VECTOR INTRODUCTION AND MALARIA INFECTION ON GUAM

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ABSTRACT. The Mariana Islands lie well within the vast "malaria-free" region of the central and south Pacific Ocean. However, *Anopheles indefinitus* was discovered on Guam in 1948, and an additional four species of *Anopheles* were collected on the island during 1970-75. Early malaria cases on Guam were diagnosed as relapsing infections with the disease having been contracted in other areas. Small outbreaks of malaria were recorded on Guam in 1966 and 1969, and autochthonous cases were indicated in both. Since vector capability for malaria does exist on Guam, quarantine procedures at the air and seaports combined with public health disease surveillance and an integrated anopheline control program are recommended for the island.

INTRODUCTION

The growing worldwide problem of malaria reflects a breakdown in local disease control measures as well as the introduction of this disease into new areas (Bruce-Chwatt 1970, Schultz 1974). This historical review discusses the introduction of anophelines and incidence of malaria on Guam, the largest island in the Mariana archipelago which is located in the western Pacific Ocean. While the Marianas were described as malaria-free by Russell (1952), an anopheline species had been collected on Guam in March 1948 (Yamaguti and LaCasse 1950). The strap-shaped island of Guam is 6.5 to 16.6 km wide, 49.9 km long, has an area of 558 km^2, and is situated 2,160 km south of Tokyo and 2,240 km east of Manila. The combination of a constant flow of international travelers, some previously infected with malaria parasites in other areas, and the unchallenged introduction of vector-capable mosquitoes on incoming ships and aircraft provide the potential for local outbreaks of malaria on the island.

DISCUSSION

Prior to 1899, when Guam was ceded from Spain to the United States at the Treaty of Paris, very little was done in the areas of entomology or public health (Gressitt 1954). Beginning in 1899, the island was administered by a naval governor appointed by the President of the United States. The governor was always a senior naval officer who also commanded the naval and marine facilities. Public health affairs were administered by a naval medical officer who was also in charge of the medical programs on the island. Annual sanitation and disease reports written by the Guam Surgeon are the earliest reliable public health accounts.

The first record of a mosquito species occurring on Guam was in 1905 when J. F. Leys reported to the Surgeon General, U.S. Navy, that *Stegomyia fasciata* [*Aedes aegypti* (Linn.)] was abundant there. In 1911 D. T. Fullaway, entomologist at the Hawaii Agricultural Experiment Station, was detailed by the U.S. Secretary of Agriculture for a few months' duty on Guam. Fullaway (1912) listed only two species of mosquitoes in his collection from Guam but subsequent examinations of the specimens by Swezey (1942), Stone (1939), Bohart and Ingram (1946), and Bohart (1957) revealed four. All belonged to the genera *Aedes* or *Culex*.

Early authors writing on the fauna agreed that while mosquitoes were numerous throughout the islands, anophelines did not occur anywhere in the Marianas (Fullaway 1912, Schnee 1912, Esaki 1939 and 1940, Sogen 1941, Swezey 1942).

The principal pre-World War II survey of the mosquito fauna on Guam was accomplished in 1936 by O. H. Swezey (1942) who collected five species and mentioned an additional unidentified specimen. Guam was heavily populated with both Japanese and American military forces during World War II. An outbreak of dengue fever occurred in 1944 and the island was subjected to extensive vector surveys by medical entomologists assigned to the U.S. armed forces. The known mosquito fauna on Guam at the end of 1945 was 10 species and included no anophelines (Nowell 1980).

The immediate post-World War II period was one of reconstruction and redevelopment Pacific-wide and these activities were particularly apparent on Guam. Commercial air traffic was reestablished and there was a steady influx of Filipino laborers from Luzon, American contractors and technicians from the continental United States, and U.S. military personnel and their dependents. This was also the genesis of the Far Eastern and western Pacific tourist trade.

The first collection of an *Anopheles* mosquito on Guam occurred in March 1948, during a comprehensive mosquito survey by the 207th Malaria Survey Detachment, U.S. Army, as reported by Yamaguti and LaCasse (1950). The Guam survey had been requested as a follow-up

to the Japanese B encephalitis epidemic which occurred on the island from December 1947, through March 1948. Presence of the anopheline was verified by Reeves (1948), Reeves and Rudnick (1951), and confirmed by Hull in 1952 and Hu in 1953. Reeves (1953) considered this discovery of *Anopheles subpictus indefinitus* Ludlow to be extremely important because it was the first record of established anopheline breeding in Micronesia.

It was not until the 1970s that additional anopheline species were collected on Guam. Adult and immature forms of *An. subpictus* Grassi and *An. vagus* Dönitz were collected at Apra Heights in 1970 by R. F. Darsie, Jr. (Darsie and Ramos 1971). Reisen et al. (1972) reported taking a single male of *An. sinensis* Wiedemann in a light trap at Andersen Air Force Base in 1970, and *An. baezai* Gater, *An. lesteri* Baisas and Hu, and *An. tessellatus* Theobald were collected the following year by W. K. Reisen and reported by Reisen and Basio (1971). Two additional species, *An. barbirostris* van der Wulp and *An. litoralis* King, were reported by Ward et al. in 1976, bringing the number of species of anopheline mosquitoes reported from Guam to nine. Only five of the collection records have been verified, however.

At the end of 1983 the mosquito fauna on Guam was 24 established species according to Ward (1984). This population comprised seven endemic species and 17 introduced species. The latter may, according to R. A. Ward (1984) be separated into four elements: a cosmotropical or world wide group of three species, four species present only in the Oriental area, one species only present in Micronesia, and a group of nine species occurring in the Oriental and one to four other faunal areas. The total shows an increase of 14 species since the end of World War II, and their collection data reported by Nowell (1980) indicates sustained introductions during the period 1944-76. This reflects lack of a strict quarantine inspection program along with absence of a comprehensive island-wide mosquito surveillance and control program.

The history of malaria as a disease of mankind on Guam is less precise. The first comments on the infection were by surgeons assigned to the U.S. Navy Hospital on Guam in their annual reports on health, sanitation and disease submitted to the Surgeon General, U.S. Navy. The infection appeared first in a report by P. Leach (1900) in which he wrote: "Diseases classed as malarial are to be regarded as due, possibly, to some other cause. Manifestations presumed to be malarial are very rare, and it is not certain that malaria exists at all in the island." J. F. Leys (1905) stated that the *Anopheles* mosquito had not been found and further that there was no malaria on the island of Guam. F. E. McCullough (1909) also claimed the island was free from malarial disease, and both he and C. P. Kindleberger (1912) emphasized that the mosquito host for malaria was not present on Guam.

S. R. Vandenberg, entomologist at the Guam Agricultural Experiment Station, also pointed out in 1926 that the genus *Anopheles* was not known to be represented on Guam, and he was the first to mention the number of cases on record of patients coming to Guam suffering from malarial fever contracted elsewhere and being hospitalized on the island. In a subsequent article (Vandenberg 1928) he explained that the *Anopheles* mosquitoes were the necessary intermediate hosts of malaria and that the malarial fevers could not become epidemic and thus endemic on Guam since the island was free from this genus. F. E. Porter (1932) listed 22 blood examinations positive for malaria. These could have been on samples drawn from patients of the type described by Vandenberg in his 1926 paper.

E. P. Mumford and J. L. Mohr discussed malaria on Guam in their 1943 report which summarized the situation by stating: "Malaria has been recorded sporadically from Guam, but infection apparently had taken place in other areas, since Guam has to date no anophelines." In an earlier paper Mumford (1942) suggested that as a result of the war, "*Anopheles* may be brought into Pacific areas hitherto free of them."

In a separate review of arthropod-borne diseases in Micronesia, D. S. Farner (1944a) commented that "malaria has apparently never been an autochthonous disease of Micronesia, a fact to be associated with the absence of anopheline mosquitoes." As for the few cases of malaria treated on Guam, Farner concluded they had been imported. In a second article Farner (1944b) cited two early references pertaining to occurrence of *Anopheles* on Guam. One was a 1928 report by Lieutenant Commander R. C. Satterlee, U.S. Navy, in which he reported the presence of *Anopheles* in Micronesia (Guam), and the other was an article, "*Anopheles* that carry malaria in the Marianas," published in the Third (1928) Edition of the U.S. Hydrographic Office's *Pacific Islands Pilot.* The latter article was probably based on the results of Satterlee's sanitary survey, and since neither reference was verified by the actual collection of *Anopheles* specimens, Farner considered both to be erroneous.

The first anopheline reported on Guam, *An. subpictus indefinitus* Ludlow (in 1966 J. A. Reid elevated this subspecies to species level) exhibited a wide range of breeding habitats, e.g., freshwater marshes, stagnant water, slow moving streams, brackish water pools, and temporary

ground pools. It was suggested by Morrill et al. (1952) that the mosquito had been introduced by means of inadequately disinsected aircraft. W. C. Reeves (1953) surmised that it might have entered by means of surface craft during military operations. W. B. Hull (1952) thought it likely the species was introduced from the Philippine Islands where it was not uncommon.

The fact that *An. indefinitus* was found to be widely established on Guam and not isolated in a single focus at the time of its initial collection was interpreted by Reeves (1948) and by Yamaguti and LaCasse (1950) to mean that the species had been on the island for some time. In their analysis of this species, Reeves and Rudnick (1951) cited the following malaria data for Guam.

> "At the time of this discovery relapsing malaria infection commonly was reported on Guam in the military and civilian personnel. A total of 74 military and 79 civilian cases was reported and confirmed by blood smears during the fiscal year July 1, 1947, to June 30, 1948. Follow-up investigations by health authorities demonstrated that all of these 153 cases had histories of previous malaria infection contracted in other areas. In the first quarter of the fiscal year 1948, 18 additional cases with similar histories were reported and confirmed. Up to January 1, 1949, there had been no proven cases of autochthonous malaria infection in native, armed forces, or dependents of military personnel on this island."

Their conclusion was that the new species of *Anopheles*, known elsewhere to be essentially zoophilic, was not an active vector on Guam.

The significance of the recovery of this species on the island was that an anopheline mosquito had invaded the hitherto malaria-free area, and that it was established on the island.

The Korean War started in June, 1950, and Guam became a major military staging and logistics center. As the number of cases of malaria in the United Nations forces in Korea began to increase dramatically there was concern over the epidemiologic sensitivity of using the island as a medical treatment point for infected soldiers. Another mosquito survey of Guam from August to December 1951, by W. B. Hull (1952) broadened the distribution of *An. indefinitus* though Hull noted "no autochthonous malaria is known on Guam at present." One year later a survey conducted by S. M. K. Hu (1953) showed the mosquito still breeding in abundance. Again no local incidence of malaria had been reported on the island.

The U.S. Navy initiated mosquito surveys of its housing and operational areas under supervision of a commissioned medical entomologist in 1955. In the first of these Captain R. T. Holway, U.S. Navy, noted in his report of the 1955 survey that although *An. indefinitus* was more widespread and common than in 1951, autochthonous malaria was still not present on Guam. Numerous breeding sites were located within 700 m of the commercial port of Guam at Apra Harbor, and this was interpreted as indicating that conditions there were favorable for the introduction of other species of *Anopheles*, among which might be an efficient malaria vector. In a 1964 survey conducted by Captain Holway, larval *An. indefinitus* were collected inside the Apra Harbor area.

In an overview of the epidemiology of malaria, P. F. Russell (1959) noted that the introduction of *An. indefinitus* on Guam in 1948 was apparently the only instance of an *Anopheles* mosquito becoming established in the central Pacific Micronesian area during and immediately after World War II. The method of introduction had still not been determined, and as of that year (1959) the species was not known to have transmitted a single case of malaria on the island.

Active U.S. military participation in the Vietnam War began in 1965, and patients included victims of arthropod-borne disease in addition to combat casualties. Guam was used as a treatment center for the malaria cases from southeast Asia. By 1966 approximately 155 malaria cases had been treated on the island (Savage 1966). The patients were maintained in screened quarters and it was felt that the chance of malaria transmission was unlikely on the island because *An. indefinitus* was known to be a poor vector. However, in 1966 five cases of falciparum malaria were reported. Ostensibly all were contracted on Guam and at least three were introduced autochthonous cases (Brown 1966, U.S. Navy 1967, Holway 1968). One case occurred in late spring; the other four during the fall months. The patients included two U.S. Naval officers billeted on ships berthed in Apra Harbor along with two Guamanian natives and one Trust Territory student who were living in Dededo Village. Records showed that two wounded Guamanian U.S. Army enlisted men suffered malaria relapses earlier in the same year while at their homes in Dededo Village on medical leave from Vietnam. Patient and case data are shown in Table 1. The vector had to be *An. indefinitus* or another species of *Anopheles* on Guam.

Along with the realization of the ramifications of malaria transmission of the island came intensified control at the military airport (Andersen AFB) and in the Apra Harbor area where the commercial and military ships docked.

Table 1. Case data: Malaria outbreaks on Guam—1966[1] and 1969.[2]

Year	Case no.	Home country	Sex	Occupation	Date arr. Guam	Reason for being on Guam	Primary residence time of infection	Disease symptom onset on Guam	Malaria diagnosis	Travel outside USA, Hawaii & Mariana Islands	Presumptive source for the infection	Case classification (for Guam)
1966	1	Guam	M	US Army	1966 (mil. leave)	Home on mil. leave	Dededo Village	1966	*Plasmodium falciparum*	Vietnam (1966)	Vietnam	Imported
	2	Guam	M	US Army	1966 (mil. leave)	Home on mil. leave	Dededo Village	1966	*Plasmodium falciparum*	Vietnam (1966)	Vietnam	Imported
	3	USA	M	US Navy officer	Early spring 1966	1 week temporary duty	On-ship in Apra Harbor	Spring[3] 1966	*Plasmodium falciparum*	Not known	Guam	Cryptic
	4	USA	M	US Navy officer	Not known	Station assigned	On-ship in Apra Harbor	Oct 66	*Plasmodium falciparum*	Not known	Guam	Cryptic
	5	Guam	M	Civilian	Native	Native resident	Dededo Village	5 Nov 1966	*Plasmodium falciparum*	None	Guam	Introduced autochthonous
	6	Guam	M	Civilian	Native	Native resident	Dededo Village	8 Nov 1966	*Plasmodium falciparum*	None	Guam	Introduced autochthonous
	7	Saipan	M	Civilian	Oct or Nov 1966	Awaiting enlistment US Armed Forces	Dededo Village	Oct or Nov 66	*Plasmodium falciparum*	None	Guam	Introduced autochthonous
1969	1	Phil. Is.	M	Civilian	Oct 68	Immigrant	Civilian community, Guam	Early Aug 69	*Plasmodium falciparum*	Philippine Is. (native of)	Philippine Is.	Imported or introduced autochthonous
	2	USA	M	US Air Force sergeant	17 Aug 1969	Station assigned	Andersen AFB, Guam	16 Sep 1969	*Plasmodium falciparum*	None	Guam	Introduced autochthonous
	3	USA	M	US Air Force officer	28 Sep 1969 & Oct 1969	Temporary duty	Kadena AB, Okinawa	5 Oct 1969	*Plasmodium falciparum*	Okinawa & Thailand (1969)	Thailand or Okinawa	Imported
	4	USA	M	US Armed Forces	19 Oct 1969	R&R leave return—Hawaii to Vietnam	DMZ and Danang, Vietnam	19 Oct 1969	*Plasmodium falciparum*	Vietnam (May 1969)	Vietnam	Imported
	5	USA	M	US Armed Forces	19 Oct 1969	R&R leave return—Hawaii to Vietnam	Chu Lai, Vietnam	20 Oct 1969	*Plasmodium falciparum*	Vietnam (July 1969)	Vietnam	Imported
	6	USA	M	US Air Force sergeant	1 May 1969	Station assigned w/ temporary duty periods at Clark AB, Philip. Is.	Off-base civilian community, Guam	21 Oct 1969	*Plasmodium falciparum*	Vietnam (1966—67), and Philip. Is. (1969)	Philippine Is. or Vietnam	Imported or introduced autochthonous

[1] Data source: Brown, R.B. (1966); Holway, R.T. (1968).
[2] Data source: Hayes, G.R., Jr., and B.T. Whitworth (1969).
[3] Subsequently admitted to the U.S. Naval Hospital, Subic Bay, Luzon, Philippine Is.

As the war in Vietnam escalated, Guam resumed its now traditional role as a major aerial terminal for military personnel and cargo carriers flying between the continental United States and the combat zone. Uniformed armed forces personnel, Federal Government and contract employees who had served in Vietnam or been in other Far Eastern areas where malaria was epidemic were continually passing through Guam enroute to the U.S. From August through October 1969, another six cases of clinically diagnosed malaria (five confirmed) occurred on Guam. This outbreak was similar in number of cases to that of 1966, but there was one difference: this one centered around Andersen AFB. According to the U.S. Public Health Service consultants who were sent to Guam to investigate the outbreak, "none of the patients had previously experienced symptoms of malaria, had given or received blood during the preceding six months, nor was able to define any periods of exposure to mosquitoes which had been worse than normal" (Hayes and Whitworth 1969). Attention was focused on possible local malaria transmission.

Hayes and Whitworth (1969) reviewed all aspects of the cases and presented a thorough analysis of the outbreak. The case data are shown in Table 1. Since *An. indefinitus* was the only anopheline known to be established on Guam at the time, the consultants concluded it "must be suspected as a potential vector of malaria as long as local transmission cannot be discounted and a more efficient vector cannot be found on the island."

Five of the six cases in the 1969 outbreak were military personnel associated with Andersen AFB (Table 1). The sixth case was a Filipino immigrant who lived in nearby (12 km) Dededo Village. All of the cases were due to *Plasmodium falciparum* infection and only one represented local transmission according to data collected by Sawyer (1969). This single introduced autochthonous case could have resulted from a bite by an *An. indefinitus* which had become a host on Guam after feeding on a malarious individual or it could have been caused by a recently infected *Anopheles* transported onto Guam by an aircraft originating from or having made a stop in an endemic malaria area.

The immediate effect of the 1969 outbreak was awareness that it might evolve into an epidemiological catastrophe. Consideration was given by the Government of Guam to broadening the scope of disease and vector control. Public health capabilities were bolstered along with increased emphasis on mosquito surveillance. A Vector Control Branch was established within the Bureau of Environmental Health and Consumer Protection to conduct island-wide surveys and perform control activities in territorial areas. It was expected that this branch would supplement the U.S. Air Force/Navy programs on the military facilities and insure island-wide surveillance capability. There was acceptance by the military of quarantine procedures at its airports and seaports, along with realization of the need for knowledge about other possible arthropod vectors on the island. The objective of the first surveys was to discover alternate vector species, if any, for *An. indefinitus*. The ensuing collection of four additional anopheline species during 1970-75 was described above.

Between April 23 and June 4, 1975, approximately 120,000 Vietnamese refugees arrived on Guam prior to resettlement in the U.S. as part of "Operation New Life" (Shaw 1977). The arrival of these evacuees more than doubled the normal population of the island in just a little over one month. Malaria was diagnosed in 70 of the refugees (Shaw 1977).

Although dengue was the primary arthropod-borne disease of concern according to Haddock et al. (1979) it was believed any actions taken to protect the population on Guam from the mosquito vector(s) of dengue fever would also be applicable to the control of the mosquito vector(s) of malaria. Insecticide fogging of at least one of the several refugee camps was accomplished every night for mosquito control. The ultimate measure was to spray each of the refugee encampments and surrounding areas with insecticide (95% malathion) at the rate of 3 ounces per acre by aerial application. This treatment significantly reduced the populations of the *Aedes* mosquitoes, potential vectors of dengue fever, and it was believed that it minimized the possibility of disease transmission within the refugee housing areas and neighboring native living areas. There was no incidence of either dengue or malaria in the Guamanian communities during the encampment of the refugees. This negative pattern continued after departure of the Vietnamese refugees from the island.

There was no record of vector-borne disease being contracted by Andersen AFB personnel from the Vietnamese nationals who were processed through that station during "Operation New Life" during April-July 1975 (Valder 1975). Two previously unrecorded anophelines were collected in light traps during May and June 1975, but surveys indicated both species were probably established on the island prior to the start of "Operation New Life" (Ward et al. 1976). These collections showed both species survived the aerial spray treatment during the last week of May 1975.

Vector surveillance continued to be performed

Table 2. Malaria reported on Guam, 1980–86 (13 cases).

Year reported	Travel history	Resident status
1980	Africa	Guam resident
	Malaysia	Guam resident
	Nicaragua	U.S. resident
	Solomon Islands	Guam resident
1981	Solomon Islands	Guam resident
	Solomon Islands	Guam resident
	India	Guam resident
1982	Solomon Islands	U.S. tourist
	Philippines	U.S. military
1983	Papua-New Guinea	Japanese tourist
1984	Papua-New Guinea	Ship crew member
	Philippines	U.S. military dependent
1985	Papua-New Guinea	Ship crew member

routinely on both the Air Force base and Navy facilities on the island after "Operation New Life" was concluded. *An. indefinitus* was recovered in light trap collections, but there was no record of any cases of malaria being diagnosed in the military population after July 1975.

After 11 years of zero incidence the Guam Department of Public Health and Social Assistance began receiving notices of on-island treatment of malaria cases by local physicians. Thirteen cases of malaria were reported between 1980-86. They are shown in Table 2. All of the cases were classified as introduced (R. L. Haddock; personal communication, 1985).

SUMMARY AND CONCLUSION

The potential for malaria transmission continues to exist on Guam; however, it is doubtful that malaria has become endemic on the island. Autochthonous malaria has occurred on two occasions. It is necessary that additional malaria vector species be kept off the island, and that malarious visitors or residents be kept isolated from the local anopheline population.

The island of Guam is a popular tourist terminal. As the number of interisland and international flights into and out of Guam increases, it will become imperative that an effective aircraft disinsection program be established at both the commercial and military airports. Quarantine procedures have been advocated for Guam since 1911 (Fullaway 1912), but the standard approach has been to place emphasis on mosquito surveillance and area treatment programs for vector control.

Without effective aircraft disinsection and quarantine measures the total number of introduced mosquito species on Guam will continue to increase with the possibility that more efficient malaria vectors may arrive. Dispersal of vectors via transport aircraft and ships from Guam to other islands within Micronesia is also a possibility. Control of the vector population can be achieved on Guam through the coordinated application of public health disease surveillance, quarantine procedures at the air and sea ports, and a territorial pest management capability for administering an integrated anopheline control program throughout the island.

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