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Review

MALARIA ENDEMIC PATTERNS ON LOMBOK AND SUMBAWA ISLANDS, INDONESIA

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ABSTRACT: Nusa Tengara Barat (NTB) province consists of two main islands, Lombok and Sumbawa, to the east of Bali Island, Indonesia. Most of the area is known to be moderately malaria endemic, but the exact malaria epidemiology has not been elucidated. At least 30 deaths per year are thought to be caused by falciparum malaria in Lombok alone, judging from the hospital data. According to the Gebrak Malaria Team in West Lombok, the annual incidence in the district of West Lombok from 1996 to 1999 was consistently over 40‰.

In the present report, we describe the small malaria endemic foci in the West Lombok and Sumbawa districts. Falciparum malaria is predominant over vivax malaria and other types of malaria. There are 11 species of *Anopheles* vector, but three of these species, *An. subpictus*, *An. maculates* and *An. barbirostris*, are of primary importance in malaria transmission and *An. sundaicus* and *An. aconitus* are of secondary importance. Our data from Sekotong, West Lombok, and Sumbawa supported the importance of *An. subpictus* in coastal areas but suggested the existence of different transmission peaks according to environmental conditions. The usual transmission peak comes in the dry season but is affected by climatic and geographical conditions. Although there were many malaria endemic foci along the coast, the width and grade of the foci varied widely. The presence of malaria endemic foci inland, although likely, has not been definitively reported to date.

INTRODUCTION

Indonesia is known as a country where tourists are at a high risk for malaria infection. But the incidence of malaria varies widely among different islands and even among different areas of the same island. It is important to obtain exact information on the epidemiological conditions of malaria on each island. In this report, we describe the epidemiology of malaria in parts of Lombok and Sumbawa islands on the basis of our experience and local data (Fig.1).

1) Malaria situation in Indonesia;

Malaria is still a major public health problem in Indonesia. In 1995, the National Health Household Survey estimated that around 32,000 deaths were caused by malaria. [1]. Indonesia is a large archipelago consisting of 12,508 islands of various sizes and shapes located along the equator and had a total population of 209 million in 1999. About 70% of the population live in Java and Bali, where malaria has been mostly eradicated, although even today small outbreaks are reported every year. In the outer islands, however, a much higher incidence of malaria is seen in general. But the incidence of malaria varies from hypo-to hyper-endemic depending on the environmental and socio-economic conditions of an area. The natural and social environment of the Indonesian islands varies widely, resulting in different malaria conditions. Furthermore, even on a single island, malaria endemic situations vary in degree and

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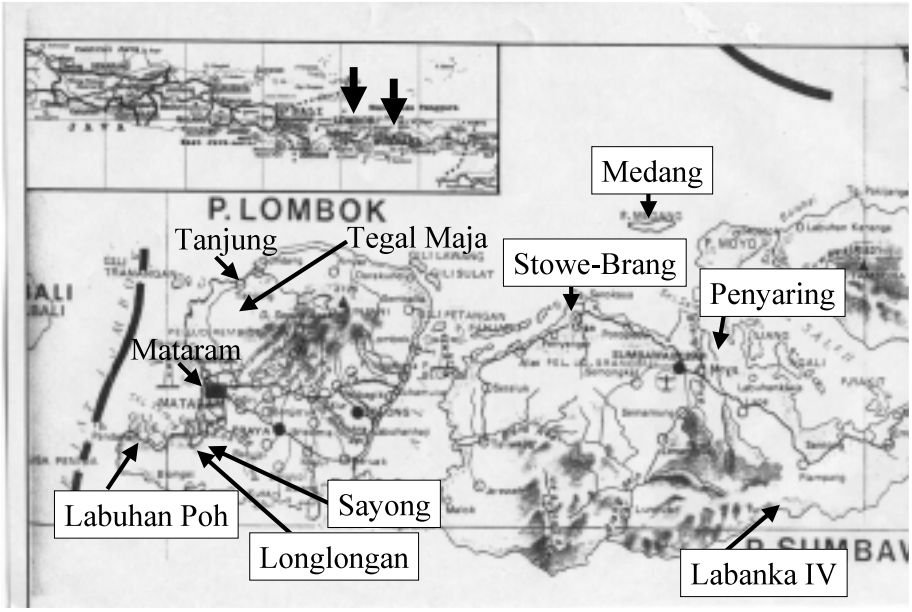

Fig. 1 Location of places described in the text on Lombok and Sumbawa islands, Indonesia

size according to geographical conditions. No exact information on malaria epidemiology in each area has been published, especially in English. In this review, we introduce the conditions of malaria in Lombok and Sumbawa islands based on our epidemiological studies conducted under Japan Society for the Promotion of Science (JSPS) sponsorship, and on local data and reports offered by concerned health organizations.

2) The collaborative survey of Indonesian and Japanese researchers; In 1991 we had an opportunity to conduct an epidemiological malaria survey on Lombok island as one of the collaborative works in a large scale cooperative study between Kobe University School of Medicine, Japan and the Tropical Disease Center (TDC), Airlangga University, Surabaya, Indonesia under the sponsorship of JSPS. The malaria epidemiological study was carried out continuously in Lombok and later in Sumbawa for ten years until the JSPS project reached completion in 2000.

3) Malaria situation in West Lombok; The West Lombok district is located in the western part of Lombok island, NTB province. The province is composed of two major islands, Lombok and Sumbawa, each of them containing three districts. The capital of the province is the municipality Mataram, which is located in the center of West Lombok district. West Lombok consists of nine subdistricts, in all of which malaria is endemic. According to the report by Gerback Malaria Team in West Lombok [2], the annual incidence in the district was over 40 per 1,000 population every year from 1996 to 1999. Falcipaum malaria is more common than vivax and other types of malaria. The transmission peak is usually observed between July and September. There are 11 species of *Anopheles* vector but, of these, three, *An. subpictus*, *An. maculates* and *An. barbirostris*, are of primary importance in malaria transmission and *An. sundaicus* and *An. aconitus* are of secondary importance.

Figure 2 shows the monthly slide-positive cases observed in 2000 and 2001 in Tanjung and Tegal Maja villages by the health center in Tanjung, which is located in the northernmost part of West Lombok. The village of Tanjung lies on the northern coast while the village of Tegal Maja is located south of it in the inland. At the former, the clear peak of malaria cases was seen in October, which was two months later than the usual transmission peak between July and

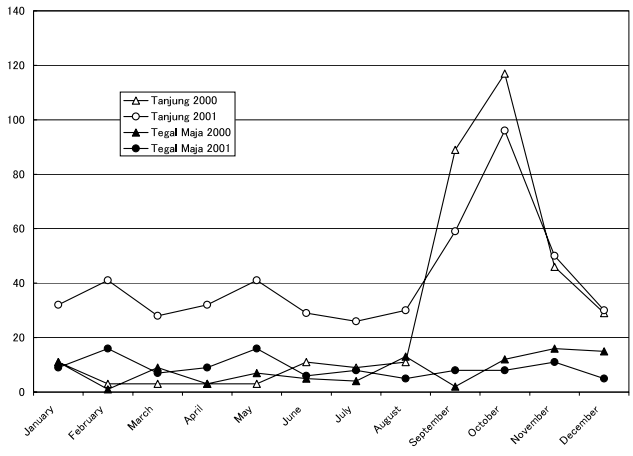

Fig. 2 Number of slide positive cases in two villages of Tanjung health center

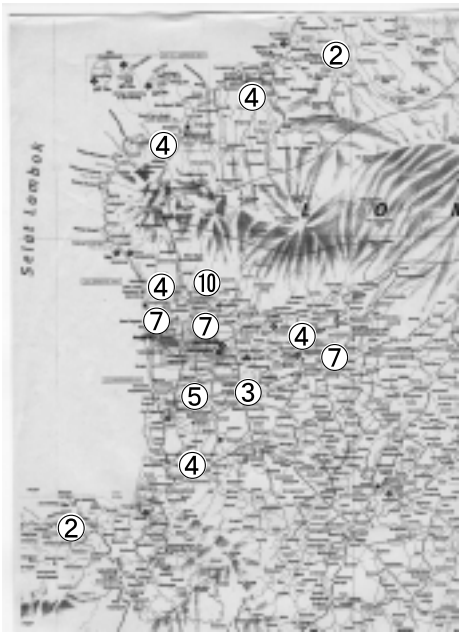

Fig. 3 Number of cerebral malaria cases at Mataram hospital shown by the place of residence

September mentioned in the local report [2]. This type of transmission is thought to be caused by *An. sundaicus* rather than *An. subpictus* according to a previous study by one of the present authors [3]. We obtained the data on malaria patients hospitalized in the Mataram hospital in 2001 and the first half of 2002. In total, 809 malaria patients were hospitalized. These were composed of 580 falciparum malaria patients including 71 with cerebral malaria, 54 vivax malaria patients and 175 clinical malaria patients. A total of 39 died of falciparum malaria, and 29 of these were cerebral malaria patients. We marked the number of cerebral malaria patients on a map according to the place of residence recorded in their patient-reports (Fig. 3). The cases were distributed equally in coastal and inland areas. This indicates that more careful attention should be given to the inland areas to identify malaria endemic foci.

STUDIES IN WEST LOMBOK

1) Survey areas in West Lombok

Malaria epidemiological study target areas were selected on the basis of discussions between TDC and the Nusa Tenggara Barat (NTB) provincial health office. The subdistricts (kecamatan) Batulayar and Sekotong were selected for the preliminary survey. Subjects for blood and spleen examination were randomly selected from different subvillages (dusun) in the two subdistricts. A total of 36 subvillages, or 10 from Batulayar and 26 from Sekotong, were subjected to the survey. Although the number of persons examined in each subvillage was too small for evaluation, we selected three subvillages in Sekotong for the longitudinal survey, namely, dusun Labuhan Poh from desa (village) Sekotong Barat, and dusun Longlongan and Sayong from desa Sekotong Tengah. (Fig. 1, Fig. 4 and Table 1).

2) Geographical differences among subvillages (Table 1)

At subvillage Labuhan Poh, the land gradually rises away from the coast toward the inland. The largest river in this village passes through the subvillage and creates a wide lagoon during the dry season (Photo. 1). Many branches of

Fig. 4 Geographical distribution of the three subvillages selected for malaria survey at Sekotong

Table 1 Geographical features and population of three subvillages of Sekotong Barat and Tengah in 1992

Subvillage	hill	wet rice field	beach	dry field	population
Labuhan Poh	16.5%	0	21.3%	62.2%	855
Sayong	30.6%	67.7%	1.7%	0	1,247
Longlongan	71.5%	4.3%	16.1%	8.1%	805

Photo 1. A huge lagoon formed after closing the river's exit to the sea at Labuhan Poh, Sekotong, West Lombok

the river extend into mangrove areas where large mangrove trees have been cut for fuel, leaving many water pools exposed to sunshine and resulting in breeding places for brackish species of *Anopheles* mosquitoes such as *An. sundaicus* and *An. subpictus*. Subvillage Sayong lies on flat ground. Most of the area is occupied by wet rice fields, and in the coastal part of the flat land once covered by mangrove forest, fish ponds were made after the removal of mangrove trees. Subvillage Longlongan has a complex topography; the narrow flat land along the coast, originally mangrove forest, was developed for fish ponds, and the following sharp sloping land leads to a rather flat hilly area where rice fields were developed between stands of grass or bush in the rainy season.

3) Survey methods and subjects

The longitudinal survey was started in August 1992 and carried out five times until June 1993 [4]. At the initial step, in order to determine the seasonal changes in malaria transmission, we intended to collect blood samples from the same subjects randomly selected from all age groups through all the surveys in a year. After the third survey, however, we had to replace the subjects with a new group composed of almost the same proportion of age groups, because of difficulties encountered in obtaining informed consent and cooperation from the former subjects. In the survey, the subjects were usually gathered in one place such as a school or a village health office (pustu) on an appointed date, and a 1−2 ml venous blood sample was obtained from each person along with in a syringe, a drop of blood for thin smear and another drop for thick smear on separate slide-glasses. The blood in a syringe was transferred into a small tube for serum collection. All the samples were carried to TDC for parasitological and serological examination. Medical examination was administered to each person after blood collection, and if necessary, medicines were given. On the same day the entomological survey was conducted, consisting of the examination of breeding sites and larva collection in the daytime, and adult mosquito collection at night.

4) Malaria prevalence in the survey areas

Table 2 and Fig. 5 present the results of the blood examinations. We cannot accurately compare the results of the first three surveys with those of the last two surveys because of the replacement of subjects. In total, the malaria positive rate gradually declined after the first survey in August 1992. However, the malaria transmission trend in each subvillage differed from that in others (Fig. 5). A relatively stable slide positive rate was found in dusun Labuhan Poh in August, October and December 1992, while in other subvillages it varied by month, especially in dusun Longlongan.

Table 2 Results of blood examinations in a longitudinal malaria survey conducted in three subvillages of Sekotong, Lombok from August 1992 to June 1993

	August 1992					October 1992					December 1992				
Subvillage	PR	Number of positive cases				PR	Number of positive cases				PR	Number of positive cases			
	%	Pf	Pv	Pm	Mix	%	Pf	Pv	Pm	Mix	%	Pf	Pv	Pm	Mix
Labuhan Poh	11.5 (14/122)	10	4	0	0	9.8 (12/122)	9	2	0	1	12.3 (15/122)	11	3	0	1
Sayong	11.9 (18/151)	6	11	0	1	6.0 (9/150)	4	5	0	0	6.0 (9/150)	4	5	0	0
Longlongan	21.1 (20/95)	12	8	0	0	6.4 (6/95)	5	1	0	0	2.1 (2/95)	1	1	0	0
Total	14.1 (52/368)	28	23	0	1	7.4 (27/367)	18	8	0	1	7.1 (26/367)	16	9	0	1

	April 1993					June 1993				
Subvillage	PR	Number of positive cases				PR	Number of positice cases			
	%	Pf	Pv	Pm	Mix	%	Pf	Pv	Pm	Mix
Labuhan Poh	3.7 (4/107)	3	1	0	0	1.1 (1/89)	0	0	1	0
Sayong	0.72 (1/139)	1	0	0	0	0 (0/129)	0	0	0	0
Longlongan	1.0 (1/98)	1	0	0	0	9.0 (8/89)	5	2	0	1
Total	1.7 (6/344)	5	1	0	0	2.9 (9/307)	5	2	1	1

PR, positive rate; Pf. *Plasmodium falciparum*; Pv, *Plasmodium vivax*; Pm, *Plasmodium malariae*; Mix, mix infection; ( ), actual number

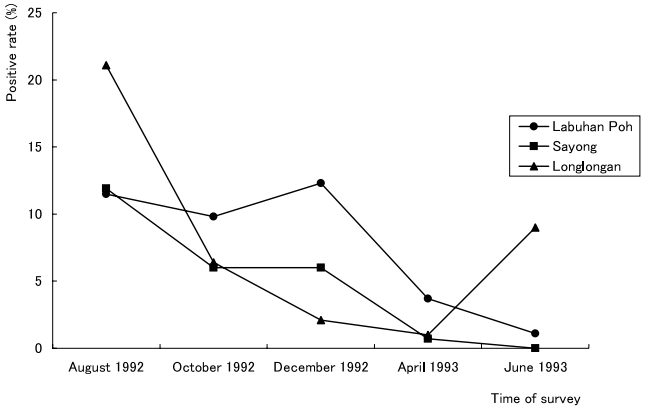

Fig. 5 Slide positive rates in the three subvillages of Sekotong, Lombok from August 1992 to June 1993

This difference may be attributable to the different environmental and geographical conditions of each subvillage (Table1). Especially in dusun Longlongan, the malaria in the hilly area may have a different transmission mode.

5) Entomological observation in the survey area

The results of the entomological examination also showed a wide variety (Table 3 and 4). As expected, a relatively stable number of adult *Anopheles subpictus* mosquitoes were captured at all three subvillages, especially at dusun Labuhan Poh (Table 3), but *An. sundaicus*, *An. barbirostris* and *An. aconitus*, which have been recognized as malaria vectors in Indonesia, were captured sporadically once or twice in five surveys conducted one year except *An. sundaicus* at dusun Labuhan Poh [4, 5]. The fluctuation in the number of captured mosquitoes suspected to be malaria vectors did not correspond to the parasitological data (Table 2, 3 and Fig. 5). The most stable larva collection of the brackish *Anopheles* species was obtained at lagoon and mangrove areas in dusun Labuhan Poh but at fish-ponds in dusun Sayong and Longlongan (Table 4). These results, taken with the parasitological data, indicate that *An. subpictus* (and additionally *An. sundaicus*) play a major role in malaria transmission in these subvillages. The previous intensive study on mosquito fauna in Lombok island by Lee et al.

Table 3 Adult collection of *Anopheles* species known as malaria vector in three subvillages of Sekotong (1992-1993)

SUBVILLAGE	COLLECTION METHOD	Aug 92	Oct 92	Dec 92	Apr 93	Jun 93
		(species / no. mosq. collected per night*)				
LABUHAN POH	Outdoor Human Bait (OHB)	sub/14 sun/4	sub/9 sun/8	sub/6 sun/2	bar/14 sub/4	sub/6 sun/3
	Indoor Human Bait (IHB)	sub/2	sub/11 sun/22	sub/6 sun/5	0 0	sub/4
	Indoor Resting (IR)	0	sun/5	0	0	0
	Bednet Trap (BT)	0	sub/7 sun/16	0	0	0
	Cattle Bait (CB)	sub/11 sun/1 bar/1	sub/12	sub/1	sub/2 acon/1	sub/5 sun/1
SAYONG	OHB	sub/7	sub/14 sun/3	sub/10 acon/5	sub/8 acon/1	sub/1
	IHB	0	sub/4	sub/9 acon/2	acon/2	0
	IR	0	0	0	0	0
	BT	bar/1	0	0	0	0
	CB	sub/5	sub/16	sub/6	acon/4 sub/9	sub/9
LONGLONGAN	OHB	sun/3	sub/15 sun/3	sub/4	sub/19	0
	IHB	0	sub/3 sun/1	sub/17 sun/1	sub/3	sub/1
	IR	0	0	0	0	sub/1
	BT	sun/1	0	0	0	—
	CB	sub/7 bar/1	sub/17	sub/8	sub/10 acon/7	sub/9 acon/1

*40 min per hour from 6 pm−12 pm.

sub, *Anopheles subpictus*; sun, *An. sundaicus*; acon, *An. aconitus*; bar, *An. barbirostris*

Table 4 Type of breeding place and density of *Anopheles* larvae (per dip) in three subvillages of Sekotong

Type Br. Pl.	*Anoph*. Species	Aug. 92	Oct. 92	Dec. 92	Apr. 93	Jun. 93
Labuhan Poh						
I. Lagoon	1. *An. subpictus*	n. d.	1.87	1.30	1.40	0.95
	2. *An. sundaicus*	n. d.	0.70	0.40	0	0.30
II. River	1. *An. flavirostris*	1.00	0	0	0	0
	2. *An. minimus*	0.50	0	0	0.70	0
	3. *An. vagus*	0	0	0	0.11	0.10
	4. *An. subpictus*	1.56	0	1.50	0	0
	5. *An. sundaicus*	0.12	0	0	0	0
III. Mangrove	1. *An. subpictus*	1.00	0	1.60	0.67	(−)
	2. *An. sundaicus*	0	0	0.40	0	(−)
IV. Rice field	1. *An. vagus*	(−)	(−)	1.40	(−)	0.10
V. Fishpond	1. *An. subpictus*	(−)	(−)	(−)	0.10	0
Sayong						
I. Fishpond	1. *An. subpictus*	0.80	0.80	1.00	0.05	0.90
	2. *An. sundaicus*	0	0	0	0.05	0
	3. *An. annularis*	0	0	0	0.05	0
II. Rice field	1. *An. aconitus*	0	0	0.40	0.60	0.25
	2. *An. barbirostris*	0.70	0	0	0	0
	3. *An. vagus*	0	1.50	2.20	0	0.28
III. Fresh water	1. *An. barbirostris*	0.60	0	0	0	0
	2. *An. annularis*	0	0	3.40	0.60	0
Longlongan						
I. Well	1. *An. barbirostris*	0.40	0	0	0	0.35
	2. *An. annularis*	0	0	0	0.10	0
	3. *An. vagus*	0	0	1.20	3.00	0.70
II. River	1. *An. aconitus*	0.02	0	0	0	0
	2. *An. barbirostris*	0.77	0	0	0.40	0
	3. *An. vagus*	0.85	0.67	1.80	0	0.23
III. Ricefield	1. *An. barbirostris*	0	0.05	0	0.25	0.01
	2. *An. annularis*	0	0	0	0.01	0.01
	3. *An. vagus*	1.00	0.80	4.20	2.07	0.55
IV. Fishpond	1. *An. subpictus*	0.08	1.38	1.20	1.80	1.03

(−), no water at the time examined; Br. Pl., Breeding Place; n. d., not done

identified three *Anopheles* species, *An. annularis*, *An. barbirostris* and *An. subpictus*, as potential vectors [6]. Recently, Miyagi et al also found *An. subpictus* and *An. sundaicus* in coastal areas and *An. barbirostris*, *An. leucosphyrus* group and *An. minimus* in fresh water and cited them as potential vectors [7]. In 2001, Sukowati, S. et al., Health Ecology Research Center, NIHR&D found *Plasmodium falciparum* (*P. f.*) sporozoite-positive *An. subpictus* in this area (report to the Indonesian health ministry). In the subvillage Longlongan, in addition to the coastal area, malaria was found in the hilly area where more than half of the population of this subvillage live, but we could not determine the vector mosquitoes there. Because of windy conditions and the collection confined to one night during the survey, the entomological staff were able to capture only a few adult mosquitoes. From the larvae examination we inferred two probable transmission vectors. One is *An. barbirostris*, the larvae of which were found in rice-fields, stagnant water along small rivers and wells, and the other is *An. subpictus*, which was consistently found in fish ponds along the coast and is thought to be able to move back and forth between the coast and the hills with the wind.

6) Endemic situation of malaria

We selected subjects equally from all the age groups to determine the degree of endemicity. Our results showed no difference in malaria prevalence among age groups [4] (data, not shown), indicating a hypo-or meso-endemic pattern in the area. The additional serological examination of antibodies to *P. f.* crude antigens using ELISA also demonstrated a meso-endemic pattern at dusun Labuhan Poh (Fig. 6), that is, the positive rate was low (about 20%) at the age of 0 but rose to nearly 100% at the age of 6 or over. In this area, three *Plasmodium* species were detected, that is, about

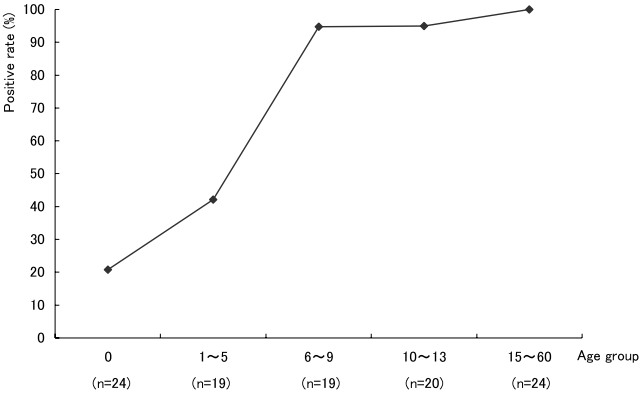

Fig. 6 Sero-positive rate to P. f. crude antigens among persons examined in subvillage Labuhan Poh in October 1992

60% *P. falciparum*, 40% *P. vivax* and only one *P. malariae* (Table 2). The *P. malaria* case was confirmed by PCR using the ribosomal DNA sequence [8]. Our results did not confirm the peak of transmission between July and September as described in the local report [2].

STUDIES IN SUMBAWA

1) Survey areas in Sumbawa

In Sumbawa, four subvillages in different subdistricts were examined for prevalence of malaria from 1996 to 1999 (Fig. 1). One subvillage, dusun Medang, is a small island accessible in one hour from Sumbawa Besar by small motorboat. In this subvillage, the preliminary spleen examination was

Table 5 Parasite positive rate and spleen rate in the longitudinal survey conducted in three subvillages of Sumbawa

	December 1996					July 1997				
Subvillage	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)
Penyaring	7.1 (8/112)	7	1	0	0	—	—	—	—	—
Labangka IV	14.3 (16/112)	10	6	0	8.0	7.1 (8/112)	4	4	0	14.3
Stowe Brang	33.9 (38/112)	8	25	5	25.9	15.3 (17/111)	13	3	1	34.2
Total	18.5 (62/336)	25	32	5	11.3	11.2 (25/223)	17	7	1	16.0*
	March 1998					October 1998				
Subvillage	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)
Penyaring	1.8 (2/112)	2	0	0	0	0.9 (1/112)	1	0	0	0
Labangka IV	0.9 (1/112)	1	0	0	0	13.0 (9/69(74))**	4	3	2	23.0
Stowe Brang	8.0 (9/112)	7	2	0	12.5	1.8 (2/112)	1	1	0	4.5
Total	3.6 (12/336)	10	2	0	4.2	14.1 (12/293)	6	4	2	7.4
	December 1998					February 1999				
Subvillage	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)	Positive Rate (%)	Number of positive cases Pf	Pv	Mix	Spleen Rate (%)
Penyaring	0.9 (1/112)	1	0	0	0	3.6 (4/111)	3	1	0	0
Labangka IV	5.3 (5/95)	1	4	0	1.1	5.4 (6/111)	2	3	1	0
Stowe Brang	0 (0/112)	0	0	0	0	ND (—/108)	ND	ND	ND	0.9
Total	1.9 (6/319)	2	4	0	0.3	4.5 (10/222)	5	4	1	0.3

P. f., *Plasmodium falciparum*; P. v., *Pl. vivax*; Mix, mix infection

—,data lost

* The number of subjects in Penyaring was assumed to be 112.

** 74 persons were subjected to spleen examination, but only69of these underwent blood examinations.

ND, not done

conducted on 161 1st and 2nd grade school-children and showed a 42.9% spleen rate (meso-endemic), but afterwards neither blood nor mosquito examinations was conducted because of the risk of the available boat capsizing. Therefore, three subvillages were selected for the longitudinal survey. The methods were the same as those used in Lombok.

2) Malaria prevalence in the Sumbawa survey areas

The slide positive rates and spleen rates at three subvillages are shown in Table 5. All three subvillages are located along the coast. Subvillage Penyaring and Stowe Berang face the ocean to the north and subvillage Labangka IV to the south. The former two subvillages are geographically similar. They have mangrove beaches and flat lands. The mangrove beaches were developed for fish ponds in both subvillages. Despite the environmental similarities, subvillage Penyaring showed a very low slide-positive rate and 0% spleen rate, while dusun Stowe Berang showed rather high positive rates for both examinations. Subvillage Labangka IV showed a medium endemic pattern with seasonal epidemics.

3) Entomological observation and epidemiological analysis

The entomological examination clearly demonstrated a high density of adults and larvae of *An. subpictus* at subvillage Stowe Berang but a very low density at subvillage Penyaring (data, not shown). This was due to the difference in breeding sites between the two subvillages, namely, many abandoned fish-ponds with algae and weeds were found at the former (Photo. 2) while most of the fish ponds were well maintained at the latter. The sharp decline in positive rates for spleen and blood examinations at dusun Stowe Berang from October 1998 was due to two malaria control projects conducted from January 1998 for a year, that is, the distribution of insecticide impregnated mosquito-nets and the cleaning of abandoned fish-ponds (Fig. 7). Our reports in 1996 and 1997 note that these control projects were conducted by the Sumbawa district health office, and suggest that the control methods worked effectively. In subvillage Labangka IV, an outbreak of malaria was observed just before our survey in October 1998. This subvillage has a very narrow sandy beach with a steep cliff rising behind. A rather flat hilly area spreads away from the cliff. The entomological survey found that the captured *Anopheles* mosquitoes were exclusively *An. subpictus* and that there were several lagoons on a small beach where *An. subpictus* larvae bred. According to staff in the Sumbawa district health office, the outbreak may be related to the custom of villagers to gather around the cliff (cape) at night to catch a species of bird during this season.

Photo 2. An abandoned fish pond at Stowe Brang, Utan, Sumbawa

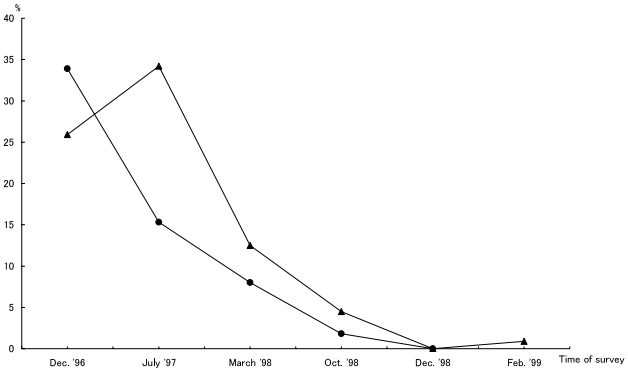

Fig. 7 Changes in slide−positive rate (●) and spleen rate (▲) in Stowe Brang, Sumbawa during the three−year period after malaria control activities in January 1998

SUMMARY

Although our data are still insufficient to determine the full range of epidemiological features, we can draw the following conclusions about malaria in Lombok and Sumbawa.

1) Malaria endemic areas are located mainly along the seacoast and less frequently inland.

2) The degree of endemicity is hypo-endemic to meso-endemic.

3) The main transmission vectors are *Anopheles subpictus* and *An. sundaicus*, which breed in brackish water.

4) Although similar species of vector play a role in transmission in coastal endemic foci, the mode and the season of transmission vary with the ecological characteristics of the vector and social and environmental conditions.

5) Small endemic foci are found in hilly areas inland, but the responsible vector species have not been determined.

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