The impact of development and malaria control activities on its vectors in the Kinabatangan area of Sabah, East Malaysia

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Abstract

A study was carried out from July 2001 until January 2003 in the Kinabatangan area of Sabah, part of Borneo island, where malaria used to be mesoendemic. Vector surveys determined that Plasmodium falciparum was the predominant species and Anopheles balabacensis the primary vector. Malaria cases have dropped drastically over the years but P. falciparum is still predominant. In the present study, Anopheles donaldi was the predominant species and was positive for sporozoites. Although An. balabacensis was present, none were infective. An. donaldi bite more outdoors than indoors and have a peak biting time from 18:00 to 19:00 h when most people are still out of their homes. An integrated malaria control programme along with area development has helped in the control of malaria and its vector.

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1. Introduction

Malaria is a serious public health problem in many countries in South East Asia, with Sabah being one of the more affected regions in recent history. The State of Sabah covers an area of 76,114.92 km² and is situated on the northern part of the island of Borneo. Malaria cases in the early 1990s were around 50,000, with the past 3 years seeing a steady decline to 6050, 5096 and 1770 for years 2001, 2002 and 2003, respectively (VBDCP Sabah). There is a history of well organised antimalarial operations and entomological surveys in Sabah dating back to 1914 (Hii, 1985a).

In the 1950s, Anopheles balabacensis Baisas was recognised as the most dangerous vector in Sabah (McArthur, 1950; Colless, 1952). Colless (1952) determined that a strong correlation existed between the adult density and the sporozoite rate in An. balabacensis and that adult longevity correlated well with climatic conditions. In 1955, a malaria pilot project was initiated...
and from 1961 to 1970, the Malaria Eradication Project was launched with WHO support. In the 1970s and 1980s, extensive studies continued (Hii, 1980; Hii et al., 1985, 1988), with An. balabacensis maintaining its place as the main vector (Hii et al., 1985; Hii and Vun, 1985) throughout Sabah with the exception of cleared lands and townships (Hii, 1985a). In the coastal areas, Anopheles sundacius (Rodenwaldt) was found to be a secondary vector and Anopheles flaviventer (Ludlow) in the coastal parts of Banggi islands, Pitas and Sepomora districts (Hii, 1985a).

The establishment of primary health care volunteers for malaria in Sabah has resulted in some significant success in areas such as Kudat, where there was a major reduction in slide positivity and parasite rates from 1990 to 1991 (Hii et al., 1996).

Currently both indoor residual spraying (IRS) and insecticide-treated bednets (ITNs) using lambdacyhalothrin and deltamethrin are used as malaria vector control tools (Chooi and Tanrang, 2000) in the study area with an estimated 80–85% coverage of homes. This study, with approval from the Ethical Committee of the Ministry of Health Malaysia, investigates the current malaria situation and the vectors in the Kinabatangan area of Sabah.

2. Materials and methods

2.1. Study area

Six villages from the Kinabatangan district were selected (5°18′N, 118°17′E). Four of these villages Alintang, Mengkawago, Minusu and Saguwan were in the forested, hilly subdistrict of Penengah, an area around 100 m above sea level. Most houses are built on stilts, are made of wood, have thatched or zinc roofs and commonly incomplete walls. The two other villages Sogo Sogo and Tongodon were in the more accessible subdistrict of Entiblon. The houses were of a similar design to those in Penengah, but with more complete walls. In both test areas, there was a noticeable absence of cattle and buffalos.

2.2. Entomological surveys

Mosquito collections were carried out in July, September and November 2001, July and September 2002 and January 2003. Both indoor and outdoor landing catches were completed with two men sitting indoors and two outdoors from 18:00 to 06:00 h. All volunteers were given prophylaxis at the start of each survey. Each test period involved two nights of collections in and around two houses from each village. Mosquitoes were collected using small tubes (Vythilingam et al., 1995). All collected Anopheles sp. mosquitoes were identified (Reid, 1968) and dissected with the ovaries examined for parity and the guts and glands examined for oocysts and sporozoites.

2.3. Mass blood surveys

Mass blood surveys were carried out in July and September 2001, July 2002 and January 2003 with only six malaria cases detected. Malaria data for the study villages was, therefore, obtained from the respective health centers responsible for the villages.

2.4. Statistical analysis

The confidence intervals (95% CI) for the parous rate was calculated using Fleiss quadratic (Fleiss, 1981). Chi-square ($\chi^2$) tests used to determine the significance of indoor biting between An. donaldi and An. balabacensis and the parous rate of these two mosquitoes during the different months.

3. Results

3.1. Species composition and exophagy

Five species of Anopheles were obtained from the study villages. Of these, the predominant species was An. donaldi (Table 1). In some villages, An. donaldi

<table>
<thead>
<tr>
<th>Species</th>
<th>Total collected</th>
<th>% Biting outdoors (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. balabacensis</td>
<td>185</td>
<td>75.96 (68.98–81.82)</td>
</tr>
<tr>
<td>An. donaldi</td>
<td>1746</td>
<td>90.09 (88.57–91.43)</td>
</tr>
<tr>
<td>An. maculatus</td>
<td>315</td>
<td>88.89 (84.76–92.04)</td>
</tr>
<tr>
<td>An. tessellatus</td>
<td>272</td>
<td>93.01 (89.13–95.63)</td>
</tr>
<tr>
<td>An. vanus</td>
<td>58</td>
<td>89.66 (87.16–95.72)</td>
</tr>
</tbody>
</table>
Fig. 1. Showing: (A) rainfall, (B) B/M/N and (C) parous rate.
comprised more than 80% of the total *Anopheles* collection with *An. balabacensis* at 2.6–9.5% of the total population. Most of the mosquitoes were exophagic, with almost 80% biting outdoors. 24% of *An. balabacensis* bit indoors with the other species ranging from 7 to 11%. Indoor biting rates between the main species were often statistically different (e.g. *An. balabacensis* versus *An. donaldi* ($\chi^2 = 11.25; P < 0.05$).

### 3.2. Changes in landing rate and parous rate over time

Fig. 1 shows the average man biting rate and parous rate of the two dominant species (*An. balabacensis* and *An. donaldi*) in the study villages in correlation to rainfall. Rainfall data was obtained from Sandakan, the closest Meteorological Station to the study site. Heavy rains seem to readily wash out *An. donaldi*. The parous rate of *An. balabacensis* was highest in the villages in the month of November 2001 as shown in Fig. 1. Significantly different from the parous rate from this species in January 2003 ($\chi^2 = 6.58; P < 0.05$). During the survey period, the highest rainfall was recorded in November and the two preceding months creating suitable breeding sites for *An. balabacensis*. The parous rate of *An. donaldi* went above 50% only in November 2001 and January 2003, significantly higher compared to the other months ($\chi^2 = 6.52; P < 0.05$). The parous rate of *An. balabacensis* was generally higher than *An. donaldi*.

### 3.3. Biting cycles

Fig. 2 shows the biting cycle of *An. donaldi* and *An. balabacensis*. The percent human landing rate per hour was plotted separately for indoor and outdoor collections. *An. donaldi* showed peak biting activity from 18:00 to 21:00 h outdoors and this decreased towards midnight with some biting continuing until 06:00 h. The peak biting time for *An. balabacensis* was between 19:00 and 20:00 h but continued throughout the night outdoors. The peak biting indoors was between 22:00 and 23:00 h.

### 3.4. Sporozoite and oocyst rates of Anopheles

The overall sporozoite rate for *An. donaldi* was 0.23, not significantly different from that of *An.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number dissected</th>
<th>Sporozoite rate (95% CI)</th>
<th>Oocyst rate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. donaldi</em></td>
<td>1738</td>
<td>0.23 (0.07–0.63)</td>
<td>0.23 (0.05–0.63)</td>
</tr>
<tr>
<td><em>An. balabacensis</em></td>
<td>183</td>
<td>0.0 (0.0–2.56)</td>
<td>0.55 (0.0–3.47)</td>
</tr>
</tbody>
</table>
Table 3

<table>
<thead>
<tr>
<th>Species</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. falciparum</td>
<td>123</td>
<td>53</td>
</tr>
<tr>
<td>P. vivax</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>&lt;15 years</td>
<td>98</td>
<td>45</td>
</tr>
<tr>
<td>&gt;15 years</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>

balabacensis (*P* = 0.38; Fisher’s Exact Test, Table 2).

More An. donaldi were positive for oocysts compared to An. balabacensis. Of note is that infected mosquitoes do not necessarily become infective.

3.5. Distribution of malaria cases in study area for 2001 and 2002

Annual records showing microscopically confirmed malaria cases obtained from health centers are shown in Table 3. According to the case distribution, it seems more cases occur during the wet periods at the beginning of each year. Most of the cases were *P. plasmodium falciparum* with mainly children below 15 years infected.

4. Discussion

McArthur (1954) demonstrated that when shade is completely removed from mosquito breeding sites, hyperendemic malaria almost disappears. The recent development and associated forest clearance in large areas of Sabah must clearly feature as one of the main reasons for the decrease in An. balabacensis and malaria incidence. With better roads and the more efficient use of dipsticks to identify malaria parasites in blood so allowing treatment of only positive cases, the work of primary health care volunteers has also allowed the more efficient use of limited resources.

In Banggi island studies, An. donaldi was found to be the predominant species but none were infected with malaria or filarial parasites (Hii et al., 1985). Similar studies carried out in the Kinabatangan area at the same time showed that An. balabacensis was the vector for malaria (sporozoite rate 2.27) and W. bancrofti (Hii et al., 1985). This current study found the L3 stage of W. bancrofti in An. donaldi in Saguan in July 2001. Other studies carried out in Ranau on the west coast of Sabah found that An. maculatus was the predominant species followed by An. balabacensis and An. donaldi (Rohani et al., 1999). However, only An. balabacensis was found positive for sporozoites.

In earlier studies in Kinabatanang (Hii et al., 1987), An. balabacensis was the predominant species followed by An. donaldi and An. maculatus (Hii et al., 1985). An. dirus, a species closely related to An. balabacensis, is the main vector in the Mekong area. An extremely efficient vector, An. dirus is long-lived, anthropophilic and small populations can maintain high malaria endemicity (Rosenberg et al., 1990).

It is, therefore, recommended that the incidence of An. balabacensis continue to be closely monitored in Sabah.

In Sabah, malaria is now under control and An. balabacensis which used to be the predominant vector has now been largely displaced. An. donaldi, a species found mostly in swamps and large pools with covering vegetation and are mostly zoophilic (Colless, 1952), is a likely secondary vector in the study area, but its role in the transmission of malaria is not well understood. Reid (1980a,b) believed that An. donaldi could have been a vector in certain areas of Kuala Lumpur in the 1960s. But later studies carried out in Pos Betau, Pahang, Malaysia did not reveal sporozoites in An. donaldi although it was the predominant species next to An. maculatus (Vythilingam et al., 2000). In Pos Legap, oocysts were observed on the midguts of two An. donaldi but Cx protein was not detected in both specimens. Two pools of undissected An. donaldi were positive by ELISA for *P. falciparum* (Delorme et al., 1989), but this is not “proof positive” that An. donaldi is a vector.

In Sarawak, An. leucosphyrus used to be the main vector of malaria but has been displaced by An. donaldi (Chang et al., 1997). Perhaps, there is a strain difference between An. donaldi in peninsular Malaysia and the Island of Borneo. In our study, ELISA was not carried out but the sporozoites morphologically looked similar to those of human malaria. The peak biting time for An. donaldi outdoors is between 18:00 and 19:00h, exactly when most people would be available for attack, but studies have shown that An. donaldi will also attack man by day in the shade (Reid, 1962) and it is advised that communities should be informed so that necessary precautions can be taken. Further studies are
recommend to determine the status of An. donaldi as a vector. The peak biting period of *An. balabacensis* is now 19:00–20:00 h, much earlier than previously documented 21:00–22:00 h. (Hii, 1985b; Tanrang et al., 1999). Although more bite outdoors than indoors, it has been shown that *An. balabacensis* will still rest indoors albeit for short periods (Tanrang et al., 1999). Thus, indoor residual spraying and use of insecticide-treated bednets will have an impact on this vector. In 2002, cases of malaria decreased at levels significant in three of the test villages *(P < 0.05)* and no positive mosquitoes were obtained. Children were more prone to malaria as they have not developed immunity.

It can be concluded that both integrated malaria control programmes coupled with the removal of habitat have acted to reduce malaria cases along with the primary vector *An. balabacensis* in Sabah. The use of village health volunteers in remote areas, who can provide malaria surveillance and presumptive chemotherapy combined with indoor residual spraying and use of insecticide-treated bednets, has undoubtedly brought significant changes to the prevalence of both malaria and its vectors in this area. Use of bednets have in cases proven more useful than indoor residual spraying as many of the houses do not have proper walls. Use of protective clothing early evening is also to be advised.

As islands neighboring Sabah still face a problem with malaria, it is important that malaria surveillance is continued with additional studies suggested on potential secondary vectors that could transmit malaria.

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