Tropical Medicine and Health Vol. 38 No. 2, 2010, pp. 81-86

Short Communication

Mosquito breeding sites and People's knowledge of mosquitoes and mosquito borne diseases: A comparison of temporary housing and non-damaged village areas in Sri Lanka after the tsunami strike in 2004

Shin-ya Ohba[1, 2*], Saori Kashima[3], Hiromi Matsubara[1], Yukiko Higa[2], Udage Kankanamge D. Piyaseeli[4], Hideki Yamamoto[3] and Fusao Nakasuji[3, 5]
Received 13 September, 2009 Accepted 5 March, 2010 Published online 1 April, 2010

Abstract: Although it is very important in view of public health to understand the mosquito breeding sites and key reservoirs existing around residential areas, such information is lacking in temporary housing sites constructed after the serious tsunami strikes on 26 December 2004 in Sri Lanka. This study clarified the situation regarding mosquito breeding 14 months after the tsunami in Sri Lanka by surveying temporary housing and non-damaged village areas, and also by examining people's knowledge related to mosquito breeding sites and mosquito-borne diseases. The relative frequency of mosquito larvae in wastewater pools was significantly higher in temporary housing than in village areas. The prevalence of storage containers at temporary housing and village areas was not significantly different. It was found that wastewater pools in temporary housing sites were the main breeding site of *Culex quinquefasciatus* Say, *Cx. tritaeniorhynchus* Giles, and *Aedes albopictus* Skuse whereas storage containers in village areas were the main breeding site of *Cx. quinquefasciatus* and *Ae. albopictus*. No mosquitoes bred in storage containers in the temporary housing but some *Ae. albopictus* did so in village areas. The questionnaires indicated a significant difference between residents of temporary housing and villages in response to the question: Do you know where mosquitoes breed? The proportion of the "wastewater pools" response was higher among temporary housing residents than among village residents. This knowledge among temporary housing residents may relate to the fact that wastewater pools are latent breeding sites for mosquitoes in temporary housing sites. Although residents in the temporary housing sites put salt and abluent into storage containers to prevent mosquitoes from breeding, wastewater pools receiving a constant supply of wastewater provided the best breeding site for mosquitoes.

INTRODUCTION

A tsunami occurred on 26 December 2004 causing extensive damage to the Sri Lankan shoreline. Many people who lost their houses were compelled to live in temporary housing areas. To improve their quality of life and prepare for future disasters, the proportion of public health information on mosquito breeding sites and people's knowledge related to mosquitoes and mosquito borne diseases is necessary.

Kalutara, located in the southwest of Sri Lanka, was badly damaged by the tsunami. People in Kalutara had to move into basic living conditions with the emergency support of NGOs (Non-Governmental Organizations) and organizations of the United Nations. A half a million people in Kalutara lost their houses and 80% of these lost their means of livelihood as result of the tsunami [1].

There are vector mosquitoes (Diptera: Culicidae) of malaria, Japanese encephalitis, dengue fever, and filaria in Sri Lanka. The mosquito fauna in rice fields [2, 3], seasonal occurrence [4], and geographical features [5, 6, 7, 8] of vector mosquitoes and malaria were studied previously. Dengue and dengue hemorrhagic fever were endemic around the Kalutara district, and a few malaria cases were reported in recent years. Generally, mosquito breeding sites around residences exist in tree holes, rock holes, and tires [9, 10]. It was speculated that the large-scale change of environment as a result of the tsunami might have produced new

1 Graduate School of Natural Science and Technology, Okayama University, Tsushima, Okayama 700-8530, Japan
2 Department of Vector Ecology and Environment, Institute of Tropical Medicine, Nagasaki University, Sakamoto, Nagasaki 852-8523, Japan
3 Graduate School of Environmental Science, Okayama University, Tsushima, Okayama 700-8530, Japan
4 National Institute of Health Sciences, Nagoda Road, Kalutara, Sri Lanka
5 Present address: Sanyo 2-14-4, Akaiwa, Okayama 709-0827, Japan
*Corresponding Author:
Center for Ecological Research, Kyoto University, Otsu, Shiga 520-2113, Japan (Present address)
E-mail: oobug@hotmail.com

breeding sites for vector mosquitoes and influenced mosquito ecology, including density and species composition. It was considered important, therefore, to examine the mosquito breeding situation in areas affected by the tsunami. However, the relative frequency of mosquito breeding sites around temporary housing areas after the tsunami remains poorly understood in Sri Lanka.

For these reasons, we investigated mosquito breeding sites around residences in both temporary housing and non-damaged village areas. In addition, people's knowledge about mosquitoes and mosquito-borne diseases were examined using a questionnaire. The mosquito control measures after the tsunami in Kalutara, Sri Lanka are discussed.

MATERIALS AND METHODS

Study Site

Field collections to examine mosquito breeding sites in Kalutara (6°33'N, 79°58'E; Fig. 1) in Sri Lanka were conducted from 10 to 20 February 2006. This period was within the dry season. Katukurunda camp (KAC), Rangers Ground camp (RGC), Mahaheenatiyamgala camp (MC), Sumanarama camp (SC), Kalamulla Playa Ground camp (KGC), and Pulinathalaruma Temple camp (PT) were selected from among temporary housing sites, and Rosawatta (ROS), Weniwalkatiya (WEN), Rajawatha (RAJ), Kochikotuwa (KOC), Guwan Gama (GG), Kaleel Place (KP), and Kahchariya Wattha (KW) were selected as non-damaged village areas (Fig. 1). We defined a place where temporary housing was constructed within one month after the tsunami as a temporary housing site. Wooden houses were densely constructed in the temporary housing sites. A village areas that suffered no damage due to the tsunami was defined as a non-damage village area. The houses in non-damaged village area were made of concrete or wood. Generally, the population density in a temporary housing site was higher than that in a non-damaged area.

Mosquito collection

Collections were conducted around residences in both temporary housing and village areas. The presence or absence of mosquito larvae was confirmed in all aquatic habitats within each area. When mosquito larvae were found, the larvae were collected using a 500 μm mesh dipnet (8 ×

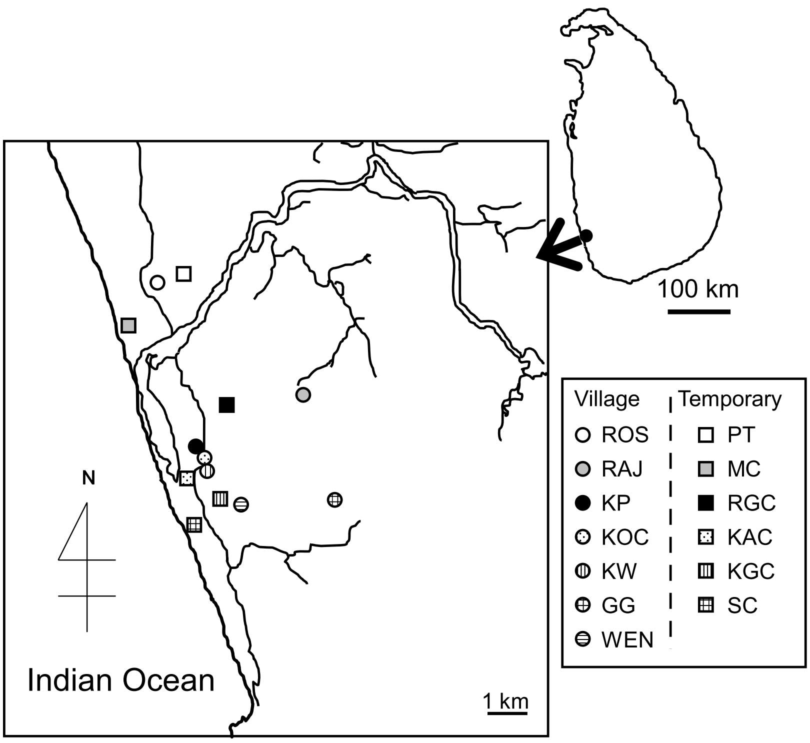

Fig. 1. Map showing study areas in Kalutara, Sri Lanka. Temporary housing sites: Pulinathalaruma Temple camp (PT), Maha Heenatiyamgala camp (MC), Rangers Ground camp (RGC), Katukurunda camp (KAC), Kalamulla Plya ground Camp (KGC), Sumanarama camp (SC). Non-damaged village areas: Rosawatta Village (ROS), Rajawatha Village (RAJ), Kaleel Place Village (KP), Kochikotuwa Village (KOC), Kahchariya Wattha Village (KW), Guwan gama (GG), Weniwalkatiya Village (WEN).

5 cm mouth opening) and pipette. When mosquito larvae were found in a large pool (>0.5 m diameter), the above-mentioned dipnet was pulled for 0.3 m along the water surface 5 times. The collected larvae were preserved in 70% ethanol until identification. All larvae, excluding damaged and/or 1st-3rd instar larvae, were identified. The breeding sites were classified into three categories: wastewater pool (including ditch), storage container (buckets, kettles and pots), and others (natural small pools, tap water tanks, rivers and fish aquaria) (Fig. 2). Wastewater was pooled from each household, the largest part of a wastewater pool being more than 50 cm and the shape circular, vertically long, and square. Although all wastewater pools in temporary housing sites had been made simply by excavation on the ground ad hoc, some of those in village areas were U-shaped concrete ditches. On the other hand, storage containers were made from column-shaped plastic, and the diameter was less than 50 cm. The mosquito-positive containers were not adequately covered with a lid in either temporary housing or village areas. The largest mosquito positive aquatic habitats were measured and classified into five categories: <30, 31-50, 51-100, and >100 cm.

Resident's Knowledge of Vector-borne Diseases

To elucidate residents' knowledge about mosquito problems, questionnaires were distributed by Public Health Instructors (PHI) in Kalutara. Each PHI randomly selected 20 houses in each area. The government had distributed posters describing mosquito problems and the sources of mosquito outbreaks to educate residents of temporary housing just after the tsunami. We expected to observe a difference in knowledge about mosquito problems between temporary housing and village areas. Two questions were posed: 1. Do you know where mosquitoes breed? (Multiple choice: Pond, River, Wastewater pools and Storage containers), 2. Do you feel that mosquitoes cause problems? (6 stage score from "serious = 1" to "not serious = 6").

Statistical Analyses

The proportion of mosquito larva-positivity in wastewater pools and storage containers was compared between temporary housing and village areas using Mann-Whitney U test. The median of largest size of mosquito positive aquatic habitat between temporary housing and non-damaged village areas was compared using Mann-Whitney U-test. The composition of breeding sites, species, and residents' knowledge of mosquito breeding sites (question 1) were compared between the two areas (temporary housing and village) using $R \times C$ tests of independence [11] after pooling of the data from the above-mentioned subsites. The answers to question 2 were compared for resi-

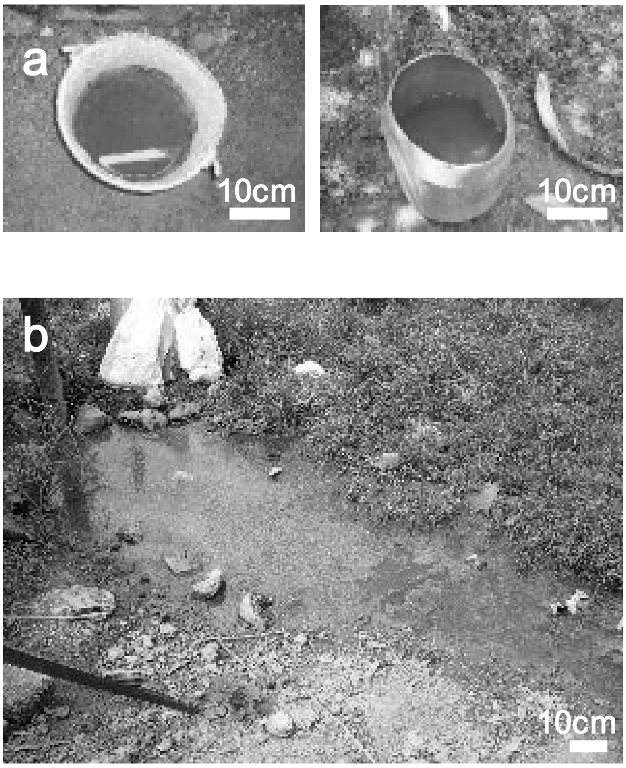

Fig. 2. Mosquito breeding sites in Kalutara, Sri Lanka. a) Storage containers in village areas, b) wastewater pool in a temporary housing sites.

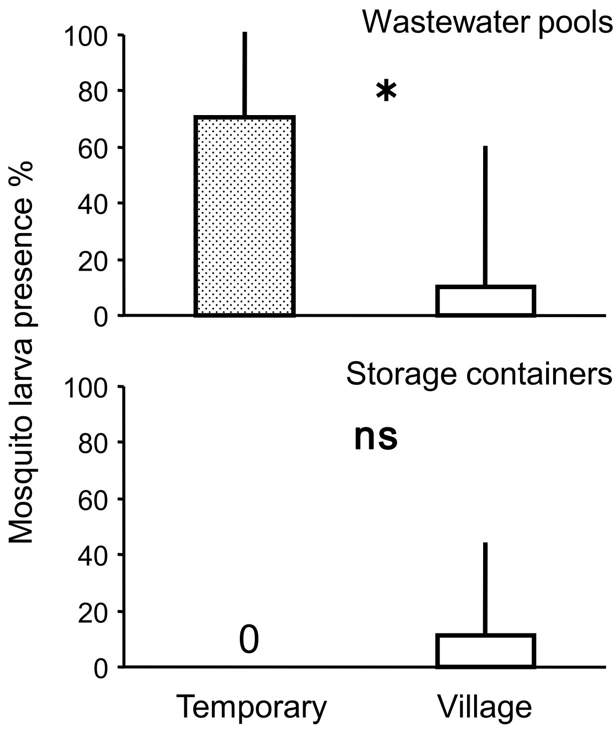

Fig. 3. Comparison of main potential mosquito breeding-habitats between the two housing types in Kalutara. Mean ± S.D. $^{*}P < 0.05$, Mann-Whitney U test.

dents of temporary housing and village areas using Mann-Whitney U test, excluding “no answer” responses. Statistical significance was inferred as $P < 0.05$. All calculations were performed using JMP software (JMP version 7, SAS Institute, 2007).

Ethical Considerations

This study was part of the work of the National Institute of Health Sciences, Sri Lanka. Questionnaire survey and field samplings were only conducted after the purpose of the study had been explained to residents, who were given the right to withdraw at any time without consequence.

RESULTS

Mosquito Breeding Sites

Mosquito breeding sites were comprised of wastewater pools in temporary housing and wastewater pools and storage containers in village areas (Table 1). The composition of the sites was significantly different between temporary housing and village areas ($R \times C$ tests, *d.f.* = 2, $\chi^2 = 10.6$, $P = 0.005$; Table 1). The relative frequency of mosquito larvae in wastewater pools was significantly higher in temporary housing than in village areas (Mann-Whitney, $Z = 2.85$, $P = 0.004$; Table 1). The prevalence of storage containers at temporary housing and village areas was not significantly different ($Z = 1.29$, $P = 0.199$). These results showed that wastewater pools were the main mosquito breeding sites in temporary housing areas.

Table 1. Number of containers positive in each study site.

			Storage containers				Wastewater pools				Others*			
Housing type	Name of settlement	Abbr.	+	-	Total	Positive %	+	-	Total	Positive %	+	-	Total	Positive %
Temporary housing site	Katukurunda camp	KAC	0	33	33	-	10	6	16	62.5	0	2	2	-
	Kalamulla Playa Ground camp	KGC	0	12	12	-	3	1	4	75.0	0	0	0	-
	Maha Heenatiyangalal camp	MC	0	26	26	-	2	2	4	50.0	0	0	0	-
	Pulinathalaruma Temple camp	PT	0	6	6	-	2	1	3	66.7	0	0	0	-
	Rangers Ground camp	RGC	0	42	42	-	1	0	1	100.0	0	2	2	-
	Sumanarama camp	SC	0	0	0	-	0	3	3	-	0	0	0	-
Village area	Guwan Gama	GG	2	7	9	22.2	0	1	1	-	0	0	0	-
	Kochikotuwa	KOC	0	0	0	-	0	0	-	-	1	0	1	100.0
	Kaleel Place	KP	0	8	8	-	5	7	12	41.7	0	1	1	-
	Kahchariya Wattha	KW	3	11	14	21.4	0	1	1	-	1	0	1	100.0
	Rajawatha	RAJ	0	2	2	-	0	3	3	-	0	1	1	-
	Rosawatta	ROS	0	6	6	-	1	1	2	50.0	0	1	1	-
	Weniwalkatiya	WEN	2	4	6	33.3	0	4	4	-	0	1	1	-

+: no. mosquito positive containers, -: no. mosquito negative containers
*Others include rivers and fish aquaria.

Table 2. Mosquito species and number of individuals in temporary housing and village areas.

		Temporary housing							Village							
Habitat type		KAC	KGC	MC	PT	RGC	SC	Total	GG	KOC	KP	KW	RAJ	ROS	WEN	Total
Wastewater pools	No. mosquito larvae	101	235	1	1855	485	4	2681	0	0	5	0	0	29	0	34
	No. identified	53	95	1	503	213	1	866	0	0	5	0	0	18	0	23
	Cx. quinquefasciatus	51	-	-	496	210	1	758	-	-	-	-	-	17	-	17
	Cx. tritaeniorhynchus	-	93	-	-	-	-	93	-	-	-	-	-	-	-	0
	Culex spp.	-	2	-	7	-	-	9	-	-	-	-	-	-	-	0
	Ae. albopictus	-	-	1	-	-	-	1	-	-	-	-	-	-	-	0
	Armigeres spp.	-	-	-	-	3	-	3	-	-	5	-	-	-	-	5
	Lutzia spp.	2	-	-	-	-	-	2	-	-	-	-	-	1	-	1
Storage containers	No. mosquito larvae	0	0	0	0	0	0	0	6	0	0	76	0	0	12	94
	No. identified	0	0	0	0	0	0	0	6	0	0	27	0	0	12	45
	Cx. quinquefasciatus	-	-	-	-	-	-	0	6	-	-	-	-	-	-	6
	Cx. tritaeniorhynchus	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0
	Culex spp.	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0
	Ae. albopictus	-	-	-	-	-	-	0	-	-	-	27	-	-	12	39
	Armigeres spp.	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0
	Lutzia spp.	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0

From the wastewater pools, a total of 2,681 mosquito larvae (758 *Cx. quinquefasciatus*, 93 *Cx. tritaeniorhynchus*, 9 *Culex* spp., 1 *Ae. albopictus*, 3 *Armigeres* spp. and 2 *Lutzia* spp.; a natural enemy of mosquitoes) were collected from temporary housing areas (Table 2). On the other hand, only 34 mosquito larvae (17 *Cx. quinquefasciatus* and 5 *Armigeres* spp. and 1 *Lutzia* spp.) were collected from village areas. The species composition of mosquito larvae in wastewater pools was significantly different between temporary housing and village areas ($R \times C$ tests, $d.f. = 5$, $\chi^2 = 128.4$, $P < 0.001$). Although no mosquito larvae were found in storage containers in temporary housing, 94 mosquitoes (6 *Cx. quinquefasciatus* and 39 *Ae. albopictus*) were collected from storage containers in village areas. Larvae of *Anopheles* spp. were not found in either temporary housing or village areas. The size of mosquito positive aquatic habitat in temporary housing was significantly larger than that in non-damaged village areas (Mann-Whitney, $Z = 2.12$, $P = 0.034$).

Resident's Knowledge on Vector-borne Diseases

The recovery rate for completed questionnaires was 98.1% (260 distributed, 255 collected). The basic information on respondents was as follows: Age: Temporary; 40.64 ±13.42 (S.D.), 19-79 (min.-max.), Village; 50.77±13.89, 19-86, Family; Temporary; 4.03±1.45, 1-8, Village; 4.38± 1.45, 2-10, Sex: Temporary; 90, 22 (male, female), Village; 110, 28. The questionnaire sheet census indicated significant differences between the responses of temporary housing and those of village residents to question 1 (Do you know where mosquitoes breed?) ($R \times C$ tests, $d.f. = 4$, $\chi^2 = 23.6$, $P < 0.001$; Fig. 4). Government efforts improved the awareness of people living in temporary housing areas. The proportion of "no answer" response was higher among village residents (23%) than among temporary housing residents (13%). In contrast, the proportion of "wastewater pools" response was higher among temporary housing residents (61%) than among village areas (38%). While no significant difference in awareness of problems caused by mosquitoes was observed between temporary housing and village areas (median score = 4 for both areas, Mann-Whitney, $Z = 0.55$, $P = 0.58$).

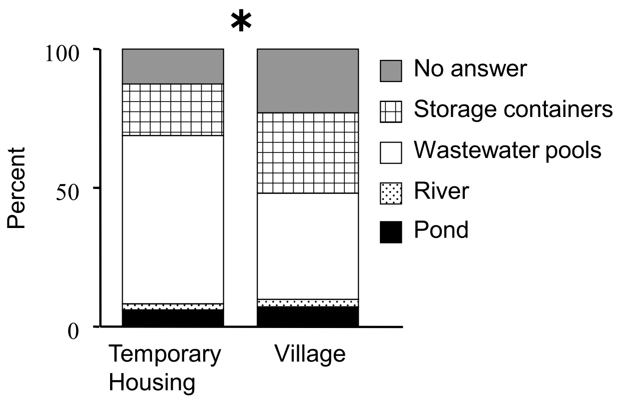

Fig. 4. Results of questionnaire concerning the composition of breeding site (Do you know where mosquitoes breed? [Multiple choice: Pond, River, Wastewater pools, Storage containers)]. $^*P < 0.05$, $R \times C$ tests of independence.

DISCUSSION

Mosquitoes bred occasionally in storage containers in village areas but not in temporary housing sites (Table 1 and 2). These results may reflect the thoroughness of education and heightened awareness of people living in temporary housing. People in the temporary housing sites put salt and abluent in storage containers to prevent mosquitoes from breeding. In addition, people in temporary housing areas split coconuts before throwing them out on dump sites (S. Ohba, unpublished data), which reduced the accumulation of small water reservoirs. These efforts will decrease the density of container-breeding mosquito, *Ae. albopictus* (Table 2).

In contrast to storage containers, vector mosquito larvae (*Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, and *Ae. albopictus*) proliferated in wastewater pools fed from each household in temporary housing sites (Table 1 and 2; Fig. 2-b). Wastewater pools did not disappear because they had been made simply by excavation. In addition, further wastewater was supplied constantly to the pools by residents, creating a breeding site preferred by *Cx. quinquefasciatus* [12]. Thus, wastewater pools provided the best breeding site for *Cx. quinquefasciatus* and will continue to do so until removed from around temporary housing sites.

In village areas, vector mosquito larvae (*Cx. quinquefasciatus* and *Ae. albopictus*) bred in some storage containers in gardens (Table 1 and 2, Fig. 2-a), whereas few vector mosquito larvae appeared in wastewater pools. Wastewater pools in village areas were smaller than those in temporary housing sites (S. Ohba, unpublished data), suggesting that they are more likely to dry up occasionally.

In conclusion, it was found that wastewater pools in temporary housing areas were breeding sites of *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, and *Ae. albopictus*, whereas storage containers in village areas were breeding sites of *Cx. quinquefasciatus* and *Ae. albopictus*. Eliminating wastewater pools in temporary housing areas and storage containers in village areas may be an effective approach to reducing the risk of mosquito-borne diseases.

AUTHORS' CONTRIBUTIONS

SO conceived the question, carried out the field samplings, performed final analyses, and drafted the manuscript. SK and HM made questionnaire sheets and reviewed the manuscript. YH checked mosquito species and improved the manuscript. HY, UKDP and FN participated in the design of the study. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

We wish to express our appreciation to H. Tsumuki and S. Yanagi of Okayama University for their valuable comments. We thank T. Ikemoto of Teikyo University for assisting with the identification of mosquito larva, and the public health instructors and other members of the National Institute of Health Sciences for their assistance. We also thank the Nilmini family and D.S. Amal for their kind support. This study was supported in part by Initiatives for Attractive Education in Graduate Schools by the Ministry of Education, Culture, Sports, Science and Technology, Japan (b-4).

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