

# A Review of the Biology, Ecology, and Surveillance of *Aedes aegypti* in Puerto Rico

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Dengue has long been a major public health problem in Puerto Rico, and the emergence of chikungunya and Zika has added to this burden. These arthropod-borne viruses are transmitted primarily by the domestic mosquito *Aedes aegypti*. This review synthesizes peer-reviewed studies published from 1974 through 2024 on *Ae. aegypti* biology, ecology, and surveillance that were conducted in Puerto Rico or that used mosquitoes collected in Puerto Rico. References were identified through PubMed and Google Scholar and supplemented by the author's curated collection. Collectively, the literature shows that persistence of *Ae. aegypti* in Puerto Rico is supported by desiccation-resistant eggs, the use of a broad range of natural and artificial containers, and year-round access to aquatic habitats maintained by both rainfall and human activity. The reviewed studies also indicate that mosquito production is spatially heterogeneous, with a small number of container types and cryptic habitats often contributing disproportionately to adult emergence. Surveillance tools for eggs, immature stages, and adults are available, but each is best suited to specific operational objectives, including identifying productive containers, monitoring adult abundance, detecting arboviruses, and evaluating control interventions. Important knowledge gaps remain regarding egg viability under field conditions, the contribution of overlooked aquatic habitats, the role of *Aedes mediiovittatus* and other potential vectors, seasonal variation in adult survival; and the influence of socioeconomic factors, spatial structure, and other determinants on mosquito abundance and arbovirus transmission. Addressing these gaps through operationally relevant research could improve prevention and control strategies for dengue and other arboviruses in Puerto Rico.

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Dengue has affected Puerto Rico for decades and remains a major public health concern (1). What began as intermittent outbreaks evolved into endemic, and later hyperendemic, transmission, characterized by the co-circulation of multiple serotypes and periodic increases in severe disease and mortality (1). After transmission declined during 2015–2017, coinciding with the Zika outbreak period, dengue activity increased again in 2019, culminating in a major outbreak in 2024 (2).

In Puerto Rico, *Aedes aegypti* is the principal vector of dengue virus serotypes 1–4, chikungunya virus, and Zika virus. Transmission can occur year-round because populations of *Ae. aegypti* remain high across much of the island. Another mosquito species present in Puerto Rico, *Aedes mediiovittatus*, is a competent laboratory vector of dengue viruses (3–5). It can also transmit Zika virus under laboratory conditions, although it is less susceptible to infection than *Ae. aegypti* (6). *Aedes mediiovittatus* occurs in rural and urban environments with abundant vegetation, where it may coexist locally with *Ae. aegypti* and occur in areas with human dengue cases. However, natural infections with dengue or Zika virus have not been demonstrated in this species in Puerto Rico, so its epidemiologic role remains uncertain.

The mosquito fauna of Puerto Rico includes more than 40 species (Table 1) (5, 7–9). Several have historical or potential medical importance in disease transmission. *Anopheles albimanus* formerly transmitted malaria on the island (10), and *Culex quinquefasciatus* was implicated in transmission of Bancroftian

filariasis (11). During the 2007 epizootic of West Nile virus, several mosquito species—including *Ae. taeniorhynchus*, *Cx. bahamensis*, *Cx. habilitator*, *Cx. nigripalpus*, and *Cx. quinquefasciatus*—tested positive for viral infection, and human exposure was documented among infected blood donors (12). Although those investigations did not indicate the sustained endemic transmission of West Nile virus in Puerto Rico, they underscore the broader medical relevance of the island's mosquito fauna.

This review synthesizes peer-reviewed studies published from 1974 through 2024 on the biology, ecology, and surveillance of *Ae. aegypti* that were conducted in Puerto Rico or that used mosquitoes collected in Puerto Rico. References were identified through searches of PubMed and Google Scholar and supplemented by the author's curated collection. Search terms combined *Aedes aegypti* and Puerto Rico with specific surveillance-related keywords: general surveillance terms (population surveillance, vector surveillance, entomological surveillance), indices (larval index\*, Breteau index, house index, pupal index, container index), and trap-related terms (ovitrap\*, BG-Sentinel, gravid trap\*, gravidtrap\*). Basic research conducted elsewhere that did not directly inform the

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main themes of this review was excluded, as were studies focused primarily on mosquito control, which are covered in a separate review.

### Biology/Ecology

Effective management of *Ae. aegypti* in Puerto Rico depends on understanding how the mosquito persists across aquatic and terrestrial habitats and how weather, human behavior, and species interactions shape its abundance. Collectively, studies from Puerto Rico show that local populations are maintained by three interacting factors: desiccation-resistant eggs, use of a broad but unevenly productive range of natural and artificial containers, and year-round availability of water-filled habitats created by both rainfall and human activity. This body of work also shows that mosquito production is spatially heterogeneous, with a relatively small number of container types and sites often contributing disproportionately to adult emergence. These patterns are operationally important because they help explain why interventions that target only visible containers or only one life stage may have limited impact.

### Immature stages

#### Eggs

Egg desiccation resistance is a central mechanism underlying *Ae. aegypti* persistence. Classic observations and laboratory studies with Puerto Rican mosquitoes indicate that eggs can remain viable for months after oviposition, with high hatching rates early after oviposition and occasional survival for much longer periods (13,14). Modeling work further supports the importance of this egg bank because predictions of mosquito abundance improved when rain-triggered hatching and relative humidity were incorporated into the model (15). These findings suggest that dormant eggs help populations recover rapidly after rainfall or after containers are refilled by residents and may reduce the effectiveness of interventions directed only at larvae or adults. However, the persistence of eggs under natural field conditions in Puerto Rico remains insufficiently quantified, so egg longevity outdoors should be framed as an important local knowledge gap rather than as an established estimate. Better field data on egg survival would improve the timing and expected residual performance of larval control measures.

**Table 1.** List of mosquito species reported in Puerto Rico and historical medical importance

| Genus                 | Subgenus             | Species                                  | Medical importance                      | Reference |
|-----------------------|----------------------|------------------------------------------|-----------------------------------------|-----------|
| <i>Aedes</i>          | <i>Stegomyia</i>     | <i>aegypti</i> (L.)                      | Dengue, Zika, chikungunya, yellow fever | 1, 32     |
| <i>Aedes</i>          | <i>Gymnotometopa</i> | <i>mediovittatus</i> (Coquillett)        |                                         |           |
| <i>Aedes</i>          | <i>Ochlerotatus</i>  | <i>obturator</i> (Dyar and Knab)         |                                         |           |
| <i>Aedes</i>          | <i>Ochlerotatus</i>  | <i>pertinax</i> Grabham                  |                                         |           |
| <i>Aedes</i>          | <i>Ochlerotatus</i>  | <i>sollicitans</i> (Walker)              |                                         |           |
| <i>Aedes</i>          | <i>Ochlerotatus</i>  | <i>taeniorhynchus</i> (Wiedemann)        | West Nile fever                         | 12        |
| <i>Aedes</i>          | <i>Ochlerotatus</i>  | <i>tortilis</i> (Theobald)               |                                         |           |
| <i>Anopheles</i>      | <i>Nyssorhynchus</i> | <i>albimanus</i> Wiedemann               | Malaria                                 | 10        |
| <i>Anopheles</i>      | <i>Anopheles</i>     | <i>atropos</i> Dyar and Knab             |                                         |           |
| <i>Anopheles</i>      | <i>Anopheles</i>     | <i>grabhamii</i> Theobald                |                                         |           |
| <i>Anopheles</i>      | <i>Anopheles</i>     | <i>vestitipennis</i> Dyar and Knab       |                                         |           |
| <i>Culex</i>          | <i>Culex</i>         | <i>bahamensis</i> Dyar and Knab          | West Nile fever                         | 12        |
| <i>Culex</i>          | <i>Culex</i>         | <i>chidesteri</i> Dyar                   |                                         |           |
| <i>Culex</i>          | <i>Culex</i>         | <i>habilitator</i> Dyar and Knab         | West Nile fever                         | 12        |
| <i>Culex</i>          | <i>Culex</i>         | <i>janitor</i> Theobald                  |                                         |           |
| <i>Culex</i>          | <i>Culex</i>         | <i>nigripalpus</i> Theobald              | West Nile fever                         |           |
| <i>Culex</i>          | <i>Culex</i>         | <i>quinquefasciatus</i> Say              | Bancroftian filariasis, West Nile fever | 11, 12    |
| <i>Culex</i>          | <i>Culex</i>         | <i>secutor</i> Theobald                  |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>atratus</i> Theobald                  |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>carcinophilus</i> Dyar and Knab       |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>elevator</i> Dyar and Knab            |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>erraticus</i> (Dyar and Knab)         |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>inhibitor</i> Dyar and Knab           |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>iolambdis</i> Dyar                    |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>peccator</i> Dyar and Knab            |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>pilosus</i> (Dyar and Knab)           |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>sardineriae</i> Fox                   |                                         |           |
| <i>Culex</i>          | <i>Melanoconion</i>  | <i>taeniopus</i> Dyar and Knab           |                                         |           |
| <i>Culex</i>          | <i>Micraedes</i>     | <i>antillummagnorum</i> Dyar             |                                         |           |
| <i>Deinocerites</i>   | <i>Deinocerites</i>  | <i>magnus</i> (Theobald)                 |                                         |           |
| <i>Mansonia</i>       | <i>Mansonia</i>      | <i>dyari</i> Belkin, Heinemann, and Page |                                         |           |
| <i>Mansonia</i>       | <i>Mansonia</i>      | <i>flaveola</i> (Coquillett)             |                                         |           |
| <i>Orthopodomyia</i>  |                      | <i>signifera</i> (Coquillett)            |                                         |           |
| <i>Psorophora</i>     | <i>Grabhamia</i>     | <i>insularia</i> (Dyar and Knab)         |                                         |           |
| <i>Psorophora</i>     | <i>Grabhamia</i>     | <i>jamaicensis</i> (Theobald)            |                                         |           |
| <i>Psorophora</i>     | <i>Grabhamia</i>     | <i>pygmaea</i> (Theobald)                |                                         |           |
| <i>Psorophora</i>     | <i>Janthinosoma</i>  | <i>johnstonii</i> (Grabham)              |                                         |           |
| <i>Toxorhynchites</i> | <i>Lynchiella</i>    | <i>portoricensis</i> (Roeder)            |                                         |           |
| <i>Uranotaenia</i>    | <i>Uranotaenia</i>   | <i>cooki</i> Root                        |                                         |           |
| <i>Uranotaenia</i>    | <i>Uranotaenia</i>   | <i>lowii</i> Theobald                    |                                         |           |
| <i>Uranotaenia</i>    | <i>Uranotaenia</i>   | <i>socialis</i> Theobald                 |                                         |           |
| <i>Wyeomyia</i>       |                      | spp.                                     |                                         |           |

### Larvae and pupae

Studies from Puerto Rico show that *Ae. aegypti* immature stages exploit a wide variety of habitats. These range from natural sites such as rock holes, conch shells, tree holes, bamboo internodes,

papaya stumps, coconut husks, and bromeliad axils to artificial containers such as buckets, barrels, tanks, cisterns, tires, discarded food and beverage containers, ornamental containers, boats, toys, cavities in structures, and underground systems including septic tanks, water meters, and storm drains (Table 2) (8,16–23). Yet the literature also shows that although habitat use is broad, productivity is concentrated. In southern Puerto Rico, 80% of female pupae originated from only 7 of 18 container types (24). This is consistent with the value of pupal surveys for identifying the habitats that contribute most to adult emergence (21,24,25). Thus, the main control implication is not simply that *Ae. aegypti* uses many containers but rather that source reduction and larviciding should prioritize the most productive container classes in each locality.

Container quality, not just container presence, influences mosquito production. Larvae developing in small, sun-exposed containers experience greater nutritional stress and tend to emerge as smaller adults, whereas larger shaded containers often provide more stable temperatures, more organic matter, and less evaporation, favoring better larval development (26). In Puerto Rico, this contrast is especially evident in unsealed septic tanks, which can support more abundant *Ae. aegypti* populations than many above-ground containers can (20, 27). These studies indicate that cryptic and nutrient-rich habitats can make a disproportionate contribution to adult mosquito emergence, which helps explain why conventional control focused on visible surface containers may underperform in neighborhoods with underground or otherwise inaccessible aquatic habitats.

In Puerto Rico, *Ae. aegypti* is also part of a broader assemblage of container-breeding mosquitoes. Its immatures have been collected with other species in tires, gutters, bromeliads, and yam or taro plants, and the most frequent co-occurring species are *Ae. mediovittatus*, *Toxorhynchites portoricensis*, *Cx. antillummagnorum*, and *Cx. quinquefasciatus* (5,8). Across the urban gradient, *Ae. aegypti* is most strongly associated with densely built environments and warmer containers, whereas *Cx. quinquefasciatus* is more frequent in larger containers in lower-density suburban settings, and *Ae. mediovittatus* and other species are more common in vegetated rural or forested habitats (5). This pattern suggests that habitat segregation among species is partial, although overlap in artificial containers creates opportunities for interaction.

Understanding the interactions between *Ae. aegypti* and *Ae. mediovittatus* in aquatic container habitats is essential, as these species may compete for space and resources, potentially affecting their distribution patterns. Laboratory experiments showed that larvae of *Ae. mediovittatus* performed better than those of *Ae. aegypti* (28), which may explain their coexistence in urban habitats. However, experiments with caged adults showed that *Ae. aegypti* can interfere with *Ae. mediovittatus* reproduction by mating with virgin females, preventing further insemination by male *Ae. mediovittatus* (29). If mating interference occurs in natural settings, *Ae. aegypti* will gain a competitive advantage over *Ae. mediovittatus*.

Evidence from free-roaming nonhuman primates further supports ecological overlap between forest-associated and

peridomestic mosquitoes. Serologic assays detecting anti-saliva antibodies showed that primates had been bitten most often by *Ae. mediovittatus*, followed by *Cx. quinquefasciatus*, *Ae. taeniorhynchus*, and *Ae. aegypti* (30). This pattern is consistent with primate use of vegetated habitats while still indicating occasional exposure to the domestic vector of dengue near human-modified environments.

### Adults

Adult populations of *Ae. aegypti* persist year-round in Puerto Rico, but the literature indicates that rainfall alone does not explain this persistence. Rainfall increases the availability of water-filled containers and is positively associated with immature and adult abundance in multiple local studies (7,18,22,31,32). At the same time, permanent or repeatedly refilled containers created by human activity allow mosquito production to continue during dry periods, including drought years and episodes of El Niño–associated water stress in southern Puerto Rico (19,20,31). Simulation work in San Juan supports this interpretation because model results suggest that rain-filled containers account for most mosquito production in wetter years, whereas human-filled containers become relatively more important in drier years (33). These findings show that climatic influences on *Ae. aegypti* are mediated by infrastructure and household water-management practices rather than by rainfall alone.

Neighborhood conditions also shape *Ae. aegypti* abundance, although the evidence should be interpreted cautiously. Studies in Puerto Rico have found that abandoned houses and houses in lower socioeconomic settings tend to contain more water-holding containers and more *Ae. aegypti* pupae than houses in higher socioeconomic settings. Discarded containers and unmanaged peridomestic space may contribute to this difference by providing additional oviposition sites (17, 34). These findings suggest that socioeconomic gradients can influence mosquito production through housing quality, yard maintenance, and water-storage behavior. However, because this evidence comes from a limited number of local studies, these relationships should be framed as context-dependent rather than universal. Additional work linking socioeconomic conditions to mosquito abundance, arboviral infection, and specific container types would strengthen the operational value of this line of research.

Spatial analyses add an important operational dimension to this literature. Geographic information system (GIS)–based studies have identified persistent hotspots of adult *Ae. aegypti* within neighborhoods, indicating that mosquito abundance is spatially clustered and that these clusters can remain stable enough to guide targeted control (35). However, spatial clustering changes after heavy rainfall and after interventions that suppress mosquitoes in accessible containers, which can sometimes reveal previously overlooked cryptic breeding sites such as septic tanks or other hidden water-holding structures (20,35). Thus, spatial stability should not be interpreted as fixed; instead, it reflects the shifting balance among rainfall, container availability, and the success or failure of source reduction.

**Table 2.** Aquatic habitats of *Aedes aegypti* in Puerto Rico

| Container habitats by study                                                                          | Lee and Moore 1973 | Moore 1983 | Chadee et al. 1998 | Barrera et al. 2006 | Barrera et al. 2008 | Barrera et al. 2010 | Barrera et al. 2011 | Barrera et al. 2019 | Yee et al. 2019 | Barrera et al. 2020 | Yee et al. 2021 | Otero et al. 2022 |
|------------------------------------------------------------------------------------------------------|--------------------|------------|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|---------------------|-----------------|-------------------|
| Buckets                                                                                              | x                  |            |                    | x                   |                     | x                   | x                   |                     | x               | x                   |                 | x                 |
| Drums                                                                                                | x                  | x          |                    | x                   |                     | x                   | x                   | x                   |                 | x                   |                 | x                 |
| Tanks and cisterns                                                                                   |                    |            |                    |                     |                     | x                   | x                   | x                   |                 |                     |                 |                   |
| Animal drinking containers                                                                           | x                  |            |                    | x                   |                     | x                   | x                   | x                   |                 | x                   |                 |                   |
| Plants maintained in water                                                                           |                    |            |                    |                     |                     | x                   |                     | x                   |                 | x                   |                 |                   |
| Plant pots and saucers                                                                               |                    |            |                    | x                   |                     | x                   | x                   | x                   | x               | x                   |                 | x                 |
| Flower pots                                                                                          |                    |            |                    |                     |                     |                     |                     |                     |                 |                     |                 | x                 |
| Ornamental fountains                                                                                 |                    |            |                    | x                   |                     | x                   | x                   | x                   |                 |                     | x               | x                 |
| Tarps                                                                                                |                    |            |                    | x                   |                     | x                   |                     | x                   |                 | x                   |                 | x                 |
| Trash cans                                                                                           |                    |            |                    | x                   |                     | x                   |                     |                     |                 | x                   |                 |                   |
| Toys                                                                                                 |                    |            |                    | x                   |                     | x                   |                     | x                   |                 | x                   |                 |                   |
| Used tires                                                                                           |                    | x          |                    | x                   |                     | x                   | x                   | x                   | x               | x                   | x               |                   |
| Boats and other vehicles                                                                             |                    |            |                    | x                   |                     | x                   |                     | x                   |                 | x                   |                 |                   |
| Discarded tools and equipment                                                                        |                    |            |                    | x                   |                     | x                   |                     | x                   |                 | x                   | x               | x                 |
| Cans and other discarded food/drink containers                                                       | x                  |            |                    | x                   |                     | x                   |                     | x                   | x               | x                   | x               | x                 |
| Broken furniture/appliances                                                                          | x                  |            |                    | x                   |                     | x                   |                     | x                   |                 |                     | x               | x                 |
| Wading pools                                                                                         |                    |            |                    | x                   |                     | x                   |                     | x                   |                 | x                   |                 |                   |
| Cavities in structures (fences, hollow bricks, unlevelled floors, etc.)                              |                    |            |                    |                     |                     | x                   |                     | x                   |                 | x                   |                 | x                 |
| Rock holes                                                                                           |                    | x          | x                  |                     |                     |                     |                     |                     |                 |                     |                 |                   |
| Phytotelmata (tree holes, bamboo internodes, coconut husks, bromeliads, papaya stumps, conch shells) | x                  | x          | x                  | x                   |                     | x                   |                     | x                   |                 |                     | x               | x                 |
| Broken or open septic tanks                                                                          |                    |            |                    |                     | x                   | x                   |                     |                     |                 |                     |                 |                   |
| Flooded water meters                                                                                 |                    |            |                    |                     |                     | x                   | x                   | x                   |                 | x                   |                 |                   |
| Storm drains and drainage ditches                                                                    |                    |            |                    |                     |                     |                     |                     |                     |                 |                     | x               |                   |
| Miscellaneous (not specified)                                                                        | x                  | x          |                    |                     |                     |                     | x                   |                     | x               |                     |                 |                   |

Aedes aegypti surveillance

Surveillance of *Ae. aegypti* in Puerto Rico has used both immature- and adult-based methods, but the literature shows that these approaches answer different operational questions and should not be treated as interchangeable. Field surveys of larvae and pupae are most useful for identifying the containers that sustain local production, whereas ovitraps, aspiration, and adult traps are most useful for tracking temporal trends, estimating adult female abundance, detecting arboviruses, and evaluating control activities. The reviewed studies from Puerto Rico indicate that surveillance is most informative when the method is matched to the program objective, rather than when a single index is used as a universal measure of risk.

Immature surveillance

Inspection of water-holding containers remains the basis for identifying the habitats used by *Ae. aegypti* in Puerto Rico (Table 3; Figure 2). However, larval counts alone are an imperfect measure of population abundance because mortality from larva to adulthood can be high and variable. For that reason, pupal surveys are generally more informative for estimating the contribution of different containers to adult emergence (21, 24, 36). Studies in Puerto Rico showed that pupal production is highly aggregated, with a relatively small number of container classes accounting for most of the pupae collected in some communities (21,24). This pattern has clear operational value because it means that immature surveillance can identify the containers that should be prioritized for source reduction or larviciding, rather than treating all container types equally.

Adult surveillance

Adult-based methods provide information that immature-based methods cannot, particularly when the goal is to monitor the female mosquitoes most relevant to transmission or to assess the impact of control interventions. In Puerto Rico, adult surveillance has relied mainly on ovitraps, backpack aspiration, BG-Sentinel traps, and Autocidal Gravid Ovitrap (AGO traps), with each method sampling a different component of the population. Collectively, these studies show that trap choice should be guided by mosquito behavior and by the surveillance objective.

Ovitraps

Ovitraps have been widely used in Puerto Rico as a sensitive and low-cost method to detect oviposition activity and monitor local changes in *Ae. aegypti* abundance. They have also been used in dispersal studies and in evaluations of mosquito control. In San Juan, ovitrap egg counts were positively associated with

Table 3. Aedes aegypti surveillance tools used in Puerto Rico

| Surveillance tool               | Stage of development |        |       |        |                                                                                              |
|---------------------------------|----------------------|--------|-------|--------|----------------------------------------------------------------------------------------------|
|                                 | Eggs                 | Larvae | Pupae | Adults | Indicator                                                                                    |
| Larval surveys (trays, dippers) |                      | x      | x     |        | Percentage of positive containers; container types; number of larvae and pupae per container |
| Pupal surveys (trays, dippers)  |                      |        | x     |        | Number of pupae per container; most productive container types; estimated adult emergence    |
| Miniature funnel traps          |                      | x      | x     |        | Presence or absence; number of larvae and pupae per trap                                     |
| Standard ovitraps               | x                    |        |       |        | Percentage of ovitraps with eggs; number of eggs per ovitrap                                 |
| PAM ovitraps                    | x                    |        |       |        | Percentage of ovitraps with eggs; number of eggs per ovitrap                                 |
| Larvitrap                       |                      | x      |       |        | Percentage of positive larvitrap; number of larvae per larvitrap                             |
| BG-Sentinel traps               |                      |        |       | x      | Percentage of positive traps; number of adults per trap                                      |
| AGO traps                       |                      |        |       | x      | Percentage of positive traps; number of adults per trap                                      |

Abbreviations: AGO, Autocidal Gravid Ovitrap; PAM, polyacrylamide-gel

captures of gravid females in AGO traps, suggesting that ovitraps can reflect relative temporal trends under stable conditions (32). However, studies in Puerto Rico also show why ovitrap data should be interpreted cautiously: when alternative oviposition sites are removed or become limited, females may concentrate eggs in the traps, inflating egg counts without a proportional increase in the adult population (37–39). Thus, ovitraps are most useful for detection and relative change, but the data they generate should not be interpreted as a direct measure of adult abundance without considering habitat availability.

Because conventional ovitraps contain standing water and must be serviced frequently to avoid producing adults, investigators in Puerto Rico also developed a polyacrylamide-gel (PAM) ovitrap that remains attractive to gravid females while preventing successful adult emergence (40). Field evaluations in San Juan showed that PAM ovitraps collected similar numbers of eggs as standard ovitraps. This modification is a good example of how surveillance tools can be adapted to reduce operational risk without sacrificing sensitivity.

Larvitrap

Similar devices can be used to monitor larvae hatching from eggs collected in ovitraps instead of eggs themselves, which facilitates the identification of the specimens and yields similar results. Using bamboo internode larvitrap (Figure 2) helped improve understanding of how mosquito species vary across an urban gradient in San Juan and showed that the most common mosquito species were *Ae. aegypti*, *Cx. quinquefasciatus*, *Ae. mediovittatus*, *Cx. antillunmagnorum*, and *Tx. portoricensis* (5).

### Backpack aspirators

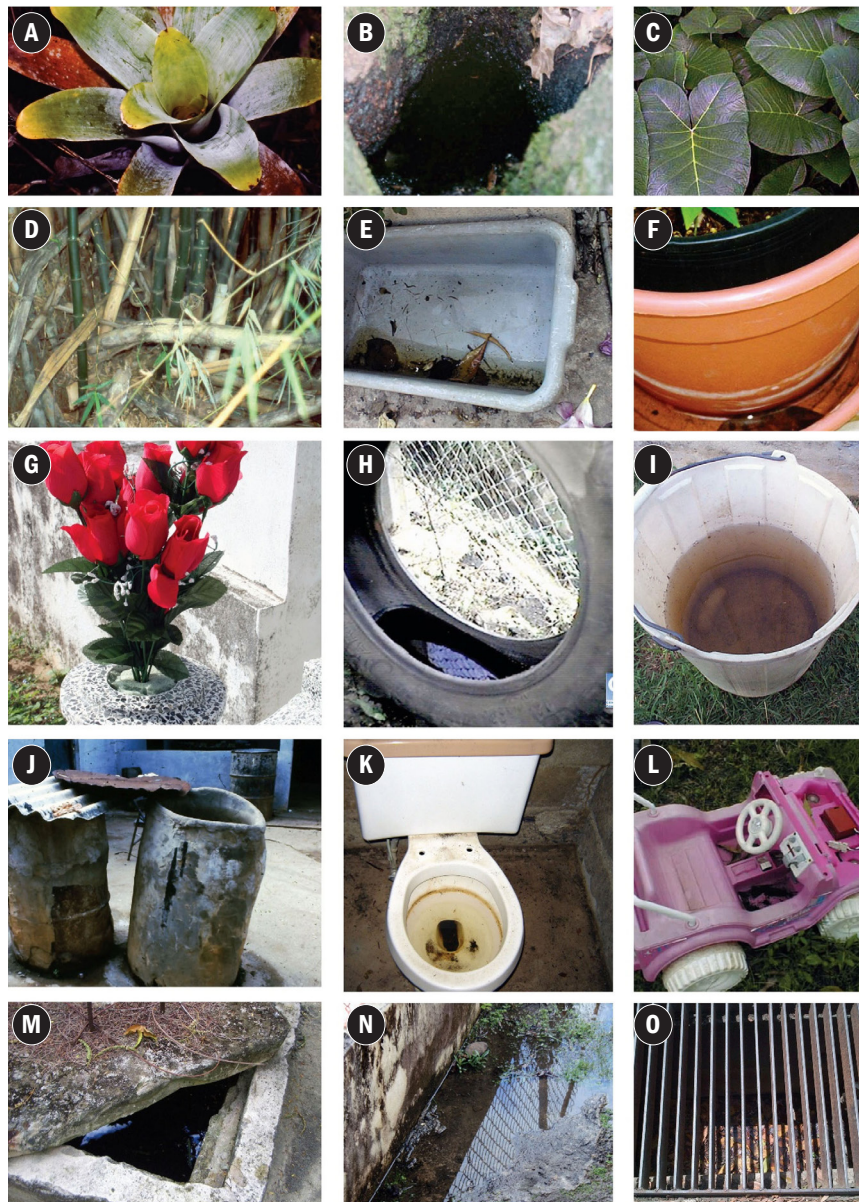
Backpack aspiration and other adult sampling methods have been especially valuable for ecological studies. The Centers for Disease Control and Prevention (CDC) backpack aspirator has been used to sample indoor resting mosquitoes and to investigate blood-feeding patterns, seasonal abundance, survival, dispersal, and the effects of control interventions on adult populations (20,41,42). However, though these methods can provide detailed information on adult ecology, they are labor-intensive and operator-dependent, which limits their practicality for large routine surveillance programs.

### Adult traps

The 2 principal adult traps used in Puerto Rico are the BG-Sentinel trap and the CDC AGO trap (Table 3; Figure 2). These traps are complementary rather than redundant because they target different physiological stages of the mosquito population. BG-Sentinel traps, especially darker-colored modified versions, have been used to monitor host-seeking females, seasonal abundance, spatial distribution, blood sources, and mosquito community composition (18,19,43–45). In contrast, AGO traps are passive gravid-female traps developed in Puerto Rico that have become central to both surveillance and control-oriented studies (46–51). Their practical advantages include lower servicing demands than standard ovitraps, the possibility of adding larvicides without reducing attractiveness, and support for the molecular detection of dengue, chikungunya, and Zika viruses in captured mosquitoes (32,46–51).

Studies of AGO trap placement further suggest that capture rates are influenced more by neighborhood-level mosquito abundance than by small differences in immediate microhabitat, making it feasible to place surveillance AGO traps near the front of houses rather than deeper inside properties (52). Even so, locations that are shaded and protected from the rain remain preferable to preserve specimens for identification. Taken together, the adult trapping literature from Puerto Rico indicates that AGO traps are especially useful when the goal is to monitor gravid female abundance, detect arboviruses, or evaluate suppression programs. BG-Sentinel traps and aspiration provide

**Figure 1.** Natural and artificial containers used by *Aedes aegypti* for immature development: A, bromeliads; B, tree holes; C, plant axils; D, bamboo internodes; E, Trays; F, plant pots and saucers; G, flower pots; H, discarded tires; I, pails and buckets; J, water-storage containers; K, discarded household items; L, discarded toys; M, septic tanks; N, flooded structural cavities; and O, storm drains.



more informative data on host-seeking females, blood feeding, and short-term spatial dynamics.

Overall, the Puerto Rico literature shows that no single surveillance method is sufficient on its own. Immature surveys are the most informative for identifying productive containers and concealed aquatic habitats, ovitraps are sensitive indicators of oviposition activity, and adult-based methods provide the most direct information on the female mosquitoes responsible for transmission. A surveillance system that combines these

**Figure 2.** Tools used for surveillance of immature and adult stages of *Aedes aegypti*: A, equipment used to collect larvae and pupae from water-filled containers; B, water collected from a discarded tire; C, polyacrylamide (PAM) gel ovitrap; D, bamboo internode larvitrap; E, paired ovitraps; F, miniature funnel trap; G, BG-Sentinel 2 trap; and H, Autocidal Gravid Ovitraps (AGO).



surveillance approaches, according to the epidemiologic and operational question being addressed, is therefore likely to be more informative than reliance on any single index.

## Conclusion

Studies conducted in Puerto Rico collectively show that *Ae. aegypti* persists because it combines desiccation-resistant

eggs with flexible use of a wide range of natural and artificial containers and year-round access to aquatic habitats formed and replenished by both rainfall and human activity. The same literature also shows that mosquito production is highly heterogeneous in space: a limited number of container types, household sites, and cryptic habitats can contribute disproportionately to adult emergence, while adult abundance varies with rainfall, neighborhood-level conditions, and local environmental context. Surveillance tools for both immature and adult stages are available and useful, but their value depends on matching each method to its operational purpose, whether that is identifying productive containers, monitoring adult females, detecting arboviruses, or evaluating control interventions.

The most important remaining knowledge gaps are those that directly affect control decisions. First, field-based studies are needed to quantify how long *Ae. aegypti* eggs remain viable under different environmental conditions in Puerto Rico and to determine how this persistence influences the timing and residual effect of larvicides. Second, more work is needed to define the contribution of cryptic and understudied aquatic habitats, including underground drainage structures, catch basins, facility vaults, bromeliads, and tire-related businesses, to local mosquito production. Third, the role of *Ae. mediovittatus* requires further clarification, both as a possible arbovirus vector in urban or peri-urban settings and as a species that may alter the population dynamics of other container-breeding *Aedes*.

Future research should also better integrate ecological and social drivers of risk. Studies in Puerto Rico suggest that *Ae. aegypti* abundance can vary with socioeconomic setting, housing quality, and unmanaged peridomestic environments, but these relationships remain insufficiently resolved. Combining entomologic data with socioeconomic indicators, housing density, elevation, land use, vegetation, and other spatial variables in a GIS framework could improve the identification of transmission-prone areas and help prioritize

vector control. Similar work is needed in places with high human density, such as public housing complexes, condominiums, schools, and other densely populated settings, because these environments may sustain patterns of mosquito–human contact that differ from the patterns observed in single-household neighborhoods.

Another priority is to understand how seasonal changes in adult survival, longevity, and abundance affect arbovirus transmission.

Because transmission depends not only on mosquito density but also on whether adult females survive long enough to become infectious, seasonal estimates of survivorship could improve interpretation of dengue risk and help optimize the timing of interventions. Overall, the most useful next step is operational research that links entomologic findings to control action. Priority areas include evaluation of novel tools, identification of the most productive habitats, and production of high-resolution risk maps that can guide preparedness, outbreak response, and resource allocation.

## Resumen

El dengue ha sido un importante problema de salud pública en Puerto Rico, y la emergencia de chikungunya y Zika ha empeorado la situación. Estos arbovirus son transmitidos por *Aedes aegypti*. Esta revisión sintetiza estudios publicados sobre la biología, la ecología y la vigilancia de *Ae. aegypti* realizados en Puerto Rico, o con mosquitos recolectados en Puerto Rico, publicados entre 1974 y 2024. Las referencias se identificaron mediante búsquedas en PubMed y Google Scholar y se complementaron con la colección del autor. La literatura muestra que *Ae. aegypti* persiste en Puerto Rico gracias a la resistencia a la desecación de sus huevos, uso de una variedad de recipientes naturales y artificiales y al acceso a éstos durante todo el año debido a la lluvia y la actividad humana. La producción de mosquitos es espacialmente heterogénea y unos pocos tipos de recipientes y hábitats crípticos contribuyen de manera desproporcionada a la emergencia de adultos. Existen herramientas de vigilancia para huevos, estados inmaduros y adultos útiles para objetivos operacionales específicos, como identificar los recipientes más productivos, vigilar la abundancia de hembras adultas, detectar arbovirus o evaluar intervenciones de control. Persisten importantes lagunas de conocimiento, como la viabilidad de los huevos en condiciones de campo, la contribución de hábitats acuáticos desconocidos, el posible papel de *Aedes mediovittatus* y otros vectores, la variación estacional en la supervivencia de los adultos y la influencia de factores socioeconómicos y espaciales sobre la abundancia del mosquito y la transmisión de arbovirus. Abordar estas lagunas mediante investigaciones con relevancia operativa podría fortalecer las estrategias de prevención y control del dengue y de otros arbovirus en Puerto Rico.

## References

- Barrera R. Recomendaciones para la vigilancia de *Aedes aegypti*. Biomédica. 2016;36(3):454-462. doi:10.7705/biomedica.v36i3.2892
- Rodriguez DM, Madewell ZJ, Torres JM, et al. Epidemiology of Dengue - Puerto Rico, 2010-2024. MMWR Morb Mortal Wkly Rep. 2024;73(49):1112-1117. Published 2024 Dec 12. doi:10.15585/mmwr.mm7349a1
- Poole-Smith BK, Hemme RR, Delorey M, Felix G, Gonzalez AL, Amador M, et al. Comparison of vector competence of *Aedes mediovittatus* and *Aedes aegypti* for dengue virus: implications for dengue control in the Caribbean. PLoS Negl Trop D. 2015; 9(2):e0003462. <http://dx.doi.org/10.1371/journal.pntd.0003462>
- Gubler DJ, Novak RJ, Vergne E, Colon NA, Velez M, Fowler J. *Aedes (Gymnometopa) mediovittatus* (Diptera: Culicidae), a potential maintenance vector of dengue viruses in Puerto Rico. J Med Entomol. 1985;22(5):469-475. doi:10.1093/jmedent/22.5.469
- Cox J, Grillet ME, Ramos OM, Amador M, Barrera R. Habitat segregation of dengue vectors along an urban environmental gradient. Am J Trop Med Hyg. 2007;76(5):820-826.
- Zimler RA, Yee DA, Alto BW. Transmission Potential of Zika Virus by *Aedes aegypti* (Diptera: Culicidae) and *Ae. mediovittatus* (Diptera: Culicidae) Populations From Puerto Rico. J Med Entomol. 2021;58(3):1405-1411. doi:10.1093/jme/tjaa286
- Smith J, Amador M, Barrera R. Seasonal and habitat effects on dengue and West Nile virus vectors in San Juan, Puerto Rico. J Am Mosq Control Assoc. 2009;25(1):38-46. doi:10.2987/08-5782.1
- Yee DA, Reyes-Torres LJ, Dean C, Scavo NA, Zavortink TJ. Mosquitoes (Diptera: Culicidae) on the islands of Puerto Rico and Vieques, U.S.A. Acta Trop. 2021;220:105959. doi:10.1016/j.actatropica.2021.105959
- Tulloch GS. The mosquitoes of Puerto Rico. J Agric Univ Puerto Rico. 1937;21:137-167. <http://dx.doi.org/10.46429/jaupr.v21i2.14331>
- Miranda Franco R, Casta Vélez A. La erradicación de la malaria en Puerto Rico [Eradication of malaria in Puerto Rico]. Rev Panam Salud Publica. 1997;2(2):146-150.
- O'Connor F, Hulse CR. Studies in filariasis. I. In Puerto Rico. P R J Public Health. 1935;11:167-367.
- Barrera R, MacKay A, Amador M, et al. Mosquito vectors of West Nile virus during an epizootic outbreak in Puerto Rico. J Med Entomol. 2010;47(6):1185-1195. doi:10.1603/me10038
- Christophers SR. *Aedes aegypti*: the yellow fever mosquito: its life history, bionomics, and structure. Cambridge University Press; 1960.
- Fox I. Viability of Puerto Rican *Aedes aegypti* eggs after long periods of storage. Mosq News. 1974;34:274-275.
- Lega J, Brown HE, Barrera R. *Aedes aegypti* (Diptera: Culicidae) Abundance Model Improved With Relative Humidity and Precipitation-Driven Egg Hatching. J Med Entomol. 2017;54(5):1375-1384. doi:10.1093/jme/tjx077
- Otero LM, Medina-Martinez G, Sepúlveda M, Acevedo V, Toro M, Barrera R. Cemeteries as sources of *Aedes aegypti* and other mosquito species in southeastern Puerto Rico. Trop Med Int Health. 2022;27(3):300-309. doi:10.1111/tmi.13723
- Barrera R, Acevedo V, Amador M. Role of Abandoned and Vacant Houses on *Aedes aegypti* Productivity. Am J Trop Med Hyg. 2021;104(1):145-150. doi:10.4269/ajtmh.20-0829
- Barrera R, Felix G, Acevedo V, et al. Impacts of Hurricanes Irma and Maria on *Aedes aegypti* Populations, Aquatic Habitats, and Mosquito Infections with Dengue, Chikungunya, and Zika Viruses in Puerto Rico. Am J Trop Med Hyg. 2019;100(6):1413-1420. doi:10.4269/ajtmh.19-0015
- Barrera R, Amador M, MacKay AJ. Population dynamics of *Aedes aegypti* and dengue as influenced by weather and human behavior in San Juan, Puerto Rico. PLoS Negl Trop Dis. 2011;5(12):e1378. doi:10.1371/journal.pntd.0001378
- Barrera R, Amador M, Diaz A, Smith J, Munoz-Jordan JL, Rosario Y. Unusual productivity of *Aedes aegypti* in septic tanks and its implications for dengue control. Med Vet Entomol. 2008;22(1):62-69. doi:10.1111/j.1365-2915.2008.00720.x
- Barrera R, Amador M, Clark GG. Use of the pupal survey technique for measuring *Aedes aegypti* (Diptera: Culicidae) productivity in Puerto Rico. Am J Trop Med Hyg. 2006;74(2):290-302.
- Moore CG, Cline BL, Ruiz-Tibén E, Lee D, Romney-Joseph H, Rivera-Correa E. *Aedes aegypti* in Puerto Rico: environmental determinants of larval abundance and relation to dengue virus transmission. Am J Trop Med Hyg. 1978;27(6):1225-1231. doi:10.4269/ajtmh.1978.27.1225
- Yee SH, Yee DA, de Jesus Crespo R, Oczkowski A, Bai F, Friedman S. Linking Water Quality to *Aedes aegypti* and Zika in Flood-Prone Neighborhoods. Ecohealth. 2019;16(2):191-209. doi:10.1007/s10393-019-01406-6
- Barrera R. Simplified pupal surveys of *Aedes aegypti* (L.) for entomologic surveillance and dengue control. Am J Trop Med Hyg. 2009;81(1):100-107.
- Barrera R, Amador M, Clark GG. Sample-size requirements for developing strategies, based on the pupal/demographic survey, for the targeted control of dengue. Ann Trop Med Parasitol. 2006;100 Suppl 1:S33-S43. doi:10.1179/136485906X105499

26. Barrera R, Amador M, Clark GG. Ecological factors influencing *Aedes aegypti* (Diptera: Culicidae) productivity in artificial containers in Salinas, Puerto Rico. *J Med Entomol.* 2006;43(3):484-492. doi:10.1603/0022-2585(2006)43[484:efiaad]2.0.co;2
27. Burke RL. Evaluation of *Aedes aegypti* presence and abundance in septic tanks and their impact on dengue transmission. PhD diss. Uniformed Services University of the Health Sciences, Bethesda, MD; 2009.
28. Yee DA, Nelsen JA, Fijman NS, et al. Larval competition between the invasive *Aedes aegypti* (Diptera: Culicidae) and the Caribbean endemic *Aedes mediiovittatus* (Diptera: Culicidae) from Puerto Rico, USA. *J Med Entomol.* 2025;62(2):347-357. doi:10.1093/jme/tjae154
29. Fay R, Keirans J. Production of *Aedes mediiovittatus* (Coquillett) and its response to temperature and food conditions. *Mosq News.* 1971;31:488-491.
30. Hemme RR, Poole-Smith BK, Hunsperger EA, et al. Non-human primate antibody response to mosquito salivary proteins: Implications for dengue virus transmission in Puerto Rico. *Acta Trop.* 2016;164:369-374. doi:10.1016/j.actatropica.2016.08.027
31. Barrera R, Acevedo V, Amador M, Marzan M, Adams LE, Paz-Bailey G. El Niño Southern Oscillation (ENSO) effects on local weather, arboviral diseases, and dynamics of managed and unmanaged populations of *Aedes aegypti* (Diptera: Culicidae) in Puerto Rico. *J Med Entomol.* 2023;60(4):796-807. doi:10.1093/jme/tjad053
32. Barrera R, Amador M, Acevedo V, Beltran M, Muñoz JL. A comparison of mosquito densities, weather and infection rates of *Aedes aegypti* during the first epidemics of Chikungunya (2014) and Zika (2016) in areas with and without vector control in Puerto Rico. *Med Vet Entomol.* 2019;33(1):68-77. doi:10.1111/mve.12338
33. Morin CW, Monaghan AJ, Hayden MH, Barrera R, Ernst K. Meteorologically Driven Simulations of Dengue Epidemics in San Juan, PR. *PLoS Negl Trop Dis.* 2015;9(8):e0004002. Published 2015 Aug 14. doi:10.1371/journal.pntd.0004002
34. Scavo NA, Barrera R, Reyes-Torres LJ, Yee DA. Lower socioeconomic status neighborhoods in Puerto Rico have more diverse mosquito communities and higher *Aedes aegypti* abundance. *J Urban Ecol.* 2021;7(1):juab009. doi:10.1093/jue/juab009
35. Barrera R. Spatial stability of adult *Aedes aegypti* populations. *Am J Trop Med Hyg.* 2011;85(6):1087-1092. doi:10.4269/ajtmh.2011.11-0381
36. Focks DA, Chadee DD. Pupal survey: an epidemiologically significant surveillance method for *Aedes aegypti*: an example using data from Trinidad. *Am J Trop Med Hyg.* 1997;56(2):159-167. doi:10.4269/ajtmh.1997.56.159
37. Reiter P. Surveillance and control of urban dengue vectors. In: Gubler DJ, Ooi EE, Vasudevan S, Farrar J, eds. *Dengue and dengue hemorrhagic fever.* CABI; 2014:481-518.
38. Barrera R. Recomendaciones para la vigilancia de *Aedes aegypti*. *Biomédica.* 2016;36(3):454-462. doi:10.7705/biomedica.v36i3.2892
39. Focks DA. A review of entomological sampling methods and indicators for dengue vectors. World Health Organization, Special Programme for Research and Training in Tropical Diseases (TDR); 2004. <https://iris.who.int/bitstream/handle/10665/68575/?sequence=1>
40. Barrera R, Mackay AJ, Amador M. A novel autocidal ovitrap for the surveillance and control of *Aedes aegypti*. *J Am Mosq Control Assoc.* 2013;29(3):293-296. doi:10.2987/13-6345R.1
41. Scott TW, Morrison AC, Lorenz LH, et al. Longitudinal studies of *Aedes aegypti* (Diptera: Culicidae) in Thailand and Puerto Rico: population dynamics. *J Med Entomol.* 2000;37(1):77-88. doi:10.1603/0022-2585-37.1.77
42. Harrington LC, Buonaccorsi JP, Edman JD, et al. Analysis of survival of young and old *Aedes aegypti* (Diptera: Culicidae) from Puerto Rico and Thailand. *J Med Entomol.* 2001;38(4):537-547. doi:10.1603/0022-2585-38.4.537
43. Krockel U, Rose A, Eiras AE, Geier M. New tools for surveillance of adult yellow fever mosquitoes: comparison of trap catches with human landing rates in an urban environment. *J Am Mosq Control Assoc.* 2006;22(2):229-238. doi:10.2987/8756-971X(2006)22[229:NTFSOA]2.0.CO;2
44. Barrera R, Mackay AJ, Amador M. An improved trap to capture adult container-inhabiting mosquitoes. *J Am Mosq Control Assoc.* 2013;29(4):358-368. doi:10.2987/13-6343.1
45. Barrera R, Bingham AM, Hassan HK, Amador M, Mackay AJ, Unnasch TR. Vertebrate hosts of *Aedes aegypti* and *Aedes mediiovittatus* (Diptera: Culicidae) in rural Puerto Rico. *J Med Entomol.* 2012;49(4):917-921. doi:10.1603/me12046
46. Mackay AJ, Amador M, Barrera R. An improved autocidal gravid ovitrap for the control and surveillance of *Aedes aegypti*. *Parasit Vectors.* 2013;6(1):225. Published 2013 Aug 6. doi:10.1186/1756-3305-6-225
47. Acevedo V, Amador M, Félix G, Barrera R. Operational Aspects of the Centers for Disease Control and Prevention Autocidal Gravid Ovitrap. *J Am Mosq Control Assoc.* 2016;32(3):254-257. doi:10.2987/15-6525.1
48. Acevedo V, Amador M, Barrera R. Improving the Safety and Acceptability of Autocidal Gravid Ovitrap (AGO Traps). *J Am Mosq Control Assoc.* 2021;37(2):61-67. doi:10.2987/21-6996.1
49. Barrera R, Amador M, Munoz J, Acevedo V. Integrated vector control of *Aedes aegypti* mosquitoes around target houses. *Parasit Vectors.* 2018;11(1):88. Published 2018 Feb 8. doi:10.1186/s13071-017-2596-4
50. Barrera R, Harris A, Hemme RR, et al. Citywide Control of *Aedes aegypti* (Diptera: Culicidae) during the 2016 Zika Epidemic by Integrating Community Awareness, Education, Source Reduction, Larvicides, and Mass Mosquito Trapping. *J Med Entomol.* 2019;56(4):1033-1046. doi:10.1093/jme/tjz009
51. Sharp TM, Lorenzi O, Torres-Velásquez B, et al. Autocidal gravid ovitraps protect humans from chikungunya virus infection by reducing *Aedes aegypti* mosquito populations. *PLoS Negl Trop Dis.* 2019;13(7):e0007538. Published 2019 Jul 25. doi:10.1371/journal.pntd.0007538
52. Barrera R, Amador M, Ruiz-Valcárcel J, Acevedo V. Factors Modulating Captures of Gravid *Aedes aegypti* Females. *J Am Mosq Control Assoc.* 2020;36(2):66-73. doi:10.2987/20-6931.1