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Original article

Distribution of Mosquito Larvae on Kosrae Island, Kosrae State, the Federated States of Micronesia

Shinichi Noda[1]*, Sota Yamamoto[1], Takako Toma[2] and Livinson Taulung[3]
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Abstract: Surveys of mosquito larvae were carried out in six areas of Kosrae Island, Kosrae State, the Federated States of Micronesia in December 2009 and June 2012. A total of 962 larvae of six species were collected from 106 natural and artificial habitats. They were identified as *Aedes aegypti*, *Ae. albopictus*, *Ae. marshallensis*, *Culex quinquefasciatus*, *Cx. annulirostris*, and *Cx. kusaiensis*. This is the first report from Kosrae Island for three of these species—*Ae. marshallensis*, *Cx. quinquefasciatus*, and *Cx. annulirostris*. The most abundant species was *Ae. albopictus*, followed by *Ae. marshallensis*, and these two species were found in all areas. Relatively large numbers of *Cx. quinquefasciatus* and *Cx. kusaiensis* were found in five areas. Fewer *Cx. annulirostris* were found, and only in three areas. *Aedes aegypti* larvae were collected from a single habitat at Tafunsak in 2009. To prevent the outbreak of dengue fever, environmental management should focus on the destruction, alteration, disposal and recycling of containers that produce larger numbers of adult *Aedes* mosquitoes.
Key words: *Aedes albopictus*, *Aedes marshallensis*, *Aedes aegypti*, mosquito fauna, Kosrae State, Federated States of Micronesia

INTRODUCTION

Aedes aegypti and *Ae. albopictus* are major vectors of dengue fever and dengue hemorrhagic fever in urban areas of Southeast Asia and in the Western Pacific Region [1]. A dengue fever outbreak in Yap State of the Federated States of Micronesia (FSM) was reported in June and July 1995 [2]. Entomological investigations implicated a native mosquito species, *Ae. hensilli*, as the vector of the dengue virus [2, 3]. Another dengue fever outbreak occurred in Yap from May 2004 to January 2005 after Typhoon Sudal [4]. Six cases were exported to Japan via a group of visiting schoolchildren, without any known secondary spread [4, 5]. Dengue cases have occurred in Yap every year since 2007 [6], with a total of 1,108 confirmed cases between September 2011 and January 2012 [7]. A strong possibility exists that an outbreak of dengue fever will occur in the other three states of the FSM. However, little information is available on vector mosquito species. This report describes a survey regarding the geographical distribution of mosquito fauna and breeding sites of mosquitoes on Kosrae Island, Kosrae State, the FMS.

MATERIALS AND METHODS

The FSM include four states: Kosrae, Pohnpei, Chuuk, and Yap. Kosrae State is the only state in the FSM with no outer islands (Fig. 1). Kosrae Island, the easternmost island of both the FMS and the Caroline Island chain, is roughly triangular, covering an area of 109 km^2. The island interior is composed of rugged mountains and river valleys. A full 70% of the island is mountainous and another 15% is mangrove swamp. Mt. Finkol, the highest peak, rises to a height of 629 m. The average annual temperature on Kosrae is 27°C, the average annual rainfall is 5,500 mm, and rainfall is heaviest in summer (June–August) and along the west coast [8].

Surveys regarding larval mosquitos on Kosrae Island were carried out in three areas, Tafunsak, Tofol, and Utwe, in December 2009, and six areas, Tafunsak, Lelu, Tofol,

[1] Kagoshima University Research Center for the Pacific Islands, Kagoshima, Japan
[2] School of Health, Faculty of Medicine, University of the Ryukyus, Okinawa, Japan
[3] Department of Health Services, Kosrae State Government, Kosrae, Federated States of Micronesia
*Corresponding author:
Kagoshima University Research Center for the Pacific Islands, 1-21-24 Korimoto, Kagoshima 890-8580, Japan
Tel: 099-285-7390
Fax: 099-285-6197
E-mail: snoda@cpi.kagoshima-u.ac.jp

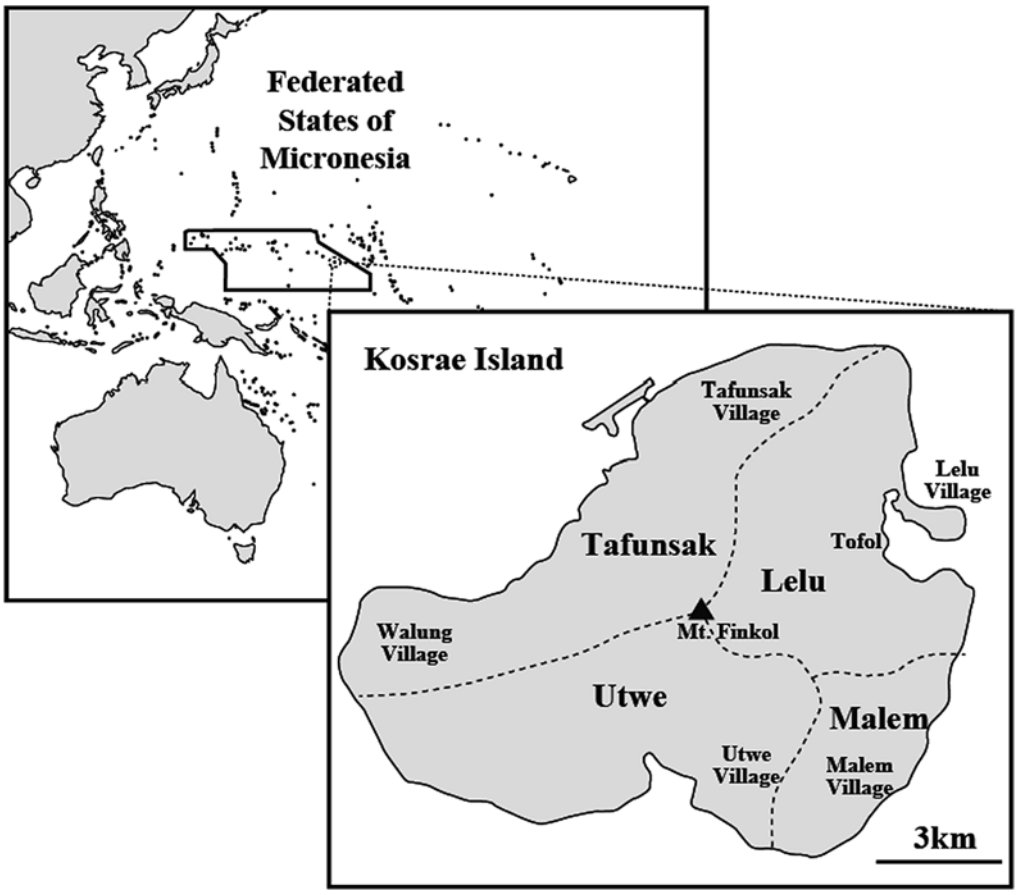

Fig. 1. Map of Kosrae Island, the Federated States of Micronesia.

Malem, Utwe, and Walung, in June 2012. Larval collections were primarily carried out at sites near residences, and also on roadsides and in fields. When a habitat was small, all of the larvae were collected. When a habitat was large, fewer than 30 larvae were collected. When larvae were young and could not be identified to species, they were excluded from the number of individuals reported in the results. Larval collections were made in 106 habitats: Tafunsak (30 habitats), Lelu (19 habitats), Tofol (9 habitats), Malem (14 habitats), Utwe (25 habitats), and Walung (9 habitats). The sampled included coconut shells, banana stumps, tins, plastic bottles, noodle containers, ceramic cups, metal containers, plastic containers, paper containers, pots, plastic bags, tree holes, tires, car parts, puddles, fountain puddlse, concrete tanks and boats. Larvae were collected using a pipette and dipper. All of the larvae collected in 2009 were preserved in 70% ethanol, but some of the larvae collected in 2012 were reared to the adult stage. Larvae and adults were identified to species using the keys and descriptions of Bohart [9] and Bohart and Ingram [10].

RESULTS

In total, 962 larvae belonging to six species were collected at 106 natural and artificial habitats. They were identified as *Aedes aegypti*, *Ae. albopictus*, *Ae. marshallensis*, *Culex quinquefasciatus*, *Cx. annulirostris*, and *Cx. kusaiensis* (Table 1). *Aedes albopictus* was the predominant species (412 larvae, 59 habitats) followed by *Ae. marshallensis* (182 larvae, 35 habitats), and these species were distributed in all areas (Table 2). The number of *Cx. quinquefasciatus* and *Cx. kusaiensis* was relatively large, and they were collected at 15 and 19 habitats in five areas, respectively. The number of *Cx. annulirostris* was relatively small, and it was collected at four habitats in three areas. *Aedes aegypti* larvae were collected in only one habitat (a tire) in Tafunsak in 2009, and it was not collected in 2012.

DISCUSSION

Six species of mosquito larvae were collected in this survey: *Ae. aegypti*, *Ae. albopictus*, *Ae. marshallensis*, *Cx.*

Table 1. Number of mosquitoes and the habitat types from which they were collected on Kosrae Island, Kosrae State, the Federated States of Micronesia.

Date	Area	Species	Number of individuals	Number of habitats	Habitat types (number of habitat)
December 2009*	Tafunsak	*Aedes aegypti*	2	1	Tire (1)
		Aedes albopictus	76	10	Coconut shell (1), Tins (3), Noodle containers (2), Ceramic cups (2), Car parts (1), Tire (1)
		Aedes marshallensis	27	1	Coconut shell (1)
		Culex quinquefasciatus	15	1	Metal container (1)
		Culex kusaiensis	31	3	Coconut shell (1), Tin (1), Ceramic cup (1)
	Tofol	*Aedes albopictus*	19	2	Banana stumps (2)
		Aedes marshallensis	40	5	Coconut shells (2), Banana stump (1), Tree holes (2)
	Utwe	*Aedes albopictus*	29	4	Tin (1), Plastic bag (1), Plastic container (1), Tire (1)
		Aedes marshallensis	46	5	Tins (2), Banana stump (1), Plastic container (1), Tire (1)
		Culex quinquefasciatus	2	1	Tin (1)
		Culex annulirostris	30	1	Puddle of fountain (1)
		Culex kusaiensis	2	1	Tire (1)
June 2012	Tafunsak	*Aedes albopictus*	70	11	Tins (2), Noodle containers (3), Plastic containers (5), Pot (1)
		Aedes marshallensis	16	4	Coconut shell (1), Tin (1), Paper container (1), Plastic container (1)
		Culex quinquefasciatus	42	4	Tin (1), Noodle container (1), Plastic containers (2)
		Culex annulirostris	5	1	Puddle (1)
	Lelu	*Aedes albopictus*	115	15	Coconut shells (2), Tins (4), Noodle container (1), Plastic containers (6), Plastic bottles (2)
		Aedes marshallensis	28	8	Coconut shells (2), Tins (2), Noodle container (1), Plastic containers (2), Plastic bottle (1)
		Culex quinquefasciatus	22	3	Coconut shell (1), Tin (1), Plastic bottle (1)
	Tofol	*Aedes marshallensis*	2	1	Tin (1)
		Culex kusaiensis	15	1	Noodle container (1)
	Malem	*Aedes albopictus*	33	6	Tins (3), Plastic bottle (1), Pot (1), Tire (1)
		Aedes marshallensis	9	3	Coconut shell (1), Pot (1), Tire (1)
		Culex quinquefasciatus	1	1	Pot (1)
		Culex annulirostris	49	2	Metal container (1), Concrete tank (1)
		Culex kusaiensis	34	6	Tin (1), Plastic containers (2), Tires (3)
	Utwe	*Aedes albopictus*	64	9	Plastic containers (2), Bamboo stumps (3), Tires (3), Boat (1)
		Aedes marshallensis	6	4	Tins (2), Tires (2)
		Culex quinquefasciatus	50	3	Tin (1), Plastic container (1), Boat (1)
		Culex kusaiensis	14	4	Tin (1), Bamboo stumps (2), Tire (1)
	Walung	*Aedes albopictus*	6	2	Noodle container (1), Plastic container (1)
		Aedes marshallensis	8	4	Coconut shells (2), Plastic container (1), Plastic bottle (1)
		Culex quinquefasciatus	22	2	Coconut shells (2)
		Culex kusaiensis	32	4	Coconut shell (1), Noodle container (1), Plastic container (1), Plastic bottle (1)

* Larval collections were not carried out on three areas, Lelu, Malem and Walung, in 2009.

Table 2. Distribution of mosquitoes on Kosrae Island, Kosrae State, the Federated States of Micronesia.

Species	Number of individuals	Number of habitats	Collected area					
			Tafunsak	Lelu	Tofol	Malem	Utwe	Walung
Aedes aegypti	2	1	○					
Aedes albopictus	412	59	○	○	○	○	○	○
Aedes marshallensis	182	35	○	○	○	○	○	○
Culex quinquefasciatus	154	15	○	○		○	○	○
Culex annulirostris	84	4	○			○	○	
Culex kusaiensis	128	19	○		○	○	○	○

quinquefasciatus, *Cx. annulirostris*, and *Cx. kusaiensis*. The distribution of *Ae. aegypti*, *Ae. marshallensis* and *Cx. kusaiensis* were previously reported for Kosrae Island [9]. We present here the first report of *Ae. marshallensis*, *Cx. quinquefasciatus*, and *Cx. annulirostris* on Kosrae Island. The first survey period in December 2009 was very short and the larvae were not reared to adults, making specific identification of *Aedes* larvae difficult. Therefore, we carried out subsequent larvae surveys on Kosrae Island in June 2012. Some of the larvae collected in 2012 were reared to the adult stage, which permitted identification of the larvae collected in 2009 by comparison with individuals reared in 2012.

Kosrae Island is the easternmost island of the FMS and adjoins the Marshall Islands. An outbreak of dengue fever on the Marshall Islands was confirmed in October 2011, and the government issued an emergency warning to prevent the spread of dengue fever the same month [11]. It was feared that dengue virus might be carried into Kosrae State. We conducted the mosquito larval surveys again across the whole area of Kosrae State in June 2012. This revealed that three *Aedes* mosquitoes and potential vectors of dengue fever, *Ae. aegypti*, *Ae. albopictus*, and *Ae. marshallensis*, were distributed on Kosrae Island. *Aedes aegypti* larvae were collected in only a single habitat (a tire) at Tafunsak in 2009, and were not collected in 2012. The other two species, *Ae. albopictus* and *Ae. marshallensis*, were distributed throughout Kosrae State. Unfortunately, the dengue virus was transmitted to Kosrae State in September 2012 after our entomological survey, and among 230 patients with suspected dengue infections, 85 were confirmed positive between 26 September and 11 November. The infection rate was extremely high within the total population of Kosrae [12].

Dengue virus is mainly transmitted in the Pacific region by *Ae. aegypti* but also other mosquitoes of this genus with varying ranges [13]. *Aedes hesilli*, which transmits dengue virus in Yap State, was not collected in our survey. *Aedes aegypti* larvae were collected only in one habitat at Tafunsak in 2009, and it was not collected in 2012. A dengue fever outbreak occurred in Hawaii in September 2001, and *Ae. albopictus* was implicated in this outbreak due to its occurrence on Oahu, Maui, Molokai, and Kauai, as well as the absence of *Ae. aegypti* [14]. *Aedes marshallensis* has been determined to be a dengue vector on a biological basis [13]. Our entomological survey suggests that *Ae. albopictus* and/or *Ae. marshallensis* transmitted the dengue virus in Kosrae State.

Aedes species lay eggs in practically all types of artificial containers, and also in some natural containers. In this survey, artificial habitats (e.g., tins, plastic containers, plastic bottles, noodle containers, tires) were seen more frequently than natural habitats (e.g., tree holes, coconut shells, banana stumps, bamboo stumps). In 2007, Zika virus, a relatively mild disease similar to dengue fever and characterized by rash, joint pain, and conjunctives, was reported on Yap Island. This was the first report of Zika virus outside of Africa and Asia [15, 16]. *Aedes hensilli* was the predominant mosquito species identified. Chikungunya virus is also transmitted to humans by virus-carrying *Aedes* mosquitoes. Chikungunya has been identified in nearly 40 countries of Africa and Asia. Therefore, environmental management programs are necessary to prevent or minimize vector propagation and human contact with the vector-pathogen by destroying, altering, removing or recycling nonessential containers that provide larval habitats [17].

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