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A SURVEY OF THE MOSQUITOES OF KOSRAE STATE, FEDERATED STATES OF MICRONESIA, 2016

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Abstract

In response to an outbreak of Zika virus that started in February 2016 on Kosrae Island, Kosrae State, Federated States of Micronesia, we conducted entomological investigations, including a survey to characterize the mosquito fauna on Kosrae, from November 29 to December 8, 2016. Mosquitoes were collected using several surveillance methods in order to sample all stages of the mosquito life cycle. Eggs were collected using ovicups, larvae and pupae were sampled using standard dippers, and adults were collected using aspirators and Biogents-2 Sentinel traps. All species previously recorded from Kosrae State were found in the current survey, confirming their continued presence on the island. *Aedes aegypti* was detected on Lelu Island, representing a new municipal record. The collection of *Ae. vexans nocturnus* represents a new species record for Kosrae, increasing the number of known taxa on this island from 6 to 7. The report herein provides updated knowledge of the mosquitoes that occur on Kosrae State, Federated States of Micronesia.

Keywords

Aedes; arbovirus; Culicidae; *Stegomyia*; surveillance

Humans in tropical and subtropical climates are exposed to arbovirus threats from mosquitoes that vector causative agents of diseases such as the dengue viruses (DENV), chikungunya virus (CHIKV), and Zika virus (ZIKV) (WHO 2017). The phenomenon of globalization since the late 1970s has resulted in a significant increase in movement of people and goods into isolated countries (Lounibos 2002, Marano et al. 2007, Paupy et al. 2009). Therefore, the potential for introducing invasive mosquitoes such as *Aedes aegypti* (L.) and pathogens into new geographic regions is greater (Kilpatrick 2011), increasing the overall risk of outbreaks of emerging and reemerging arboviruses to humans (Lounibos 2002, Marano et al. 2007, Paupy et al. 2009, Gubler 2011). Health professionals from the USA have previously deployed to the Federated States of Micronesia to investigate arboviral outbreaks—DENV on Yap Island (Savage et al. 1998), the 1st known introduction of the emerging ZIKV in 2007 (Lanciotti et al. 2008, Duffy et al. 2009), and CHIKV in 2013 (Savage et al. 2015, Pastula et al. 2017). Due to the remote location of Kosrae State and lack of mosquito control and surveillance experts on the island, knowledge of potential vector mosquitoes that inhabit Kosrae has been insufficient. Updated knowledge of the mosquito fauna that inhabit Kosrae will allow public health/veterinary personnel to design effective prevention and control programs against potential mosquito-borne disease-causing threats.

The 1st comprehensive survey of the mosquitoes of Micronesia listed a single species from Kosrae, *Ae. aegypti* (Bohart and Ingram 1946), a competent vector of several pathogens. Bohart (1956) combined surveys of 61 different investigators who had completed expeditions to the islands of Micronesia from 1911 to 1953. Three species of mosquitoes were present on Kosrae: *Ae. aegypti*, *Ae. marshallensis* Stone and Bohart, and *Culex kusaiensis* Bohart (Bohart 1956). From 1956 through 2012, surveys pertaining to mosquito fauna were not conducted. Noda et al. (2013) investigated mosquito larval distribution on Kosrae, listing 6 species including 3 new records: *Ae. aegypti, Ae. albopictus* (Skuse), *Ae. marshallensis, Cx. quinquefasciatus* Say, *Cx. annulirostris annulirostris* (Skuse), and *Cx. kusaiensis*.

In response to a ZIKV outbreak that was identified in February 2016, entomologists from Centers for Disease Control and Prevention (CDC) traveled to Kosrae to train local personnel in vector surveillance and control techniques, and to conduct a survey to update the mosquito fauna that inhabit the island. Kosrae State is a small mountainous island located 600 km north of the equator (5°19′N, 162°59′E), and has a land area that covers 110 km^2. Kosrae is located in the Intertropical Convergence Zone (ICZ). Islands in the ICZ experience periods of heavy rainfall, and because of its geographic location the climate on Kosrae is tropical oceanic (Pacific RISA 2017). The average annual temperature is 30°C, and average annual precipitation is approximately 5,500 mm; the temperature and precipitation do not vary much throughout the year (Pacific RISA 2017). The highest elevation on Kosrae is Mt. Finkol, which at the summit reaches 634 m. Due to the unique mountainous-island features of Kosrae, the island has several freshwater systems including rivers and waterfalls, and a diverse flora. Several major vegetation types dominate the island, providing diverse mosquito habitats which include cloud forests, upland forests, palm forests, areas of disturbed land composed of tall grasses and weedy species, marshes and riverine systems, swamp forests, mangrove forests, and beach strands (Falanruw 2002). Many of the plant species are native to Kosrae (Falanruw 2002). Most residents reside near the coast due to the dense jungle vegetation and steep topography, which deters development deeper into the island interior. Many of the residential homes and structures have openings in the eaves between the outer walls and roofing material (usually a thatch or corrugated steel roof), and lack adequate mosquito protection such as air conditioning, screens, solid doors or windows, which inevitably allow mosquitoes access.

Mosquitoes were collected using traps, handheld mechanical aspirators, ovicups, and larval dippers from November 29 through December 8, 2016. The municipalities of Tafunsak, Lelu, Malem, and Utwe were surveyed (Fig. 1). Specifically, 6 Biogents-2 Sentinel traps (Biogents, Regensburg, Germany) were deployed in the major villages of each municipality, except Walung, which was not sampled due to logistic challenges. Traps were set near residences with a history of ZIKV positivity when possible. In addition, traps were set near residential houses that had numerous container-type larval habitats, typically near cookhouses. Traps were set out for at least 24 h, run off of electric power at the site, and the nets were changed daily. Handheld mechanical aspirators (Clarke Mosquito Control, St. Charles, IL) were used to collect adult mosquitoes attempting to feed on field crews, and adult mosquitoes resting inside open cookhouses, outhouses, and on the vegetation around the site. Larvae were collected from artificial and natural containers, and other pools of freshwater using standard larval dippers (BioQuip Products Inc., Rancho Dominguez, CA). In the field, larvae were reared to the adult stage in 500-ml plastic cups. Eggs of container-inhabiting species were collected using 650-ml black plastic souvenir cups (Giacona Container Co., New Orleans, LA) lined with strips of seed germination paper (Anchor Paper Company, St. Paul, MN). Egg papers were shipped to CDC, Fort Collins, CO, for hatching and rearing to the adult stage. All adult mosquitoes, collected or reared from larvae or egg papers, were identified using Bohart (1956) and Rueda (2004). Male genitalia were mounted following Pecor and Gaffigan (1997) and identified using Bohart (1956) supplemented by species descriptions to confirm identification.

We collected all 6 of the previously reported mosquito species, confirming their widespread occurrence on the island (Table 1). Additionally, one mosquito species not previously recognized on Kosrae, *Ae. vexans nocturnus* (Theobald), was collected. *Aedes vexans nocturnus* larvae were collected mainly from flooded sandpits and ground pools. We collected 726 specimens and identified them to species and sex: *Ae. albopictus* (93 males, 74 females), *Ae. aegypti* (11 males, 1 female), *Ae. marshallensis* (16 males, 34 females), *Aedes* (*Stegomyia*) sp. 1 (2 females), *Ae. vexans nocturnus* (46 males, 20 females), *Cx. quinquefasciatus* (220 males, 139 females), *Cx. annulirostris annulirostris* (9 males, 53 females), and *Cx. kusaiensis* (8 females). *Aedes aegypti* was collected on Lelu Island, representing a new municipal record (Table 1). *Culex quinquefasciatus* was the most common species recorded in the survey. The greater number of *Cx. quinquefasciatus* collected is not surprising, in that *Cx. quinquefasciatus* will oviposit in a broad range of habitats, including sandpits, ground pools, natural and artificial containers such as coconut shells, tree stumps, cans, tires, flowerpots, and the inundated hulls of fishing boats and canoes. *Aedes albopictus* and *Ae. marshallensis* were also common, and collected from a wide range of container habitats including coconuts, tires, cans, rain buckets, abandoned cars, hulls of boats, etc.

There are several possible reasons why mosquitoes thrive on Kosrae. There is a lack of mosquito control, which enables the mosquitoes to complete their life cycle relatively unchecked. Additionally, modification of the natural habitat such as building new structures and human movement of artificial containers to recently disturbed habitats, and lack of sanitation, also plays a role in the production of container-exploiting species. Many of the homes on Kosrae have water-filled sandpits containing refuse such as old bowls, pots, cans, plastic cups, tires, flowerpots, etc., which provide habitats for container-exploiting mosquitoes to oviposit and develop. Aside from the artificial containers, a major fuel source for cooking is dried coconut shells, which become filled with freshwater from rain storms. The coconut shells are usually located near the cookhouse or piled up near the homes and provide additional sites for container-exploiting species to oviposit.

Our detection of *Ae. vexans nocturnus* is a new record for Kosrae; however, the species is common and has established itself throughout the island. This new record increases the total number of species known to occur on Kosrae from 6 to 7. We also report an additional mosquito taxon, represented by 2 unique females. The combination of characters described by Harbach (2015) definitively places this species in the subgenus of *Aedes* (*Stegomyia*). The 2 female specimens, reported as *Aedes* (*Stg.*) sp. 1, appear to represent an additional species, but we were unable to confirm this as adult males and larvae were not collected. Whether the detection of *Ae. vexans nocturnus* and *Aedes* (*Stg.*) sp. 1 represents recent introductions, or if these species went undetected due to a lack of surveying in recent history remains unknown.

In summary, 6 mosquito species previously known from Kosrae still occur on the island and their presence is widespread. *Aedes aegypti* was detected on Lelu Island, representing a new municipal record. One additional species not previously found, *Ae. vexans nocturnus,* was also detected. The current report provides an updated list of the mosquitoes of Kosrae, including medically important species and their known distribution on Kosrae. Implementing a mosquito surveillance program is recommended in order to make sound mosquito control decisions. In the absence of a true surveillance program, routine mosquito surveys should be conducted.

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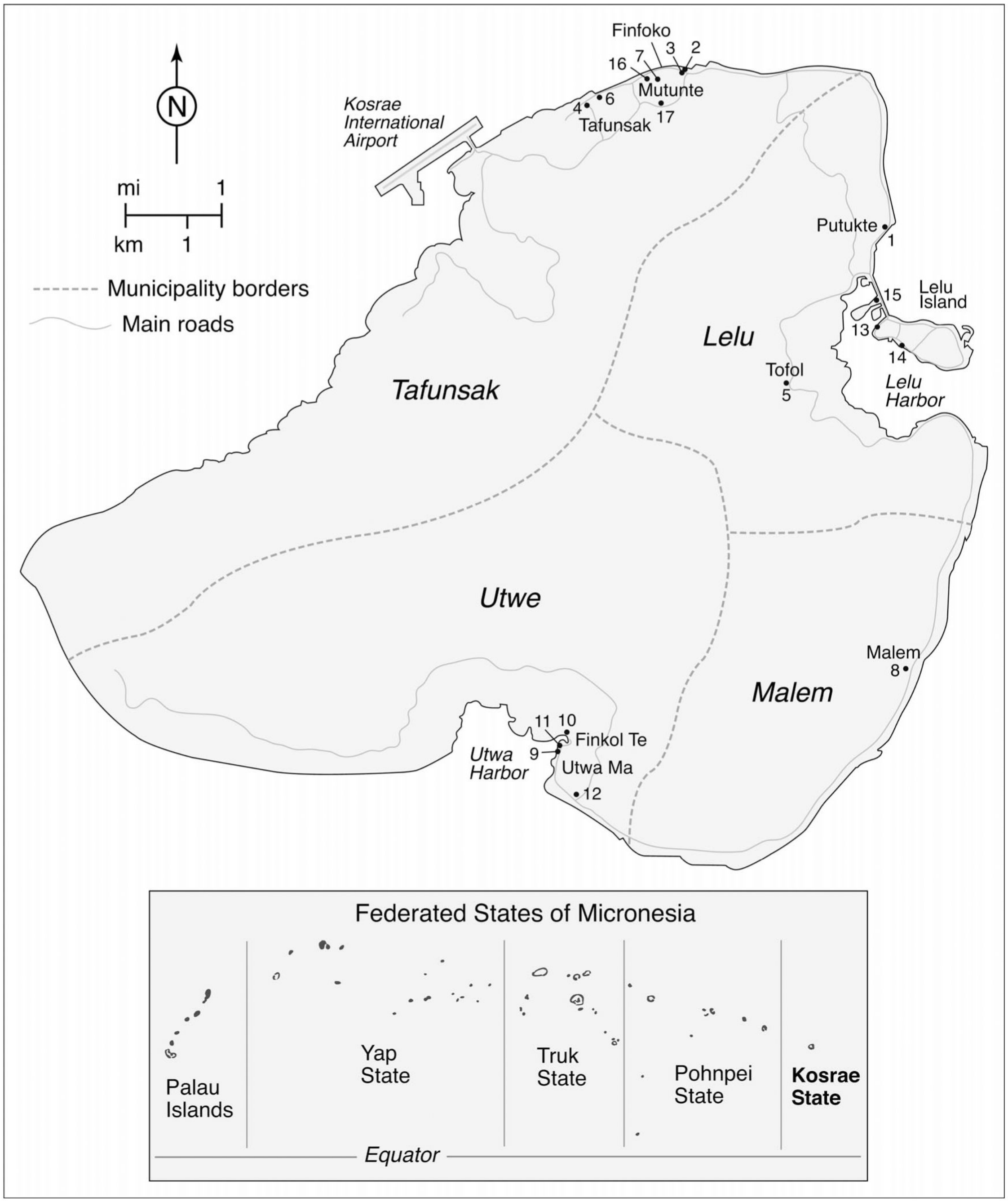

Fig. 1.

Map of Kosrae Island, Kosrae State, Federated States of Micronesia, showing the municipalities and collection sites.

Table 1.

Municipalities where a species occurs on Kosrae Island, Federated States of Micronesia, 2016.

Species	Tafunsak	Malem	Utwe	Lelu	Walung[1]
Aedes (*Stegomyia*) *aegypti*	●	–[2]	–	●	–
Ae. (*Stg.*) *albopictus*	●	●	●	●	●
Ae. (*Stg.*) *marshallensis*	●	●	●	●	●
Aedes (*Stg.*) sp. 1	●	–	●	–	–
Ae. (*Aedimorphus*) *vexans nocturnus*	●	●	●	●	–
Culex (*Culex*) *quinquefasciatus*	●	●	●	●	●
Cx. (*Cux.*) *annulirostris annulirostris*	●	●	●	●	–
Cx. (*Lophoceraomyia*) *kusaiensis*	●	●	●	●	●

[1] Data representing Walung records (Noda et al. 2013).

[2] Species not detected in municipality.