First Record of *Wyeomyia* (*Wyeomyia*) *mitchellii* (Diptera: Culicidae) in French Polynesia

J. MARIE AND H. C. BOSSIN[1]

Institut Louis Malardé, Unit of Emerging Infectious Diseases, B.P. 30, 98713, Papeete Tahiti, Polynésie Française

J. Med. Entomol. 50(1): 37–42 (2013); DOI: http://dx.doi.org/10.1603/ME12170

ABSTRACT *Wyeomyia* (*Wyeomyia*) *mitchellii* (Theobald) was discovered in 2007 and 2008, respectively, in Moorea and Tahiti, two islands of the Society Islands (archipel de la Société) in French Polynesia. A few adult specimens were captured using a CDC backpack aspirator and BG-Sentinel mosquito traps. *Wy. mitchellii* larvae were found in water-impounding bromeliads and aroids at various survey sites around Tahiti. Imported bromeliads likely played a critical role in the introduction, establishment, and maintenance of *Wy. mitchellii* in Tahiti and Moorea. Bromeliads and aroids are common in residential areas, thereby increasing the exposure of human and domestic animals to *Wy. mitchellii*, which is of public health and veterinary concern. The establishment of *Wy. mitchellii* in French Polynesia requires further study.

KEY WORDS *Wyeomyia mitchellii*, first record, bromeliad, Society Islands, French Polynesia

Wyeomyia mitchellii was first described in Jamaica, but it also is considered native to South Florida (Frank and Fish 2008). Present mostly in the tropical and subtropical regions of the New World, it is found in islands of the Greater Antilles (Cuba, Hispaniola), and in eastern Mexico (Knight and Stone 1977). It was detected outside its native range only once to this date on the Hawaiian Islands of O'ahu, Kaua'i, and Hawai'i (Shroyer 1981, Nishida 2002, Yang et al. 2003) in the Central Pacific Ocean. Here, we report its establishment in Tahiti and Moorea, two islands of the Society Islands, French Polynesia, in the South Pacific.

In its native range, *Wy. mitchellii* displays a restrictive larval habitat in the leaf axils of the water-impounding bromeliads and aroids (Belkin et al. 1970). It has been reported in numerous imported, ornamental bromeliads, including *Catopsis berteroniana* ((Schultes f.) Mez) and *Tillandsia utriculata* (L.) (Frank and O'Meara 1984), *Billbergia pyramidalis* ((Sims) Lindley) (Frank et al. 1988), and *Aechmea* spp. and *Neoregelia* spp. (Frank et al. 1988, Yang et al. 2003).

Larvae are filter feeders that develop in a nutrient-poor environment enriched by falling leaves and twigs from the tree canopy above. They compete intra- and interspecifically for food, and they have developed a remarkable ability to survive during long periods of starvation (Frank 1983). The minimum period for immature development is 2 wk (Frank and Fish 2008).

Wy. mitchellii females are active during daylight in shaded habitats (Frank and O'Meara 1985). They feed particularly at dusk on warm-blooded animals, including humans, and they typically hover over leaf axils while ovipositing (Belkin et al. 1970). Insemination seems a prerequisite for host-seeking and blood-feeding behavior and the flight range is restricted to 100 m (Nayar 1992).

Although *Wyeomyia* spp. have not been found to vector arboviruses in Florida, Venezuelan equine encephalitis virus (family *Togaviridae*, genus *Alphavirus*, VEE) has been found in *Wy. mitchellii* (Scherer et al. 1971) and Ilheus and Wyeomyia viruses have been found in *Wy. vanduzeei* (Srihongse and Johnson 1965, Srihongse and Johnson 1967). Little is known about the medical and veterinary importance of *Wy. mitchellii*. The VEE virus was shown to infect *Wy. mitchellii* (Scherer et al. 1971), but its role as a vector remains to be demonstrated. In Hawai'i, *Wy. mitchellii* is considered the least likely vector of avian malaria due to biological and ecological considerations (LaPointe et al. 2005).

A single specimen of this species was first discovered in November 2007 while collecting *Aedes* mosquitoes on Moorea in French Polynesia. Additional sabethine specimens were collected nearly a year later on the island of Tahiti in sufficient numbers to allow identification as *Wyeomyia* (*Wyeomyia*) *mitchellii* (Theobald 1905). These findings provide new records for a genus, species and tribe (Sabethini) for French Polynesia.

Although the route of introduction is not known, illegal import of bromeliads from Hawai'i seems to be the most probable source. The time of introduction is also uncertain, but the occurrence of *Wy. mitchellii* in multiple valleys of two separate islands suggests that the introduction was not recent.

[1] Corresponding author, e-mail: hbossin@ilm.pf.

Table 1. *Wy. mitchellii* specimens collected during adult and larval mosquito surveys, between 2007 and 2008

Island	Locality	Date	GPS	Plant species	Adults	Immature	Collection method
Moorea	Afareaitu	14 Nov. 2007	17° 33′14.41″ S 149° 47′34.83″ W	Not recorded	1 ♀	NR[a]	Backpack aspirator
Tahiti	Paea 1	6–22 Aug. 2008	17° 43′56.93″ S 149° 34′39.68″ W	*Alocasia* spp.	8 ♂/8 ♀	17	BG-Sentinel traps and larval sampling
Tahiti	Paea 2	24 Aug. 2008	17° 40′28.39″ S 149° 35′16.39″ W	Bromeliads	2 ♀	10	Human baited catch and larval sampling
Tahiti	Arue	4 Sept. 2008	17° 31′39.72″ S 149° 30′31.51″ W	Bromeliads	NR	70	Larval sampling
Tahiti	Papenoo	4 Sept. 2008	17° 30′38.08″ S 149° 25′38.37″ W	Bromeliads	NR	20	Larval sampling
Tahiti	Faaone	4 Sept. 2008	17° 40′33.26″ S 149° 18′54.25″ W	Bromeliads	NR	10	Larval sampling
Tahiti	Tautira	4 Sept. 2008	17° 44′52.46″ S 149° 9′45.23″ W	Bromeliads	NR	4	Larval sampling
Tahiti	Teahupoo	9 Sept. 2008	17° 51′5.18″ S 149° 15′27.33″ W	Bromeliads	NR	3	Larval sampling

[a] Not relevant.

Materials and Methods

Adult Collections. The initial specimen collected in Moorea was captured using a CDC backpack aspirator (JW Hock, Gainesville, FL), a tool convenient for (*Aedes*) mosquito field collections (Williams et al. 2006). The attractiveness of BG-Sentinel mosquito traps (Biogents, GmbH, Regensburg, Germany) (Geier et al. 2004) was later tested in Tahiti on the grounds of the ILM Medical Entomology Research Laboratory (Paea 1), where the presence of *Wy. mitchellii* also had been detected (Table 1; Fig. 1). BG-Sentinel traps are known to efficiently capture a range of diurnal mosquito species particularly *Aedes aegypti* (L.) and *Aedes polynesiensis* (Marks) (Schmaedick et al. 2008). Traps were set up for 24-h collections behind the ILM Medical Entomology Research Laboratory in shaded areas at the edge of the forest. Trapping was conducted for 18 consecutive days in August 2008 (Austral winter). Monitoring of *Wy. mitchellii* also was included as part of a weekly mosquito surveillance activity conducted at the same location. Early morning collections (8:00–11:00 a.m.) were conducted once weekly by using six BG-Sentinel traps spread over a 245-m-long transect perpendicular to the shoreline. Field data were collected for 24 mo between March 2009 and March 2011, encompassing two complete Austral summers and winters. Collected mosquitoes were identified using appropriate keys and descriptions.

Larval Collections. Sampling for immature mosquitoes was conducted systematically in 20 water-impounding plants at seven separate locations around the island of Tahiti (Table 1; Fig. 1). Survey locations included residential, horticultural, or forested areas where likely *Wy. mitchellii* larval habitats, such as bromeliads or aroids, were seen. Sampling was conducted in August, September, and October 2008, 2009, and 2010. Plants held water due to rainfall and watering. Water impounded in the central and surrounding leaf axil of these plants was siphoned using a pipette and stored in plastic tubes labeled with the date, plant species, and location. In the laboratory, larvae were identified to species and recorded.

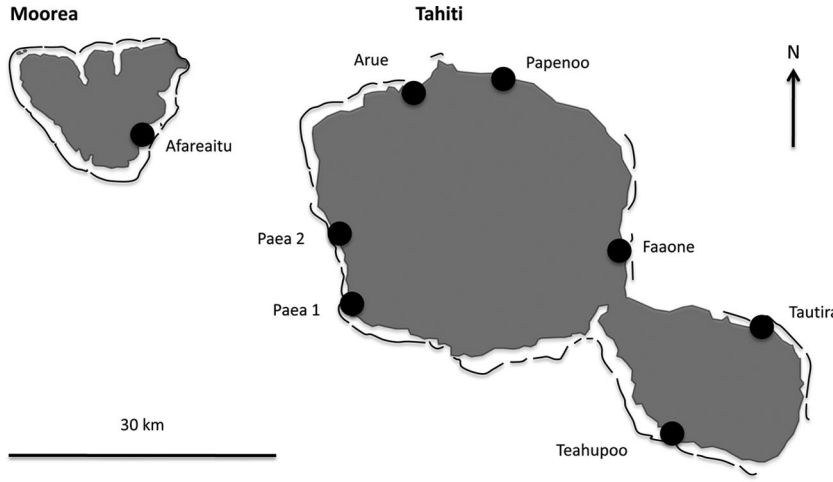

Fig. 1. Mapping of sites surveyed for *Wy. mitchellii* in Moorea and Tahiti.

Table 2. Occurrence of mosquito species in aroid and bromeliads habitats sampled in Tahiti in 2008 and 2009

Locality	Plant species		*Wv. mitchellii*	*Cx. quinquefasciatus*	*Ae. polynesiensis*
Paea 1	Aroids "Ape"	*Alocasia macrorrhizos* (L.) G. Don	+		+
Paea 1	Aroids "Ape"	*Alocasia plumbea* (K. Koch ex Van Houtte)	+		
Papenoo	Bromeliads:	*Al. fulgens* (Brongniart)	+		+
Arue	Bromeliads:	*B. pyramidalis* (Sims) Lindley	+		
Tautira	Bromeliads:	*N. spectabilis* (T. Moore) L.B. Smith	+		
Papenoo	Bromeliads:	*N. fireball* (cultivar)		+	+

Morphological Identification. Examination of the specimens caught in Moorea and Tahiti allowed identification to tribe Sabethini (Belkin 1962). Keys and descriptions in Theobald (1905), Belkin et al. (1970), and Darsie and Morris (2003) ultimately allowed identification of the immature and adult specimens as *Wy. mitchellii*. Field-collected larvae reared in the laboratory provided additional material for identification. Identification as *Wy. mitchellii* was formally confirmed by Dr. Neal L. Evenhuis of the Bernice P. Bishop Museum, Honolulu, Hawai'i, where voucher specimens are deposited.

Results and Discussion

Adults. Our first record of *Wy. mitchellii* in French Polynesia was an adult female captured late afternoon on 14 November 2007 while collecting *Aedes* mosquitoes with a CDC backpack aspirator (Table 1; Fig. 1). The specimen was captured at the edge of a forest close to a semi rural residential area in the Afareaitu valley on the island of Moorea. Additional specimens were captured nearly a year later on the island of Tahiti by using four BG-Sentinel traps deployed on the grounds of the ILM Medical Entomology Research Laboratory. Eight females and eight males were caught over 18 d in August 2008, increasing the number of collected specimens from 1 to 17 (Table 1; Fig. 1).

More *Wy. mitchellii* specimens were trapped at the ILM Research Laboratory in BG-Sentinel traps used as part of a weekly mosquito surveillance activity. Mosquitoes were collected for 24 mo between March 2009 and March 2011 encompassing two complete Austral summers and winters. Over that time period, 3,724 specimens in total were collected, encompassing five species: *Aedes* (*Stegomyia*) *aegypti* (L.) (n = 2,142); *Aedes* (*Stegomyia*) *polynesiensis* (Marks) (n = 1,548); *Wy. mitchellii* (n = 24); *Culex quinquefasciatus* Say (n = 3); and a beneficial species, *Toxorhynchites amboinensis* Doleschall (n = 7). Overall, *Wy. mitchellii* accounted for only 0.64% of all mosquitoes captured using BG-Sentinel traps compared with *Ae. aegypti* (58%) and *Ae. polynesiensis* (42%). *Wy. mitchellii* was seen active both during the dry and rainy season. Although more *Wy. mitchellii* specimens were captured during the two Austral summers combined (n = 17) compared with the Austral winters (n = 7), this seasonal difference was not significant ($\chi^2 = 2.18$, df = 1, $P = 0.14$).

Larvae. Surveys made in Tahiti revealed the presence of the species all around the island, including in Teahupoo and Tautira, two villages on the Tahiti peninsula. In total, 117 *Wy. mitchellii* larvae were collected from bromeliads and 17 larvae from *Alocasia* spp. from a similar number of plants in the surveyed areas (total number of subjects for lot size, N = 20).

A search for water-impounding plants where *Wy. mitchellii* readily breeds on the grounds of the ILM Research Laboratory revealed the presence of *Alocasia* spp. referred to locally as "ape" [*Alocasia macrorrhizos* (L.) G. Don and *Alocasia plumbea* (K. Koch ex Van Houtte)]. Three to four larvae were collected in the water impounded in each aroid leaf axil. The collected larvae were identified as *Wy. mitchellii* after emergence in the laboratory. This observation is similar to that described in Oahu, Hawai'i (Shroyer 1981).

Limited larval surveys were conducted in two additional islands of the Society Islands, the Leeward island of Raiatea (2008) and Tetiaroa (2010), a Windward atoll widely known as Marlon Brando's Estate, located 200 and 54 km north of Tahiti, respectively. No *Wy. mitchellii* were found on these islands, despite the presence of suitable water-impounding bromeliads and aroids particularly in Raiatea. The extent of the species' distribution in Moorea, on other islands of the Society archipelago, and in other archipelagoes of French Polynesia requires further investigation.

Consultation of the Nadeaud database of the flora of French Polynesia (Florence et al. 2007) confirmed that *Alocasia* spp. are frequent in the valleys of Tahiti. Water-impounding horticultural imports such as bromeliads are also popular in Tahiti, represented mostly by three species—*B. pyramidalis*, *Aechmea fulgens* (Brongniart), and *Neoregelia spectabilis* ((T. Moore) L.B. Smith)—that form attractive larval habitats for *Wyeomyia*. Our field observations indicate that when given the choice, *Wy. mitchellii* prefers bromeliads to aroids. However, in the absence of bromeliads *Wyeomyia* will readily oviposit in aroids. These cultivated plants thus constitute suitable larval habitat for *Wy. mitchellii*, especially at the edge of forests.

The bromeliad and aroid species from which larvae were collected and the occurrence of mosquito species are listed in Table 2. *Al. macrorrhizos* seems to be more attractive to *Wy. mitchellii* than *Al. plumbea* with 20 and one *Wyeomyia* immatures collected, respectively (N = 10). *Ae. polynesiensis* co-occurred with *Wy. mitchellii* immatures in 10% of *Al. macrorrhizos* sampled.

More than 20 plants were sampled at the Arue and Faaone stations in October 2008. Ninety-six *Wy. mitchellii* immatures were found in *B. pyramidalis* and only five in *N. spectabilis* or *Ae. fulgens*, suggesting *B.*

Table 3. List of mosquito species recorded in French Polynesia

Species	French Polynesia archipelagoes					Reference
	Society	Tuamotu	Australes	Gambiers	Marquises	
***Culex* (*Cx.*) *quinquefasciatus* (Say)**	+	+	+	+	+	Rivière (1988)
Culex (*Cx.*) *atriceps*[a] *(Edwards)*	+					Rivière (1988)
Culex (*Cx.*) *kesseli*[a] *(Belkin)*	+					Rivière (1988)
Culex (*Cx.*) *marquesensis*[a] *(Stone & Rosen)*						Rivière (1988)
Culex (*Cx.*) *annulirostris* (Skuse)	+	+	+	+		Rivière (1988)
Culex (*Cx.*) *roseni*[a] *(Belkin)*	+	+				Rivière (1988)
Culex (*Cx.*) *sitiens* (Wiedemann)	+	+				Rivière (1988)
Culex (*Cx.*) *toviiensis** (Klein, Riviêr & Sechan)					+	Rivière (1988)
Aedes (*O.*) *edgari*[a] *(Stone & Rosen)*	+		+			Rivière (1988)
***Aedes* (*S.*) *aegypti* (L.)**	+	+	+	+	+	Rivière (1988)
***Aedes* (*S.*) *polynesiensis* (Marks)**	+	+	+	+	+	Rivière (1988)
***Aedes* (*Ae.*) *nocturnus* (Theobald)**	+					Russell (2004)
Toxorynchites (*Tx.*) *amboinensis* (Doleschall)	+			+	+	Rivière (1988)
Wyeomyia (*Wy.*) *mitchellii* (Theobald)	+					This study

Vectors of diseases are in bold.
[a] Endemic species.

pyramidalis might be more suitable for *Wy. mitchellii* than the other two plant species. All *Wyeomyia*-positive *Billbergia* plants were located in a shaded area. *Ae. polynesiensis*, *Cx. quinquefasciatus*, and *Wy. mitchellii* co-occurred sometimes in bromeliads *Neoregelia* and *Aechmea* (Table 2). *Ae. polynesiensis* and *Wy. mitchellii* also coexisted in leaf axils of *Ae. fulgens*, a situation similar to that observed in one *Al. macrorrhizos* in Paea (Table 2).

The family Bromeliaceae is composed of ≈3,170 species native mainly to the tropical Americas. In Tahiti, an estimated 49 imported ornamental bromeliads are cultivated, usually in residential areas. Four to five of these species retain large enough volumes of water in leaf axils for the development of mosquitoes breeding in water-impounding plants. Only three genera, *Billbergia*, *Neoregelia*, and *Aechmea*, were found positive for *Wy. mitchellii* in Tahiti. Among them, *B. pyramidalis* is the most frequent bromeliad seen on the island. This plant native to Brazil can grow on the ground as well as epiphytically. It reproduces vegetatively, it needs no maintenance, and each plant can produce 100 *Wyeomyia* mosquitoes per year (Frank et al. 1988, Frank 1990). All *B. pyramidalis* plants found in Arue were positive for *Wy. mitchellii* with no co-occurrence of *Ae. polynesiensis* or *Cx. quinquefasciatus.* The coexistence of *Cx. quinquefasciatus* and *Ae. polynesiensis* was observed occasionally in *Neoregelia* "fireball" cultivar exposed to direct sun. The occurrence of *Wy. mitchellii* and *Ae. polynesiensis* also was observed on rare occasions in *Alocasia macrorrhizos* (Paea1) and *Ae. fulgens* (Faaone station). Coexistence of multiple mosquito species in bromeliads was previously described for *Alcantarea* aff. *regina* (Vellozo) Harms in Hawai'i involving three noxious species: *Aedes* (*Stegomyia*) *albopictus* (Skuse), *Wy. mitchellii*, and *Cu. quinquefasciatus* (Yang et al. 2003). Although *Cu. quinquefasciatus* and *Ae. polynesiensis* are not bromeliad specialists, their presence in these water-impounding plants can be explained by water enriched with nutrients from lawn grass clippings (Frank et al. 1988, Frank and Fish 2008) or fallen leaves.

Aroids came only second in the *Wyeomyia* preference for larval habitat. These plants offer smaller volumes of water in leaf axils with more organic materials. However when located in shade and away from bromeliads, aroids can form suitable, permanent larval habitats as previously described with *Alocasia* sp. in Oahu (Shroyer 1981). According to Florence et al. (2007), bromeliads are absent from the Marquesas, Tuamotu, Australes, and Gambier archipelagoes. If, as is suggested in the literature, bromeliads and aroids are the only plants suitable for the introduction, establishment, and propagation of *Wyeomyia* in island settings (Shroyer 1981, Frank et al. 1988, Frank 1990, LaPointe 2007, Frank and Fish 2008), then the current scarcity of suitable larval habitat is a likely obstacle to the establishment of *Wy. mitchellii* in the remaining archipelagoes of French Polynesia.

Dispersal of mosquitoes over ocean expanses is naturally limited. The first invasive mosquitoes in the Pacific may have been transported by Polynesians voyagers in their colonizing canoes as they spread across islands of the Central and South Pacific (LaPointe 2007). *Ae. polynesiensis* is thought to have been dispersed across Pacific islands by Polynesians (Marks 1954, Belkin 1962, LaPointe et al. 2005). Today, global commerce and travel greatly facilitates the dispersal of new mosquito species into the Pacific region. The global spread of the Asian tiger mosquito, *Aedes albopictus* (Skuse), perhaps the most notorious of invasive mosquitoes, is likely the result of the strong international trade in used tires (Lounibos 2002). The introduction of other mosquito species may result from horticultural imports (Lounibos 2002). A recent example of mosquito dispersal through the horticultural trade is the discovery of *Ae. albopictus* in southern California (Madon et al. 2002) and The Netherlands (Scholte et al. 2008) associated with shipments of *Dracaena sanderiana* Sander ex Mast. (Sparagalus: Dracaenaceae [Agavaceae]) known as 'Lucky Bamboo') from southern China. In 1981, the bromeliad mosquito *Wy. mitchellii* was discovered on Oahu (Shroyer 1981), well outside its native range in the

New World. This species has since become established on Kauai and Hawai'i Island (Nishida 2002). The introduction of *Wy. mitchellii* into French Polynesia that is reported here likely results from the illegal import of popular bromeliads from Hawai'i before or after the 1996's law enforcement (restricting the import of bromeliads to French Polynesia as seeds or in vitro). The time of introduction is uncertain, but the occurrence of *Wy. mitchellii* all around Tahiti and on the island of Moorea, suggests that the introduction was not recent. Transfer of ornamental bromeliads to other islands may increase the establishment of *Wy. mitchellii* elsewhere in the Pacific.

In Tahiti, most bromeliads are cultivated outdoors under direct sunlight or in shaded areas. The level of shade is known to influence the colonization of bromeliads by *Wy. mitchellii* (Frank and O'Meara 1985, Frank 1986), and the cultural practice seen in Tahiti may have limited the extent of bromeliad colonization by *Wy. mitchellii.*

Thirteen mosquito species have been recorded to date in French Polynesia (Rivière 1988). *Wy. mitchellii* constitutes the 14th recorded member of the mosquito fauna in French Polynesia (Table 3), the first introduction recognized since the discovery of *Aedes* (*Aedimorphus*) *nocturnus* (Theobald) (Theobald 1903) in 2004 on the island of Moorea (Russell 2004). The establishment of this exotic mosquito in the Hawai'ian Islands was first recorded in 1962 on Oahu (Joyce and Nakagawa 1963). The early 1960s saw a dramatic increase in air traffic in the Pacific. Commercial air travel between Hawai'i and Tahiti was launched in December 1963 by Pan American Airways (State of Hawai'i DOT 1964). These regular flights and associated horticultural imports have likely contributed to the introduction and establishment of *Ae. nocturnus,* and *Wy. mitchellii* in French Polynesia.

Although *Tx. amboinensis* is present in Tahiti, including on the grounds of the ILM research facility in Paea, its population density is very low, playing only a marginal role in controlling mosquitoes in bromeliads and other water-impounding plants.

Although the present survey provides evidence of coexistence of mosquito species in bromeliads, further investigation is warranted on species coexistence and competition to better understand the community structure and population dynamics in Tahiti.

Several vector-borne diseases of medical and veterinary importance, including dengue (Cao-Lormeau et al. 2011), lymphatic filariasis, the dog heartworm (*Dirofilaria immitis*) (Nicolas and Scoles 1997), and avian malaria (Beadell et al. 2006), are being transmitted in French Polynesia. The potential role played by *Wy. mitchellii* in the transmission of these diseases in French Polynesia is unknown.

Overall, our results indicate that bromeliads and aroids likely played a critical role in the introduction, establishment, and maintenance of *Wy. mitchellii* in Tahiti and Moorea. More attention to *Wy. mitchellii* is warranted because the plants in which it develops are common in residential areas, enhancing the contact with human and domestic animals and potentially increasing the risk of transmission of certain infectious diseases of medical and veterinary importance.

Acknowledgments

We are grateful to the owners of properties sampled in the coastal area of Tahiti, Moorea, and Raiatea, especially to Michel Cheong Sang in Raiatea. We thank Scott Ritchie, Richard Russell, Randy Mercer, Albert Tetuanui, Michel Germain, and Limb Hapairai for assistance and advice on this study. We thank our colleague Neal Evenhuis for confirming the identification of *Wy. mitchellii.*

References Cited

Beadell, J. S., F. Ishtiaq, R. Covas, M. Melo, B. H. Warren, C. T. Atkinson, S. Bensch, G. R. Graves, Y. V. Jhala, M. A. Peirce, et al. 2006. Global phylogeographic limits of Hawaii's avian malaria. Proc. Biol. Sci. 273: 2935–2944.

Belkin, J. N. 1962. The mosquitoes of the South Pacific (Diptera, Culicidae), vol. 1. University of California Press, Berkeley, CA.

Belkin, J. N., S. J. Heinemann, and W. A. Page. 1970. Mosquito studies (Diptera, Culicidae) XXI: The Culicidae of Jamaica. Contr. Am. Entomol. Inst. 6.

Cao-Lormeau, V.-M., C. Roche, M. Aubry, A. Teissier, S. p. Lastere, E. Daudens, H.-P. Mallet, D. Musso, and J. Aaskov. 2011. Recent emergence of dengue virus serotype 4 in French Polynesia results from multiple introductions from other South Pacific islands. PLoS ONE 6: e29555.

Darsie, R.F.J., and C. D. Morris. 2003. Keys to the adult females and fourth instar larvae of the mosquitoes of Florida (Diptera, Culicidae), vol. 1. Tech. Bull. Fla. Mosq. Control Assoc. University of Florida, Vero Beach, FL.

Florence, J., H. Chevillotte, C. Ollier, and J.-Y. Meyer. 2007. Base de données botaniques Nadeaud de l'Herbier de la Polynésie française (PAP). (http://www.herbier-tahiti.pf)

Frank, J. H. 1983. Bromeliad phytotelmata and their biota, especially mosquitoes, pp. 101–128. *In* J. H. Frank and L. P. Lounibos (eds.), Phytotelmata: terrestrial plants as hosts for aquatic insect communities, vol. VII. Plexus, Medford, NJ.

Frank, J. H. 1986. Bromeliads as ovipositional sites for *Wyeomyia* mosquitoes: form and color influence behavior. Fla. Entomol. 69: 728–742.

Frank, J. H. 1990. Bromeliads and mosquitoes. Fla. Dep. Agric. Conserv. Serv., Div. Plant Ind. Entomol. Circ. 331: 1–2.

Frank, J. H., and G. F. O'Meara. 1984. The bromeliad *Catopsis berteroniana* traps terrestrial arthropods but harbors *Wyeomyia* larvae (Diptera: Culicidae). Fla. Entomol. 67: 418–424.

Frank, J. H., and G. F. O'Meara. 1985. Influence of micro- and macrohabitat on distribution of some bromeliad-inhabiting mosquitoes. Entomol. Exp. Appl. 37: 169–174.

Frank, J. H., and D. Fish. 2008. Potential biodiversity loss in Florida bromeliad phytotelmata due to *Metamasius callizona* (Coleoptera: Dryophthoridae), an invasive species. Fla. Entomol. 91: 1–8.

Frank, J. H., J. P. Stewart, and D. A. Watson. 1988. Mosquito larvae in axils of the imported bromeliad *Billbergia pyramidalis* in southern Florida. Fla. Entomol. 71: 33–43.

Geier, M., A. Rose, and A. E. Eiras, inventors; University of Regensburg, assignee. 2004. Insektenfalle. Worldwide patent WO 04/054358 A2.

Joyce, C. R., and P. Y. Nakagawa. 1963. *Aedes vexans nocturnus* (Theobald) in Hawaii. Proc. Hawaii. Entomol. Soc. XVIII: 273–280.

Knight, K. L., and A. Stone. 1977. A catalog of the Mosquitoes of The World (Diptera: Culicidae), vol. VI, 2nd ed., Entomological Society of America, College Park, MD.

LaPointe, D. A. 2007. Current and potential impacts of mosquitoes and the pathogens they vector in the Pacific Region. Proc. Hawaii. Entomol. Soc. 39: 75–81.

LaPointe, D. A., M. L. Goff, and C. T. Atkinson. 2005. Comparative susceptibility of introduced forest-dwelling mosquitoes in Hawai'i to avian malaria, *Plasmodium relictum.* J. Parasitol. 91: 843–849.

Lounibos, L. P. 2002. Invasions by insect vectors of human disease. Annu. Rev. Entomol. 47: 233–266.

Madon, M. B., M. S. Mulla, M. W. Shaw, S. Kluh, and J. E. Hazelrigg. 2002. Introduction of *Aedes albopictus* (Skuse) in southern California and potential for its establishment. J. Vector Ecol. 27: 149–154.

Marks, E. N. 1954. A review of the *Aedes scutellaris* subgroup with a study of variation in *Aedes pseudoscutellaris* (Theobald). Bull. Br. Mus. (Nat. Hist.) Entomol. Ser. 3: 349–414.

Nayar, J. K. 1992. Characterization of the intracellular melanization response in *Anopheles quadrimaculatus* against subperiodic *Brugia malayi* larvae. J. Parasitol. 78: 876.

Nicolas, L., and G. A. Scoles. 1997. Multiplex polymerase chain reaction for detection of *Dirofilaria immitis* (Filariidea: Onchocercidae) and *Wuchereria bancrofti* (Filarioidea: Dipetalonematidae) in their common vector *Aedes polynesiensis* (Diptera: Culicidae). J. Med. Entomol. 34: 741–744.

Nishida, G. M. 2002. Hawaiian terrestrial arthropod checklist, 4th edition. Bishop Museum Technical Report 22. Online Database. Bishop Museum, Honolulu, HI.

Rivière, F. 1988. Ecologie de *Aedes* (*Stegomyia*) *polynesiensis*, Marks, 1951 et transmission de la filariose de Bancroft en Polynesie. Ph.D. dissertation, Université de Paris-Sud, Paris, France.

Russell, R. C. 2004. The relative attractiveness of carbon dioxide and octenol in CDC- and EVS-type light traps for sampling the mosquitoes *Aedes aegypti* (L.), *Aedes polynesiensis* Marks, and *Culex quinquefasciatus* Say in Moorea, French Polynesia. J. Vector Ecol. 29: 309–314.

Scherer, W. F., R. W. Dickerman, C. Campillo-Sainz, M. L. Zarate, and E. Gonzales. 1971. Ecologic studies of Venezuelan encephalitis virus in southeastern Mexico. V. Infection of domestic animals other than equines. Am. J. Trop. Med. Hyg. 20: 989–993.

Schmaedick, M. A., T. S. Ball, T. R. Burkot, and N. E. Gurr. 2008. Evaluation of three traps for sampling *Aedes polynesiensis* and other mosquito species in American Samoa. J. Am. Mosq. Control Assoc. 24: 319–322.

Scholte, E. J., E. Dijkstra, H. Blok, A. De Vries, W. Takken, A. Hofhuis, M. Koopmans, A. De Boer, and C. B. Reusken. 2008. Accidental importation of the mosquito *Aedes albopictus* into The Netherlands: a survey of mosquito distribution and the presence of dengue virus. Med. Vet. Entomol. 22: 352–358.

Shroyer, D. A. 1981. Establishment of *Wyeomyia mitchellii* on the island of Oahu, Hawaii. Mosq. News 41: 805–806.

Srihongse, S., and C. M. Johnson. 1967. The isolation of Ilhéus virus from Man in Panamá. Am. J. Trop. Med. Hyg. 16: 519–524.

Srihongse, S. C., and C. M. Johnson. 1965. Wyeomyia subgroup of arbovirus: isolation from man. Science 149: 863–864.

State of Hawai'i DOT. 1964. Annual Report, Year Ending, June 30. Department of Transportation, Honolulu, HI.

Theobald, F. V. 1903. A monograph of the Culicidae of the world, vol. 3. British Museum of Natural History, London, United Kingdom.

Theobald, F. V. 1905. The mosquitoes or Culicidae of Jamaica, with descriptions of some of the various stages by M. Grabham. Institute of Jamaica, Kingston, Jamaica.

Williams, C. R., S. A. Long, R. C. Russell, and S. A. Ritchie. 2006. Field efficacy of the BG-Sentinel compared with CDC Backpack Aspirators and CO2-baited EVS traps for collection of adult *Aedes aegypti* in Cairns, Queensland, Australia. J. Am. Mosq. Control Assoc. 22: 296–300.

Yang, P., R. Furumizo, L. Tangalin, C. Takekuma, and K. E. Hall. 2003. Mosquito species breeding in bromeliad axils on the island of Kauai, Hawaii. Proc. Hawaii. Entomol. Soc. 36: 95–101.

Received 5 August 2012; accepted 9 November 2012.