |
| | S4 | I & O | | | | 1 | | 30–39 |
| | S5 | O | 750–759 | | 114 (78♀) | | | 190–199 |
| | S6 | I & O | 50–59 | | 13 (10♀) | | | 653 |
| | S7 | I | | | | 1 | | |

Abbreviations: I, indoor collection; O, outdoor collection.

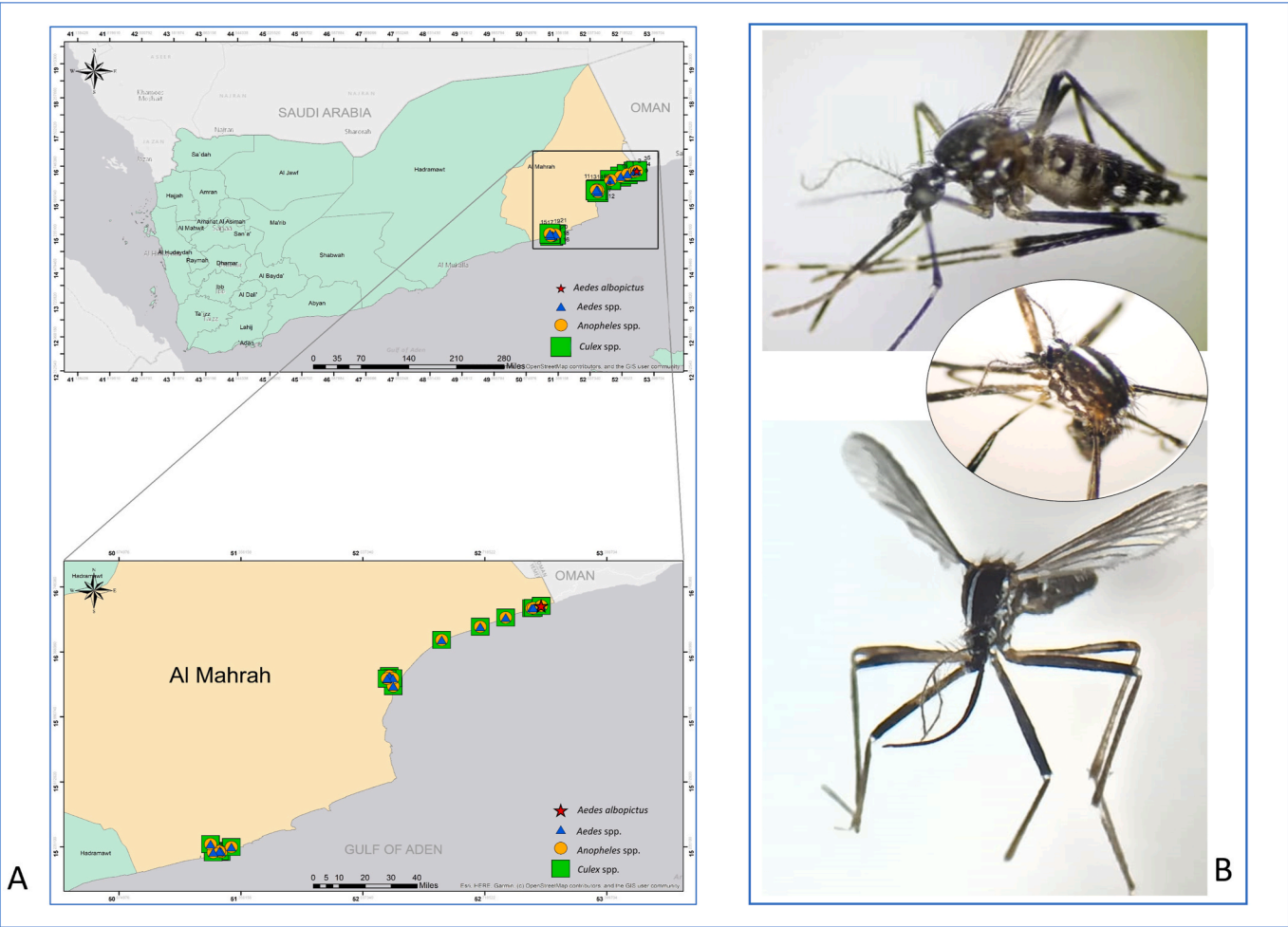


Fig. 2. A Surveillance sites in Al Mahrah showing the *Ae. albopictus*-positive site in Hawf (red star). B Adults of *Ae. albopictus* from both indoor collections of adults and emerged reared adults.

collected from containers in one spot in Hawf (Site H6: 16°38'08.0"N, 53°02'03.3"E; water temperature of 38 °C) together with *Ae. aegypti* larvae. The ratio of the emerged adults of *Ae. albopictus* to *Ae. aegypti* was 1:2. Most of the breeding containers (83%) were plastic barrels used for water storage and the remaining were cement basins (Fig. 1).

On conducting the indoor inspections in the surrounding premises (17 sites), we collected two *Ae. albopictus* females (Table 1, Fig. 2) together with *Ae. aegypti* and *Anopheles stephensi* females. The location positive for adult *Ae. albopictus* was 100 m away from the larval breeding site in Hawf (Site H5: 16°38'06.0"N, 53°02'01.0"E). We did not find *Ae. albopictus* in the rest of the sites and locations in Hawf, Al Ghaydhah or Sayhout.

4. Discussion

The geographical location, environmental and socioeconomic factors in Yemen have demonstrated suitability to *Ae. aegypti* abundance and its associated dengue and chikungunya outbreaks. Dickens et al. (2018) identified areas of high suitability for *Ae. albopictus* that overlapped with those suitable for *Ae. aegypti* in the coastal areas of the Middle East. The Middle East areas of suitability in their maps included the Indian Ocean coastline of Yemen and Oman. This is consistent with our findings in Yemen and the earlier introduction of *Ae. albopictus* in Oman (Al-Abri et al., 2020; Al Awaidy et al., 2022). At the northern borders of Yemen, there was an anticipated scenario of *Ae. albopictus* introduction into Saudi Arabia after its establishment in Lebanon, Syria (Haddad et al., 2007) and Jordan (Kanani et al., 2017). However, *Ae. albopictus* has not yet been recorded in Saudi Arabia (Dawah et al., 2023).

The proximity of Hawf to Oman border positions the area as a point of entry with a maximum risk of *Aedes* spp. establishment, as discussed by Ducheyne et al. (2018). Frequent human and trade movements may have exacerbated the likelihood of importing *Ae. albopictus* to the specific locations across the borders. Dickens et al. (2018) highlighted the role of transportation in globalization and urban spread in introducing *Aedes* spp.

According to our monthly monitoring, the *Ae. albopictus* population is not yet widely established in the Al Mahrah Governorate nor in the neighboring sites in Yemen. Nevertheless, due to the environmental suitability, potential invasion toward areas in the Southwest of Yemen, parallel to the Gulf of Aden and the Red Sea coast, is highly anticipated according to the maps and study of Kamal et al. (2018). Minimum temperatures, absolute humidity, and accessibility to the human population were considered key factors for the presence of both *Ae. aegypti* and *Ae. albopictus* (Dickens et al., 2018). The presence of nearby large water surface upsurging the absolute humidity (Dickens et al., 2018), together with the foggy atmosphere and the elevation above sea level (CBD, 2024), provide suitable environments for the occurrence of both species of *Aedes* in Hawf.

The predicted probability of *Ae. albopictus* presence in the Eastern Mediterranean Region (EMR) forecasted Yemen, among other countries, as a suitable region with high risk of establishment (Ducheyne et al., 2018). Climatic and demographic factors were identified as key determinants of *Ae. albopictus* establishment and emphasized the importance of precipitation as a limiting factor in the arid EMR (Ducheyne et al., 2018). Our results highlight the accuracy of forecasts predicting a high likelihood of *Ae. albopictus* introduction in Yemen.

5. Conclusions

We are documenting the first report on the presence of *Ae. albopictus* in Yemen. Proximity and movement between Al Mahrah and Oman may have played a role in the introduction of the vector. The presence of both *Aedes* spp. vectors in this area accentuates the need for disease surveillance and meticulous countermeasures in synergy with Oman. In coordination with health authorities, we are intensifying the surveillance efforts near the borders of Al Mahrah Governorate and in other

suspected areas to monitor the spread of the invasive species of *Aedes*. This will support Yemen's efforts in limiting the establishment of the vector population and increase the efficiency of the commenced control measures.

Ethical approval

Not applicable.

CRediT authorship contribution statement

Alia Zayed: Conceptualization, Visualization, Methodology, Validation, Writing - original draft, Writing - review & editing. Yasser Baheshm: Visualization, Supervision, Writing - review & editing. Mohammed Al Amoudi: Data curation, Investigation, Validation. Salim Bin Shabiz: Methodology, Investigation. Matthew Jensen Montgomery: Conceptualization, Visualization, Writing - review and editing.

Data availability

The data supporting the conclusions of this article are included within the article.

Disclaimer

Some authors are military service members or federal employee of the United States government. This work was prepared as part of their official duties. Title 17 U.S.C. 105 provides that "copyright protection under this title is not available for any work of the United States Government." Title 17 U.S.C. 101 defines a U.S. Government work as work prepared by a military service member or employee of the U.S. Government as part of that person's official duties. The views expressed in this article reflect the results of research conducted by the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the United States Government.

Funding

This study was supported by the Armed Forces Health Surveillance Division, Global Emerging Infections Surveillance Branch (GEIS) under grant ProMIS ID P0041_22_N3 & P0036_23_N3.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors extend their appreciation to the Health Office in Hawf for supporting the visit of the NAMRU-EAC team. We would like to thank Dr Karim Omar for developing the map.

References

- Al Awaidy, S.T., Khamis, F., Al-Zakwani, I., Al Kindi, S., Al Busafi, S., Al Sulaimi, K., Al Sidiari, H., 2022. Epidemiological and clinical characteristics of patients with dengue fever in a recent outbreak in Oman: A single center retrospective-cohort study. *Oman Med. J.* 37, e452.
- Al-Abri, S.S., Kurup, P.J., Al Manji, A., Al Kindi, H., Al Wahaibi, A., Al Jardani, A., et al., 2020. Control of the 2018–2019 dengue fever outbreak in Oman: A country previously without local transmission. *Int. J. Infect. Dis.* 90, 97–103.
- Alahmed, A.M., Munawar, K., Khalil, S.M.S., Harbach, R.E., 2019. Assessment and an updated list of the mosquitoes of Saudi Arabia. *Parasites Vectors* 12, 356.
- Al-Garadi, M.A., 2015. Epidemiological review of dengue fever in Yemen. *Int. J. Adv. Res.* 3, 1578–1584.

- Bin Ghouth, A.S., Amarasinghe, A., Letson, G.W., 2012. Dengue outbreak in Hadramout, Yemen, 2010: An epidemiological perspective. *Am. J. Trop. Med. Hyg.* 86, 1072–1076.
- CBD, 2024. Protected Area in Yemen, Yemen Biodiversity National Clearing House Mechanism. Convention on Biological Diversity. <https://ye.chm-cbd.net/hawf-protected-area>. (Accessed 10 June 2024).
- Dawah, H.A., Abdullah, M.A., Ahmad, S.K., Turner, J., Azari-Hamidian, S., 2023. An overview of the mosquitoes of Saudi Arabia (Diptera: Culicidae), with updated keys to the adult females. *Zootaxa* 5394, 1–76.
- Dickens, B.L., Sun, H., Jit, M., Cook, A.R., Carrasco, L.R., 2018. Determining environmental and anthropogenic factors which explain the global distribution of *Aedes aegypti* and *Ae. albopictus*. *BMJ Glob. Health* 3, e000801.
- Ducheyne, E., Tran Minh, N.N., Haddad, N., Bryssinckx, W., Buliva, E., Simard, F., et al., 2018. Current and future distribution of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) in WHO Eastern Mediterranean Region. *Int. J. Health Geogr.* 17, 4.
- Godsey, M.S., Abdoon, A.-M.M., Savage, H.M., Al-Sharani, A.M., Al-Mazrou, Y., Al-Jeffri, M.H., et al., 2003. First record of *Aedes (Stegomyia) unilineatus* in the Kingdom of Saudi Arabia. *J. Am. Mosq. Control Assoc.* 19, 84–86.
- Haddad, N., Harbach, R.E., Chamat, S., Bouharoun-Tayoun, H., 2007. Presence of *Aedes albopictus* in Lebanon and Syria. *J. Am. Mosq. Control Assoc.* 23, 226–228.
- Huang, Y.-M., 2004. The subgenus *Stegomyia* of *Aedes* in the Afrotropical Region with keys to the species (Diptera: Culicidae). *Zootaxa* 700, 1–120.
- Kamal, M., Kenawy, M.A., Rady, M.H., Khaled, A.S., Samy, A.M., 2018. Mapping the global potential distributions of two arboviral vectors *Aedes aegypti* and *Ae. albopictus* under changing climate. *PLoS One* 13, e0210122.
- Kanani, K., Amr, Z., Katbeh-Badr, A., Arbaji, M., 2017. First record of *Aedes albopictus* in Jordan. *J. Am. Mosq. Control Assoc.* 33, 134–135.
- Madani, T.A., Abuelzein, E.T.M., Al-Bar, H.M., Azhar, E.I., Kao, M., Alshoeb, H.O., Bamoosa, A.R., 2013. Outbreak of viral hemorrhagic fever caused by dengue virus type 3 in Al-Mukalla, Yemen. *BMC Infect. Dis.* 13, 1–6.
- Malik, M.R., Minzava, A., Mohareb, E., Zayed, A., Al Kohlani, A., Thabet, A.A., El Bushra, H., 2014. Chikungunya outbreak in Al-Hudaydah, Yemen, 2011: Epidemiological characterization and key lessons learned for early detection and control. *J. Epidemiol. Glob. Health* 4, 203–211.
- Naeem, M., Alahmed, A.M., Kheir, S.M., Sallam, M., 2016. Spatial distribution modeling of *Stegomyia aegypti* and *Culex tritaeniorhynchus* (Diptera: Culicidae) in Al-Bahah Province, Kingdom of Saudi Arabia. *Trop. Biomed.* 33, 295–310.
- Rezsa, G., El-Sawaf, G., Faggioni, G., Vescio, F., Al Ameri, R., De Santis, R., et al., 2014. Co-circulation of dengue and chikungunya viruses, Al Hudaydah, Yemen, 2012. *Emerg. Infect. Dis.* 20, 1351–1354.
- Rueda, L.M., 2004. Pictorial keys for the identification of mosquitoes (Diptera: Culicidae) associated with dengue virus transmission. *Zootaxa* 589, 1–60.
- Saghir, M.A., Ahmed, W.A.M., Dhaiban, M.M.A., Osman, M.E., Abduljabbar, N.I., 2022. Knowledge, attitude, and practices of the community toward dengue fever in Shabwah Governorate, Yemen: A descriptive study. *J. Egypt. Publ. Health Assoc.* 97, 27.
- Saied, K.G., Al-Taiar, A., Altaire, A., Alqadsi, A., Alariqi, E.F., Hassaan, M., 2015. Knowledge, attitude and preventive practices regarding dengue fever in rural areas of Yemen. *Int. Health* 7, 420–425.
- UNESCO, 2002. UNESCO World Heritage Convention, Tentative list sites in Yemen: The Hawf area. https://archiwoo.com/unesco/unesco_natural_sub_lists.php?uw_country=yemen&subsite=hawf_area. (Accessed 11 June 2024).
- USAID, 2016. Climate risk profile: Yemen. United States Agency for International Development. <https://www.climatechange.org/resources/climate-change-risk-profile-yemen>.
- Yaghoobi-Ershadi, M.R., Doosti, S., Schaffner, F., Moosa-Kazemi, S.H., Akbarzadeh, K., Yaghoobi-Ershadi, N., 2017. Morphological studies on adult mosquitoes (Diptera: Culicidae) and first report of the potential Zika virus vector *Aedes (Stegomyia) unilineatus* (Theobald, 1906) in Iran. *Bull. Soc. Pathol. Exot.* 110, 116–121.
- Zayed, A., Awash, A.A., Esmail, M.A., Al-Mohamadi, H.A., Al-Salwai, M., Al-Jasari, A., et al., 2012. Detection of chikungunya virus in *Aedes aegypti* during the 2011 outbreak in Al Hodayda, Yemen. *Acta Trop.* 123, 62–66.