Epidemiol. Infect. (2017), **145**, 41–45. © Cambridge University Press 2016
doi:10.1017/S0950268816002041

SHORT REPORT
Surveillance for malaria outbreak on malaria-eliminating islands in Tafea Province, Vanuatu after Tropical Cyclone Pam in 2015

C. W. CHAN[1]*, H. IATA[2], J. YAVIONG[2], M. KALKOA[2], S. YAMAR[2], G. TALEO[2], R. ISOZUMI[3], M. FUKUI[3], F. AOYAMA[4], A. POMER[5], K. N. DANCAUSE[6] AND A. KANEKO[1,3,7]

[1] *Island Malaria Group, Department of Microbiology, Tumor and Cell Biology (MTC), Karolinska Institutet, Stockholm, Sweden*
[2] *Ministry of Health, Port Vila, Vanuatu*
[3] *Department of Parasitology, Graduate School of Medicine, Osaka City University, Osaka, Japan*
[4] *NTT DECOMO, Tokyo, Japan*
[5] *Department of Anthropology, Binghamton University, Binghamton, NY, USA*
[6] *Département des sciences de l'activité physique, Université du Québec à Montréal (UQAM), Montréal, Québec, Canada*
[7] *Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan*

Received 30 May 2016; Final revision 29 July 2016; Accepted 10 August 2016; first published online 9 September 2016

SUMMARY

The risk of malaria outbreak surfaced in Vanuatu after Tropical Cyclone (TC) Pam in March 2015. In June and July 2015 we conducted malariometric surveys on the islands of Tanna, Aneityum, and Erromango in Tafea Province, where malaria elimination had been targeted, to determine if malaria incidence had increased after TC Pam. No *Plasmodium* infection was detected by microscopy and PCR in 3009 survey participants. Only 6·3% (190/3007) of participants had fever. Spleen rates in children aged ⩽12 years from Aneityum and Tanna were low, at 3·6% (14/387) and 5·3% (27/510), respectively. Overall bed net use was high at 72·8% (2175/2986); however, a significantly higher ($P < 0{\cdot}001$) proportion of participants from Aneityum (85·9%, 796/927) reported net use than those from Tanna (67·1%, 751/1119) and Erromango (66·8%, 628/940). A recent decrease in malaria incidence in Tafea Province through comprehensive intervention measures had reduced the indigenous parasite reservoir and limited the latter's potential to spur an outbreak after TC Pam. The path towards malaria elimination in Tafea Province was not adversely affected by TC Pam.

Key words: Malaria, outbreaks, *Plasmodium*, public health, surveillance.

Natural disasters can result in an increase in vector-borne diseases such as malaria. In developing countries the effects of natural disasters on communicable diseases can be severe because resources and infrastructure are often limited [1]. On 13 March 2015, Tropical Cyclone (TC) Pam struck the developing island nation of Vanuatu in the South Pacific (Fig. 1). Over half of the country's population (estimated 250 000) was affected, but Shefa and Tafea provinces suffered the most extensive damage because they lay in the direct path of TC Pam. The ensuing environmental condition was conducive to vector breeding and the risk of vector-borne disease outbreaks was thought to be serious [2].

* Author for correspondence: Dr C. W. Chan, Department of Microbiology, Tumor and Cell Biology (MTC), Nobels väg 16, KI Solna Campus, Karolinska Institutet, Box 280, SE-171 77 Stockholm, Sweden.
(Email: chim.chan@ki.se)

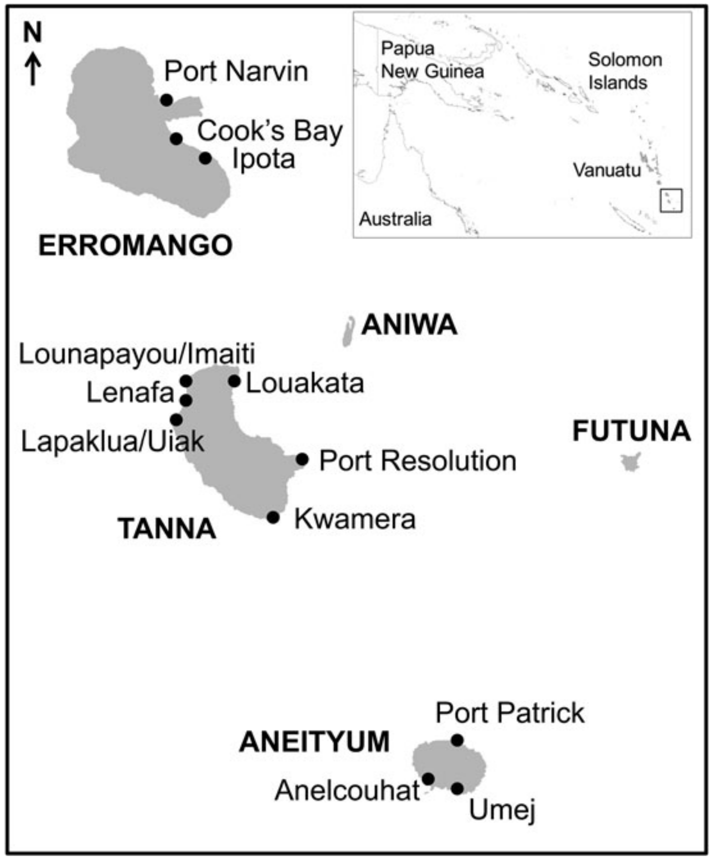

Fig. 1. Locations of 12 rural communities in Tafea Province, Vanuatu for post-Tropical Cyclone Pam malaria surveillance in June–July 2015. Inset shows the location of Vanuatu and Tafea Province (black square).

Tafea is the southernmost province of Vanuatu, and consists of five inhabited islands (Tanna, Aniwa, Futuna, Erromango, Aneityum) with an estimated population of 34 378 in 2014 (Fig. 1) [3]. Historically malaria was endemic on all islands except Futuna, and was very rare on Aniwa [4]. On Aneityum, an integrated malaria elimination project consisting of a 9-week mass drug administration that targeted the entire island population, distribution of insecticide treated nets (ITNs), introduction of larvivorous fish to known vector-breeding sites, and malaria surveillance by a community microscopist was initiated in 1991 [5, 6]. Malaria was eliminated on Aneityum by 1996, and malaria freedom has since been sustained with the exception of an outbreak of *Plasmodium vivax* in 2002 (Table 1) [7]. The Aneityum Project demonstrates the feasibility of malaria elimination in Vanuatu and informs the current national elimination strategy specifically tailored to the isolated community setting typical of most of Vanuatu. Substantial reduction in annual parasite incidence (API) in Tafea Province over the past few years enabled the province to target zero local transmission by the end of 2014 and sustainable elimination by the end of 2016 [3]. Cognisant of the sharp increase in malaria incidence on Tanna Island after TC Uma in 1987 [4], this study was initiated to examine if the progress towards elimination in Tafea Province had been reversed by malaria outbreak after TC Pam.

The study was approved by the Ethical Research Committee of Karolinska Institutet in Sweden (Protocol no. 2012/4:6) and the Ministry of Health in Vanuatu. Study participants were recruited using the convenience sampling method. The purpose, procedure, risks, and benefits of the survey were explained in both Bislama (lingua franca of Vanuatu) and indigenous 'kastom' languages by local field assistants. The consent procedure was witnessed by a neutral third party who recorded the name of each participant as he/she enrolled in the survey.

Malariometric surveys were conducted in 12 rural communities on the islands of Erromango (estimated population 2300), Tanna (29 000), and Aneityum (1200) in Tafea Province of Vanuatu in June and July

Table 1. *Major milestones of malaria elimination on Aneityum Island, Vanuatu since 1991*

Time	Activity/milestone
September 1991	First mass drug administration (MDA) commenced (week 1)
October 1991	Distribution of insecticide-treated nets (ITNs) and introduction of larvivorous fish to known vector-breeding sites
November 1991	First MDA completed (week 9); last indigenous *P. falciparum* infection detected by microscopy in a population-wide survey
1992	Selection and training of a local community volunteer for malaria microscopy
February 1993	Active case detection in visitors and passive case detection in community by the community microscopist commenced (continuously maintained to date)
February 1996	Last indigenous *P. vivax* infections detected by microscopy in a population-wide survey
1997–2000	Four population-wide surveys conducted; no indigenous *Plasmodium* infection detected by microscopy; malaria successfully eliminated
January 2002	Unusual increase in *P. vivax* cases detected through passive case detection by the community microscopist
July 2002	*P. vivax* epidemic confirmed in a population-wide survey; microscopy-positive cases limited to residents aged <20 years
November 2002	Second MDA targeting all residents aged <20 years commenced (week 1); re-strengthening of vector control and surveillance activities
December 2002	Second MDA completed (week 4); no *P. vivax* infection detected by microscopy or polymerase chain reaction (PCR) immediately after completion of second MDA
2003–2007	Four population-wide surveys conducted; *P. vivax* infections detected by microscopy and/or PCR in each of the four surveys
2010–2015	Four population-wide surveys conducted; no *Plasmodium* infections detected by microscopy or PCR in any of the four surveys; freedom from malaria re-established
March 2015	Tropical cyclone (TC) Pam struck Vanuatu
June 2015	Post-TC Pam survey; no *Plasmodium* infection detected by microscopy or PCR; malaria freedom sustained (this study)

2015, about 3 months after TC Pam struck the nation (Fig. 1). Since the population of Aneityum is relatively small and concentrated in only three communities (Anelcouhat, Port Patrick, Umej), the entire population was included. In contrast, the populations of Erromango and Tanna in particular are larger and dispersed across many communities. On these two islands, selected communities with high parasite prevalence in recent years ('historic hotspots') were targeted to maximize the likelihood of detecting *Plasmodium* infections.

Peripheral blood was obtained by finger prick for examination of *Plasmodium* infection by microscopy and polymerase chain reaction (PCR). Giemsa-stained blood smears were examined in the field under a light microscope by M.K. Blood (70 μl) was spotted on Whatman 31ET chromatography filter paper (Whatman, UK), allowed to dry, and stored at ambient temperature. DNA was extracted from quartered dried blood spots (17·5 μl) using the QIAamp DNA Mini kit (Qiagen, Japan) according to the manufacturer's instructions. A nested PCR protocol that amplifies a fragment of the *cox3* gene in the *Plasmodium* mitochondrial genome was used to detect *Plasmodium* infections [8].

Axillary temperature was determined using a digital thermometer (Terumo, Japan), and fever was defined as having axillary temperature >37·5 °C. On Tanna and Aneityum, spleen size of children aged $\leqslant$12 years was assessed by A.K. according to Hackett's method [9]. Survey participants were asked if they had slept under ITNs the previous night. χ^2 tests were used to compare the prevalence of fever, spleen rates in children, and frequencies of ITN use in the islands.

Neither microscopy nor PCR detected any *Plasmodium* infection from 3009 survey participants across three islands, indicating no immediate outbreak in Tafea Province after TC Pam (Table 2). Between 2008 and 2014, the API in Tafea Province decreased from 23·3/1000 population to 0·087/1000 population as a result of interventions specifically aimed to achieve zero local transmission, including mass ITN distributions and enhanced case management, surveillance and response [3]. These control measures have effectively reduced the local parasite reservoir that can serve as the source of malaria outbreak after natural disasters.

Overall, only 6·3% (190/3007) of participants had fever (Table 2). Prevalence of fever did not differ between islands ($P = 0·051$), although in small

Table 2. *Post-Tropical Cyclone Pam malariometric surveys in Tafea Province, Vanuatu, June–July 2015*

Island	Community	*Plasmodium* infection	Fever		Enlarged spleen		ITN use	
		No. examined	No. examined	% Fever (*n*)	No. examined	% Enlarged spleen (*n*)	No. examined	% ITN use (*n*)
Aneityum	Port Patrick	168	168	10·7 (18)	82	4·9 (4)	168	95·8 (161)
	Anelcouhat	611	610	5·4 (33)	234	3·4 (8)	610	82·3 (502)
	Umej	150	149	12·1 (18)	71	2·8 (2)	149	89·3 (133)
	Aneityum total	929	927	7·4 (69)	387	3·6 (14)	927	85·9 (796)
Tanna	Louakata	234	234	5·6 (13)	140	2·9 (4)	213	60·1 (128)
	Port Resolution	311	311	3·2 (10)	146	4·8 (7)	311	85·5 (266)
	Kwamera	279	279	6·8 (19)	134	8·2 (11)	279	57·7 (161)
	Lounapayou/Imaiti	223	223	4·5 (10)	90	5·6 (5)	223	71·3 (159)
	Lenafa	11	11	9·1 (1)			11	81·8 (9)
	Lapaklua/Uiak	82	82	3·7 (3)			82	34·1 (28)
	Tanna total	1140	1140	4·9 (56)	510	5·3 (27)	1119	67·1 (751)
Erromango	Port Narvin	436	436	8·3 (36)			436	72·7 (317)
	Cook's Bay	77	77	16·9 (13)			77	92·2 (71)
	Ipota	427	427	3·8 (16)			427	56·2 (240)
	Erromango total	940	940	6·9 (65)			940	66·8 (628)
	Survey total	**3009**	**3007**	**6·3 (190)**	**897**	**4·6 (41)**	**2986**	**72·8 (2175)**

ITN, Insecticide-treated net.

communities such as Cook's Bay on Erromango and Umej on Aneityum, fever was more common at 16·9% (13/77) and 12·1% (18/149), respectively (Table 2). The cause of these fever cases was not further investigated as participants did not present with complaints or other health complications.

Enlarged spleen was detected in 4·6% (41/897) of children aged ⩽12 years on Tanna and Aneityum (Table 2). Spleen rate was higher on Tanna (5·3%) than Aneityum (3·6%), but the difference was not statistically significant ($P = 0{\cdot}245$). We previously reported the association between parasite rate and spleen rate in Vanuatu and the decrease in spleen rates on Aneityum following malaria elimination in 1996 [10]. The low spleen rates observed in this study were consistent with the temporal trend on Aneityum and provided support that malaria incidence had not increased in Tafea Province after TC Pam.

About 72·8% (2175/2986) of participants responded that they had slept under ITNs the night before the survey (Table 2). ITN use was significantly higher ($P < 0{\cdot}001$) on Aneityum (85·9%) than Tanna (67·1%) and Erromango (66·8%). Compared to our most recent surveys conducted before TC Pam, ITN usage was consistent on both Aneityum (85·9% in June 2015 *vs*. 85·1% in January 2015) and Tanna (67·1% in June and July 2015 *vs*. 62·3% in February 2014) before and after TC Pam. Higher ITN use on Aneityum was motivated by the community's perception of the threat of malaria resurgence, and its long-term commitment to sustain malaria freedom after elimination [11].

Natural disasters can create new and favourable habitats for *Anopheles* vectors and increase the risk of malaria outbreak, even in remote island settings with low endemicity. In the Andaman and Nicobar Islands, seawater intrusion after the tsunami in December 2004 increased the number of brackish breeding sites preferred by the local vector *Anopheles sundaicus*. In Andaman district, slide positive rate for malaria increased markedly from <0·4% during 2004 to 1·6% 3 months after the tsunami, suggesting heightened transmission and risk of outbreak [12]. Previously in Vanuatu, the spike in malaria incidence on Tanna in 1987 was attributed to an outbreak after serious damage caused by TC Uma [4]. In contrast, no malaria outbreak was detected on the three main islands in Tafea Province 3 months after TC Pam in 2015. Progress made in recent years towards malaria elimination in the province likely minimized the potential for malaria outbreak stemming from indigenous parasite reservoirs. Similarly, no malaria outbreak was reported in the most affected area of the Visayas in the Philippines after Typhoon Haiyan in November 2003 [13], as malaria had been largely eliminated prior to the typhoon [14]. Both instances demonstrate that malaria elimination is robust and can provide the additional benefit in the form of protection from malaria epidemics after catastrophic natural disasters.

Preventing the reintroduction of malaria is a major challenge even in island nations with mechanisms in place to screen arriving passengers at ports of entry, such as Mauritius [15] and Sri Lanka [16]. In Vanuatu, the risk of parasite importation via human movement from other provinces to Tafea Province still exists, especially for *P. vivax* [17]. In Tafea Province, active case detection in visitors is limited to only Aneityum as part of the community-directed surveillance system established in 1993 (Table 1) [6]. High community compliance in ITN use, timely case diagnosis and treatment, and maintenance of the existing surveillance and response system will be critical to the goal of achieving and sustaining malaria elimination in the future.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

ACKNOWLEDGEMENTS

We thank the local field assistants and the people of Vanuatu for their generous hospitality and cooperation in time of extraordinary difficulty after TC Pam. We are grateful to Tomomi Kuwana and Martina Löfstedt Jalava for their administrative support at Osaka City University and Karolinska Institutet, respectively.

Financial support for this study was provided to the principal investigator (A. Kaneko) by the Swedish Research Council (grant nos. 523-2009-3233, 348-2012-6346, and 348-2013-6311); the Japan Society for the Promotion of Science (JSPS) Core-to-Core Programme B, Asia-Africa Science Platforms (JSPS KAKENHI grant no. 26257504); and the collaborative research grant of Nagasaki University Institute of Tropical Medicine.

DECLARATION OF INTEREST

None.

REFERENCES

1. **Watson JT, Gayer M, Connolly MA.** Epidemics after natural disasters. *Emerging Infectious Diseases* 2007; **13**: 1–5.
2. **World Health Organization.** Health cluster bulletin #1, Cyclone Pam Vanuatu. Suva, Fiji: World Health Organization Western Pacific Region, 2015.
3. **National Vector Borne Disease Control Program.** Annual Report 2014. Port Vila, Vanuatu: National Vector Borne Disease Control Program, 2015.
4. **Kaneko A, *et al.*** Malaria epidemiology, glucose 6-phosphate dehydrogenase deficiency and human settlement in the Vanuatu Archipelago. *Acta Tropica* 1998; **70**: 285–302.
5. **Kaneko A, *et al.*** Malaria eradication on islands. *Lancet* 2000; **356**: 1560–1564.
6. **Kaneko A.** A community-directed strategy for sustainable malaria elimination on islands: short-term MDA integrated with ITNs and robust surveillance. *Acta Tropica* 2010; **114**: 177–183.
7. **Kaneko A, *et al.*** Characteristic age distribution of *Plasmodium vivax* infections after malaria elimination on Aneityum Island, Vanuatu. *Infection and Immunity* 2014; **82**: 243–252.
8. **Isozumi R, *et al.*** Improved detection of malaria cases in island settings of Vanuatu and Kenya by PCR that targets the *Plasmodium* mitochondrial cytochrome c oxidase III (*cox*3) gene. *Parasitology International* 2015; **64**: 304–308.
9. **Hackett LW.** Spleen measurement in malaria. *Journal of National Malaria Society* 1944; **3**: 121–133.
10. **Chaves LF, *et al.*** Spleen rates in children: an old and new surveillance tool for malaria elimination initiatives in island settings. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 2011; **105**: 226–231.
11. **Watanabe N, *et al.*** Determinants of the use of insecticide-treated bed nets on islands of pre- and post-malaria elimination: an application of the health belief model in Vanuatu. *Malaria Journal* 2014; **13**: 441.
12. **Krishnamoorthy K, *et al.*** Altered environment and risk of malaria outbreak in South Andaman, Andaman & Nicobar Islands, India affected by tsunami disaster. *Malaria Journal* 2005; **4**: 32.
13. **Savage E, *et al.*** The Canadian Armed Forces medical response to Typhoon Haiyan. *Canadian Journal of Surgery* 2015; **58**: S146–S152.
14. **World Health Organization.** Public health risk assessment and interventions – Typhoon Haiyan, Philippines 16 November 2013. Manila, Philippines: World Health Organization Philippines, 2013.
15. **Tatarsky A, *et al.*** Preventing the reintroduction of malaria in Mauritius: a programmatic and financial assessment. *PLoS ONE* 2011; **6**: e23832.
16. **Dharmawardena P, *et al.*** Characterization of imported malaria, the largest threat to sustained malaria elimination from Sri Lanka. *Malaria Journal* 2015; **14**: 177.
17. **Chan CW, *et al.*** *Plasmodium vivax* and *Plasmodium falciparum* at the crossroads of exchange among islands in Vanuatu: implications for malaria elimination strategies. *PLoS ONE* 2015; **10**: e0119475.