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Sri Lanka Malaria Maps

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Abstract

Background: Despite a relatively good national case reporting system in Sri Lanka, detailed maps of malaria distribution have not been publicly available.

Methods: In this study, monthly records over the period 1995 – 2000 of microscopically confirmed malaria parasite positive blood film readings, at sub-district spatial resolution, were used to produce maps of malaria distribution across the island. Also, annual malaria trends at district resolution were displayed for the period 1995 – 2002.

Results: The maps show that *Plasmodium vivax* malaria incidence has a marked variation in distribution over the island. The incidence of *Plasmodium falciparum* malaria follows a similar spatial pattern but is generally much lower than that of *P. vivax*. In the north, malaria shows one seasonal peak in the beginning of the year, whereas towards the south a second peak around June is more pronounced.

Conclusion: This paper provides the first publicly available maps of both *P. vivax* and *P. falciparum* malaria incidence distribution on the island of Sri Lanka at sub-district resolution, which may be useful to health professionals, travellers and travel medicine professionals in their assessment of malaria risk in Sri Lanka. As incidence of malaria changes over time, regular updates of these maps are necessary.

Background

The Anti Malaria Campaign (AMC) Directorate of the Ministry of Health in Sri Lanka maintains a relatively good national case reporting system. However, maps of malaria disease distribution over the island have not been available to a wide public, until a recent publication of a map based on 1989–1994 incidence data at district resolution [1]. Travel medicine Internet sites describe in their advice to travellers to Sri Lanka merely that the risk of malaria is present all year round in all areas (below 800 m altitude), except in the districts of Colombo, Kalutara, and Nuwara Eliya, and sometimes unrealistic maps are posted.

In Sri Lanka, two species of malaria, *Plasmodium vivax* and *Plasmodium falciparum*, are present. The main vector is *Anopheles culicifacies*, which breeds mainly in pools in stagnant rivers, and therefore, its density is mostly dependent on temporal and spatial variations in rainfall and river flow. *An. culicifacies* also breeds in abandoned gem mining pits and agricultural wells. Vectors of less

importance are *Anopheles annularis*, *Anopheles subpictus*, *Anopheles tessellatus* and *Anopheles vagus* [1].

This publication provides information on spatial and temporal distribution of malaria incidence on the island of Sri Lanka. Malaria incidence maps are useful in allocating limited malaria control resources to the malaria prone areas at the right time. They may also be useful to health professionals, travellers and travel medicine professionals in their assessment of malaria risk in Sri Lanka.

Methods

The mapping is based on monthly records over the period January 1995–December 2000 of microscopically confirmed malaria parasite positive blood film readings, at the spatial resolution of Medical Officer of Health (MOH) areas. These were collected by the AMC from aggregated disease records reported by governmental hospitals and mobile clinics. MOH area boundaries are in accordance with the Divisional Secretariat Division (DSD) boundaries (See additional files 1 and 2: Map and list of Divisional Secretariat Divisions), except that some MOH areas cover multiple DSDs. DSDs are administrative units below the district level with a median population of about 50,000 and an average surface of 208 km^2. District resolution 2001 and 2002 data were included to show recent developments.

Most people in Sri Lanka with suspected malarial fever seek diagnosis and treatment in government health facilities [1]. In all provincial hospitals and in malaria endemic zones also in district and rural hospitals, and in some dispensaries, a microscopist is permanently available for laboratory diagnosis of malaria. Private clinics usually have limited facilities or expertise available for malaria detection, except the private hospitals in Colombo. When parasites are detected, patients are treated with chloroquine 10 mg/kg bodyweight, and normally with 8-amino quinaline (primaquine) against liver stages of *P. vivax*.

In the few cases where records for one month or two succeeding months were missing (due to absence of a microscopist), data were estimated by interpolation of monthly case series. In situations where malaria confirmed case data for three or more succeeding months were not available, these months' data were marked as missing.

As a denominator for the incidence calculations, population estimates (See additional file 3: Population) were made by exponential interpolation (and extrapolation to 2002) of 1994 and 2001 census data from the Department of Census and Statistics http://www.statistics.gov.lk. For those districts in the north and east not covered by the census, and for which only a district total estimate was posted, DSD populations were estimated according to the population distribution over the districts from data posted by the North East Provincial council http://www.nepc.lk/index.htm.

The GIS package ArcView was used to modify a DSD map of Sri Lanka to MOH area boundaries and ArcView and MapInfo were used to produce maps of malaria distribution across the island.

Results and discussion

There are several concerns with the quality of the data. In the North and East, malaria case data from there may be grossly underestimated. Due to the armed conflict there was shortage of trained microscopists in these areas and only a small part of the clinical cases is microscopically confirmed [2]. In the rest of the country, the availability of field assistants for blood film collection and the availability of microscopists was high, and the authors estimate the proportion of microscopically confirmed cases to be about 70% [3]. Unfortunately, we have no precise data available to study the effect of the availability of field assistants and microscopists on the number of blood films examined. In general, there is high acceptance of blood filming by the population [4,5].

It is AMC policy to cross-check 10% of *Plasmodium* positive blood films, and 10% of negative films for parasite presence and species identification, both at District and Central levels. However, after decentralisation of the AMC in 1989, cross-checking was often not performed. Only sporadically blood films were cross-checked at the central laboratory, and no records were kept. In June 2000, a new policy was installed to cross-check films at the central laboratory. Mostly films with doubtful readings were sent to the AMC central laboratory for cross-checking, and only from a limited number of districts and months. Therefore, we could not estimate the error rate for the period under study. An AMC report over the year 1988, before the decentralisation, states a species misidentification of 0%, an error of 0.2% false positives (1.6% of positive slides cross-checked), and 1% false negatives (5% of negative slides cross-checked) [6]. We believe that the quality has since improved as microscopists received more extensive training (1 year versus 6 months) since 1990.

Self-treatment with anti-malarials is relatively uncommon in Sri Lanka. In four-hundred-and-forty-three household interviews in 1992 in Kataragama, Monaragala District, none reported keeping a stock of anti-malarial drugs at home (DMG, unpublished data). In a survey in 1999 at governmental hospital level in nine malarious districts (outside the conflict area), none out of nine-hundred patients diagnosed with *P. falciparum* reported the use of anti-malarial drugs prior to presentation at the hospital, whereas 19% had taken non anti-malarial drugs, mostly

administered by the government hospital or dispensary [7]. However, in 2000 in Mallavi, Mullaitivu District (in the conflict area), 7.4% of patients reported self-treatment with chloroquine prior to presentation to the outpatient department (OPD), and 84.5% with non anti-malarial drugs [2]. It is not known how many people successfully treated themselves with anti-malarial drugs and therefore did not present themselves to the governmental facility in the latter two studies.

Patients who seek treatment at non-governmental health facilities are not registered, and this leads to further underestimation of the number of cases. In a study in three MOH areas in Monaragala, only about half the cases were treated at governmental health facilities and therefore registered, with considerable variation at Grama Nilhadari resolution [3]. Grama Nilhadari are administrative units with the highest spatial resolution used in Sri Lanka. However, at coarser resolution, gross spatial bias due to treatment at private facilities is expected to be limited, as governmental facilities are the preferred diagnosis and treatment centres (69% in an irrigation resettlement area (Mahaweli System C) in Badulla District [8], >75% in Kataragama, Monaragala District [9], 84% in a location in Hurulawewa, Anuradhapura District [4], 83 – 97% in four villages in and around Lunugamwehera irrigation project, Hambantota District [10]), even in the conflict areas (80% in Mallavi, Mullaitivu District [2]).

Another spatial bias is the fact that cases detected in occasional mass blood surveys in selected villages in high risk areas are also included in the statistics. However, these blood films tend not to exceed 1% of the total examined.

Aggregated case records from the health facilities were not corrected for recrudescence of *P. falciparum* or relapse of *P. vivax*. It is, therefore, possible that patients with treatment failure due to incomplete drug compliance or resistance, were recorded more than once, thereby overestimating the incidence. Interviews in Kataragama (Monaragala District) of malaria patients revealed that drug non-adherence is very low (none for forty-three recrudescent cases [11], three for more than seven-hundred-and-twelve cases (<0.4%) [12]). In Malavi (Mullaitivu District), however, interviews revealed 26.2% non-adherence to full treatment, mostly (58%) for reasons of side effects [2]. It is not known in how many of these cases this resulted in treatment failure. In Sri Lanka, no studies have yet employed molecular methods to differentiate between recrudescence and re-infection [13]. Instead, studies at several locations have used different arbitrary time periods between successive infections for classifying a successive infection as recrudescent or as new. Also, some studies have used active follow up methods instead of passive methods to detect recurrent infections. Corrections based on these active detection studies tend to overestimate the number of double counted *P. falciparum* cases, as chloroquine resistant recrudescent infections show less severe clinical symptoms, and therefore have a lower probability of being recorded in the AMC registers [12]. In Colombo, during 1992 – 1993, a study using active detection reported 55% (n = 129) recrudescent cases within 40 days of follow up. However, 61% of these were non patent and these people reported that they would not have sought treatment. Therefore, only 22% of cases would have been double recorded if detected passively [12]. Handunnetti and colleagues found in a passive case detection study in 1992 in Kataragama (Monaragala District), that 26% (n = 616) of *P. falciparum* episodes occurred within 31 days of the previous episode in the same person [12]. A more recent study using passive case detection during 1998–1999 in Kataragama and Buttala (Monaragala District) found 12% (n = 359) of cases re-occurring within 28 days [11]. An active case-detection follow-up study in 1999 in nine malarious districts (outside the conflict area) found parasites in 34 – 62% (Table 1) of patients within 28 days after diagnosis and treatment of *P. falciparum* [7]. It is interesting to note that there is a strong positive correlation (binomial regression, $r = 0.81$, $p < 0.01$, $n = 9$) between the proportion of recrudescence infections and *P. falciparum* incidence (even if the incidence is corrected by assuming that each recrudescent case is counted twice). Based on this regression one could consider adjusting reported cases of *P. falciparum* in each MOH area, which would bring down higher incidence rates relatively more than lower incidence rates. We did not do so because of likely overestimation of the number of double counted cases by the active detection method used in the follow up study. With regard to *P. vivax* relapses, Fonseka and Mendis [14] estimated a rate of 18% from patients in Colombo during the period 1981 – 1984. These people had acquired their infections elsewhere in the country, and most of them suffered from the relapse within 24 weeks after the primary attack.

Another concern for data quality is that the population census data may be less reliable in the North and East. Also, an important number of malaria infections may not have been contracted at the place of reporting. This may especially be true for infections contracted by military personnel in the conflict zone and reported in their place of residence while on medical leave. Furthermore, until 2000, cases were generally ascribed to the MOH area of the reporting hospital, regardless of the place of residence of the patient.

The year 1998 was the most complete in terms of malaria case records. Figure 1 shows that the annual parasite incidence (API) of *P. vivax* malaria cases at MOH area resolution had marked variation over the island. Particularly,

Table 1: Incidence and recrudescence of *Plasmodium falciparum* in 1999 in nine districts of Sri Lanka

District	*P. falciparum* cases	Population	*P. falciparum* incidence (× 1000)	Recrudes-cent cases*	Number of patients followed for 28 days*	Proportion re-crudescent*
Anuradhapura	5,132	725,557	7.07	49	99	0.49
Badulla	633	1,073,134	0.59	34	100	0.34
Hambantota	1,018	495,702	2.05	35	100	0.35
Kurunegala	2,073	1,462,149	1.42	42	100	0.42
Matale	1,116	495,511	2.25	36	100	0.36
Moneragala	7,215	448,226	16.10	62	100	0.62
Polonnaruwa	978	319,632	3.06	50	100	0.50
Puttalam	3,375	843,410	4.00	53	97	0.55
Ratnapura	2,685	1,035,690	2.59	42	100	0.42

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the districts of Jaffna, Kilinochchi and Mullaitivu in the north, and the district of Monaragala and the southeastern MOH areas in Ratnapura district show high malaria incidence. The API of *P. falciparum* (and mixed) infections (Figure 2) was generally much lower than the API of *P. vivax*, although the spatial distribution is somewhat similar. In the districts of Batticaloa and Ampara in the east, the proportion of *P. falciparum* was much lower than elsewhere in the country.

Clearly, the northern areas are facing a serious malaria problem. Difficulties in obtaining prompt treatment may have enhanced malaria transmission. In the rest of the country this factor seems of a lesser importance, as the health systems are generally well developed. Socio-economic factors such as personal protection against mosquitoes and quality of housing construction are important in explaining the distribution of malaria incidence. More important, however, are factors influencing malaria mosquitoes, such as temperature (altitude), rainfall and resulting river flow (See additional files 4: temperature, 5: altitude, 6: rainfall, and 7: rivers and lakes), but also (chemical) control efforts by the AMC. Especially the latter factor has historically played an important role in the malaria epidemiology in Sri Lanka [15]. After 1983, no more governmental vector control has been implemented in the northern areas. To learn more about the relative importance of socio-economic and environmental risk factors for malaria, a spatial regression analysis linking incidence directly to covariates (as information on vector density and distribution is scarce) is being done, the results of which will be disseminated in due course.

Figure 3 shows the trends of annual parasite incidence of *P. falciparum* and *P. vivax* malaria over the years 1995 to 2002, at district resolution. *P. falciparum* and *P. vivax* generally show similar trends over the 8-year period. However, there is considerable variation in temporal trends over the country, even at a relatively short distance: In Jaffna, malaria incidence went down after 1998, whereas it still increased in the neighbouring districts of Kilinochchi and Mullaitivu. For Mannar, data were incomplete. Although the malaria incidence showed a general increase over the 1995 – 2000 period, it declined strongly after 2000. The ongoing peace process may be an important contributing factor for the recent decline in cases in the conflict zone. Notably the access to the area for spray teams has been increased. Also, foreign aid organisations have been providing insecticide-impregnated bednets in the affected areas. The variation in temporal trends and socio-political developments illustrate the need for regular updates of malaria distribution maps such as shown in Figures 1 and 2.

Figure 4 shows the geometric mean monthly parasite incidence patterns of *P. falciparum* and *P. vivax* malaria over the period January 1995 to December 2000, at district resolution. In the northern districts, *P. falciparum* peaks around March, whereas towards the south the peak is shifted towards January. *P. vivax* generally peaks in January. Except for the northern districts, a second malaria peak of either species occurs around July. This peak is especially pronounced in the west-central districts with very low malaria incidence, where it can even outweigh the January peak. Roughly, in all districts, *P. falciparum* and *P. vivax* follow the same seasonal pattern, although *P. vivax*' seasonality is less explicit. This observation could be due to relapses (activation of hypnozoites in the liver). Therefore, the *P. falciparum* incidence seems a better proxy for *P. falciparum* malaria transmission seasonality than *P. vivax* incidence is for *P. vivax* transmission seasonality, although these patterns are also somewhat smoothed by recrudescence.

There is evidence of considerable spatial variation in the risk of malaria transmission at a higher resolution than the MOH area scale presented in this paper. Malaria is a disease of rural areas and cities are mostly unaffected. The

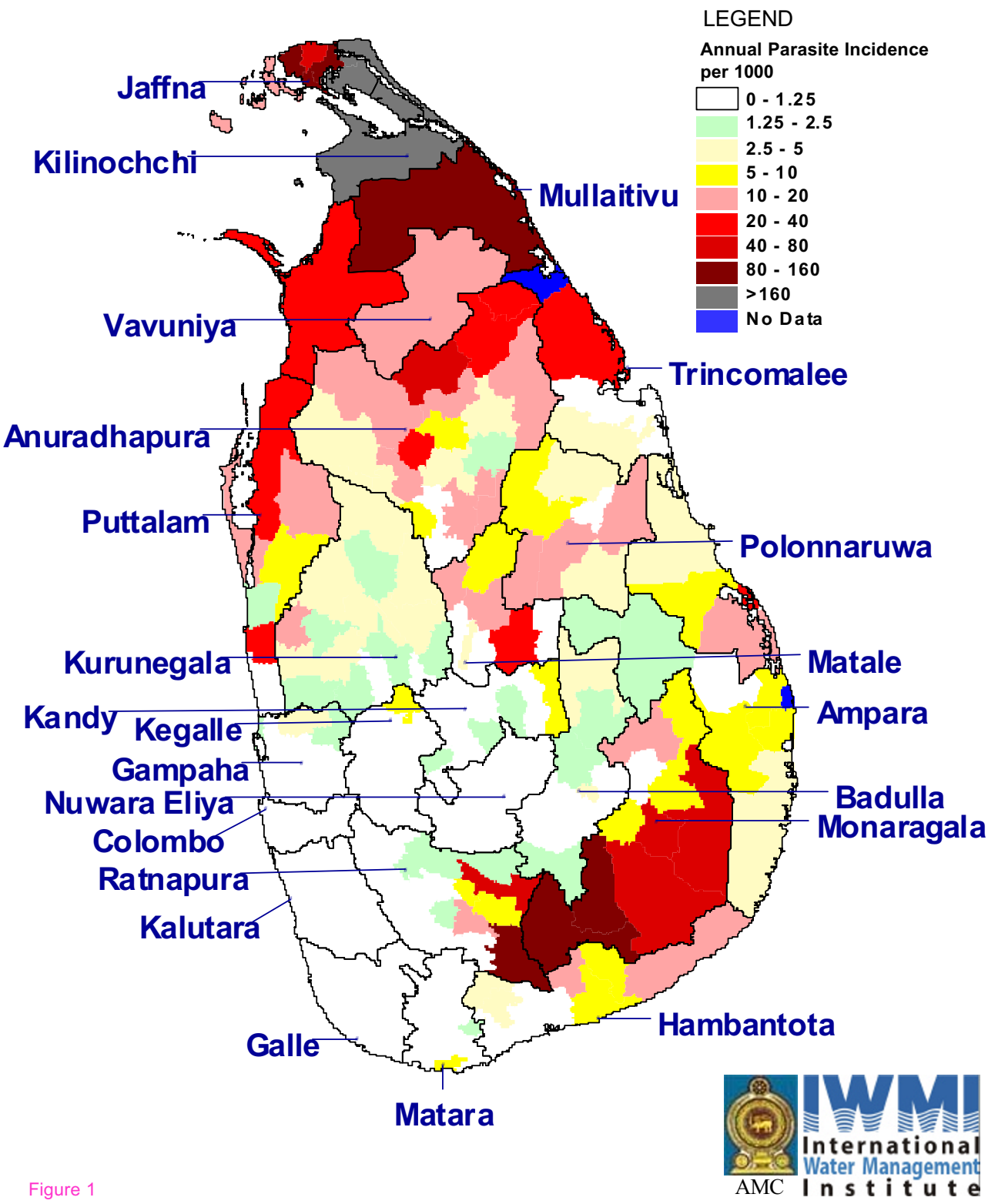

Figure 1

Figure 1
Annual parasite incidence of *Plasmodium vivax* Map of the districts of Sri Lanka with annual parasite incidence (API) of *P. vivax* malaria cases at Medical Officer of Health (MOH) area resolution over the year 1998.

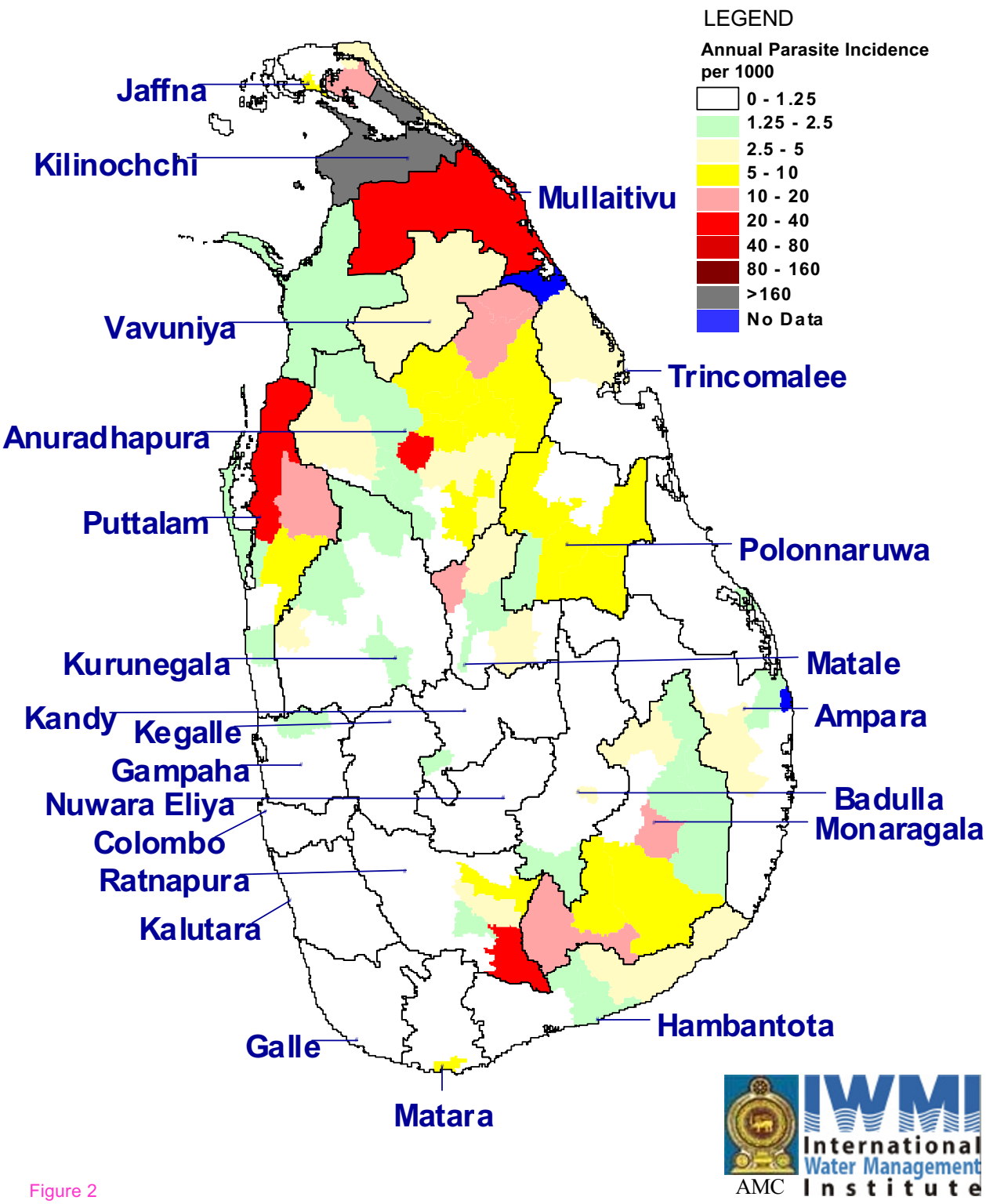

Figure 2

Figure 2
Annual parasite incidence of *Plasmodium falciparum* Map of the districts of Sri Lanka with annual parasite incidence (API) of *P. falciparum* malaria and mixed infections of both *P. vivax* and *P. falciparum* at Medical Officer of Health (MOH) area resolution over the year 1998.

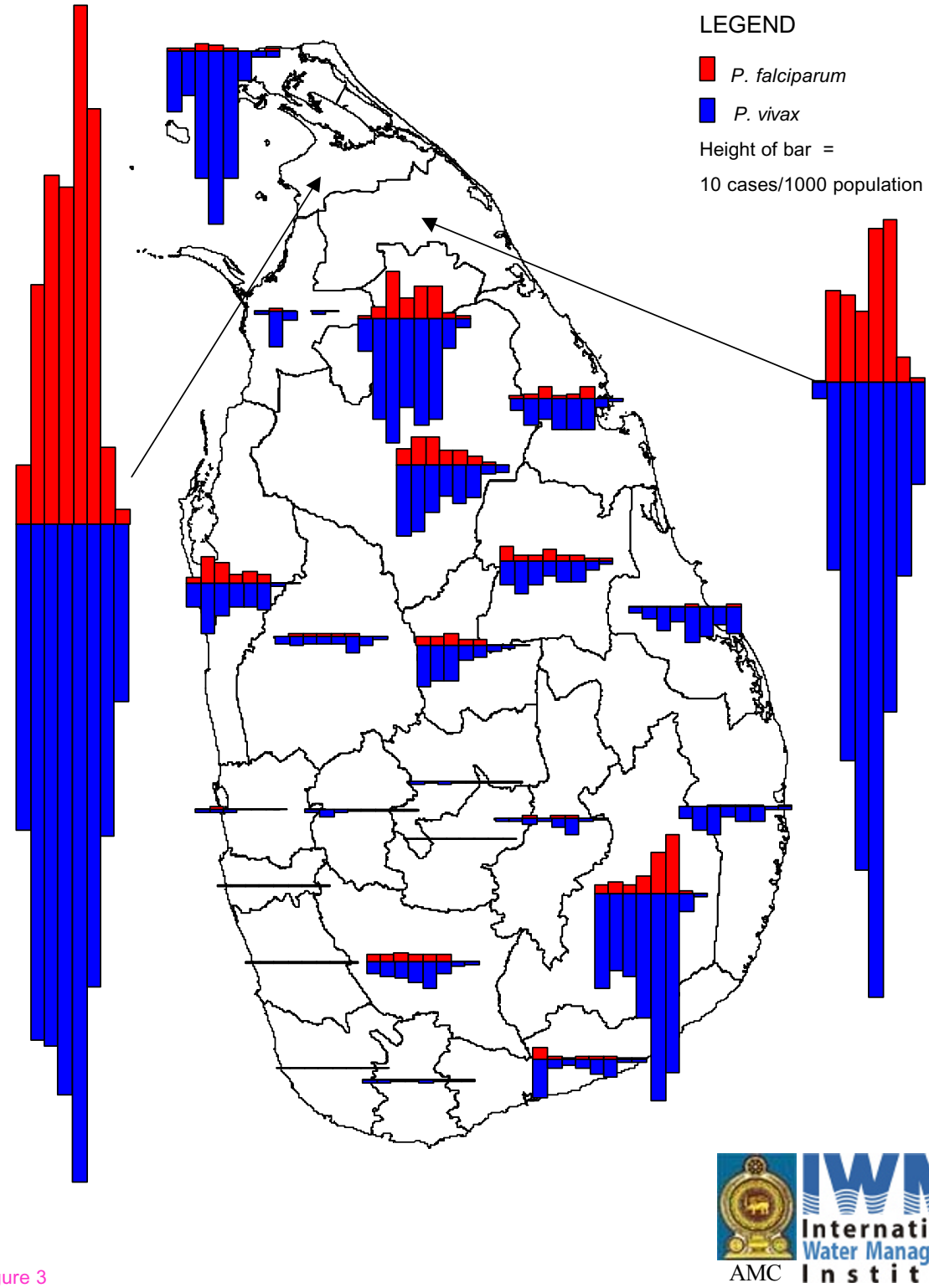

Figure 3

Figure 3
Trends of Annual parasite incidence Trends of annual parasite incidence of *P. falciparum* (red bars) and *P. vivax* (blue bars) malaria over the years 1995 (bar on far left) to 2002 (bar on far right), at district resolution. The height of the bars in the legend represents an annual parasite incidence of 10 cases per 1000 persons.

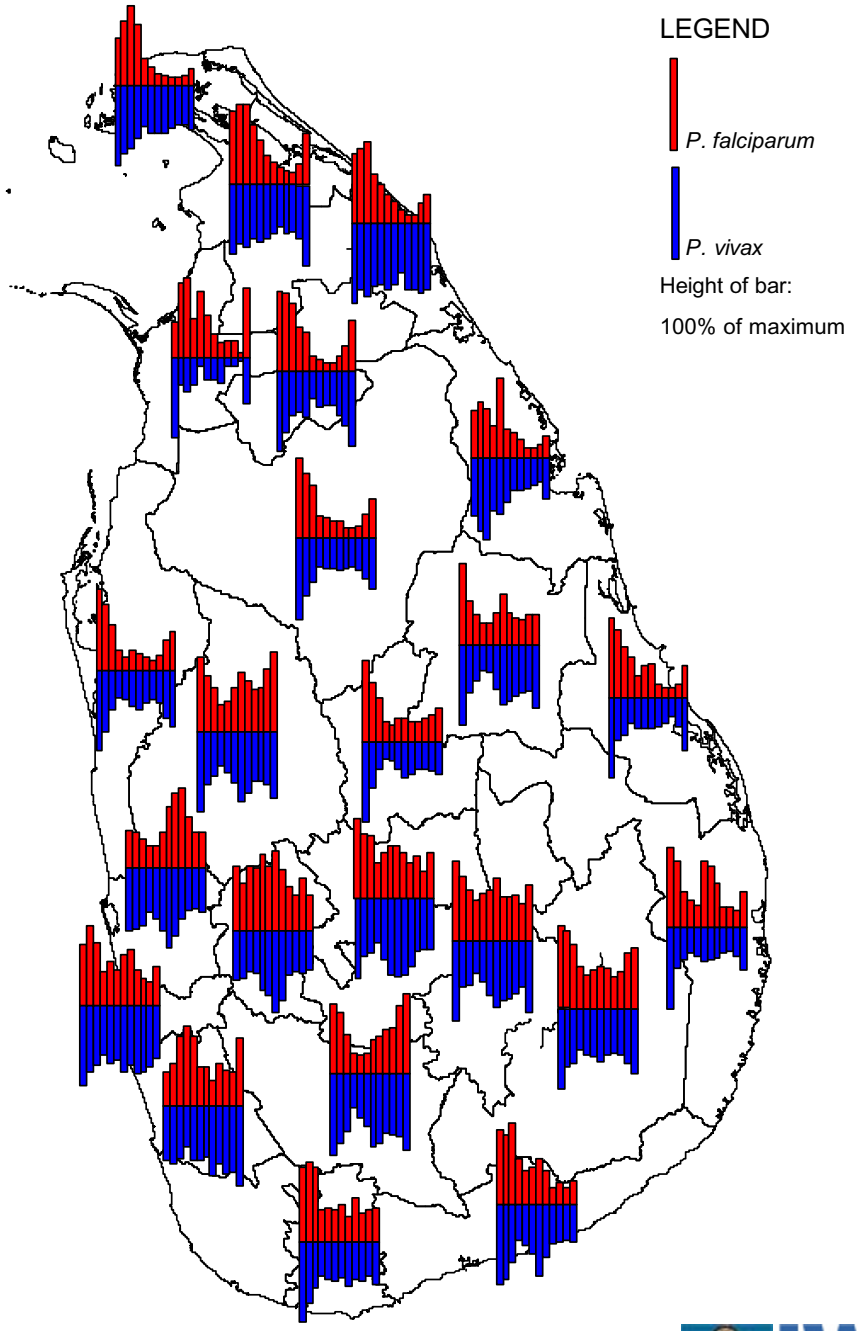

Figure 4

Figure 4
Geometric mean monthly parasite incidence patterns Geometric mean monthly parasite incidence patterns of *P. falciparum* (red bars) and *P. vivax* (blue bars) malaria from January (bar on far left) to December (bar on far right), relative to the month with the highest geometric mean incidence, over the period January 1995 to December 2000, at district resolution. The height of the bars in the legend represents 100 percent (The month with the highest geometric mean incidence for the respective malaria species).

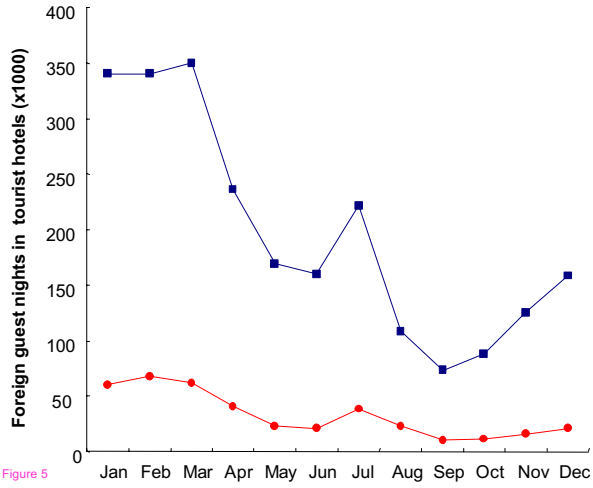

Figure 5

Figure 5
Foreign guest nights in tourist hotels Monthly foreign guest nights spent in tourist hotels in 2001 in malarious areas with an annual parasite incidence > 1 case/1000 population (red lines and dots) and non malarious areas (blue lines and squares). Source: Ceylon Tourist Board: Annual Statistical Report; 2001 [18].

distance of houses to breeding sites of malaria vectors within a MOH area is an important risk factor [16,17]. The authors of this study are currently working on a malaria risk map of the Badulla and Monaragala districts at Grama Nilhadari resolution.

On average, 370,000 tourists visit Sri Lanka annually, of whom the majority (63%) is of European origin http://www.lanka.net/centralbank/y-td_tourism.html. Roughly 14% of tourist hotel nights booked by foreigners in 2001 [18] was in areas with a risk of malaria (API > 1 case/1000 population). Of these, most were spent during months of transmission, as the tourist seasons coincide with the inter-monsoon periods (Figure 5) when malaria transmission is at its maximum. Some of the important tourist destinations, such as the ancient cities of Anuradhapura, Polonnaruwa, and Sigiriya, and the Yala and Uda Walawe national parks are situated in endemic areas, but these are mainly popular for day trips. Most tourists will therefore not be exposed during evening or night time, when *An. culicifacies* is most active. Tourist hotels generally provide anti mosquito measures such as pyrethrum mosquito coils and bed nets, and most hotel rooms have a fan or air conditioning, so contact with nocturnal indoor-biting vectors is limited. Repellents are recommended when outdoors after dusk. There is no justification for prescribing chemoprophylaxis to tourists who intend to remain in resorts in the non-malarious areas and make only day trips to destinations in the malaria endemic areas. Physicians and travel clinics should tailor their advice on prophylactic drugs to the individual traveller, taking into account the itinerary and time of travel. The AMC advises travellers to malaria endemic areas (with an API of *P. falciparum* and/or *P. vivax* above 10 per 1000 population) to take a weekly dose of 300 mg chloroquine (for adults) as prophylactic measure from one week before the visit until four weeks after the visit. In case of treatment failure due to chloroquine resistance, sulfadoxine/pyremethamine is available at all governmental health facilities in the endemic areas. Carrying anti-malarial drugs for self administration (standby treatment) should not be recommended for Sri Lanka, as facilities for diagnosis and treatment are available in all parts of the country.

Conclusions

This paper provides the first publicly available maps of both *P. vivax* and *P. falciparum* malaria incidence distribution on the island of Sri Lanka at sub-district resolution. The maps show that both *P. vivax* and *P. falciparum* malaria incidence have a marked variation in distribution over the island, even within districts. The incidence of *P. falciparum* malaria follows a similar spatial pattern to that of *P. vivax* but is generally much lower. In the north, malaria shows one seasonal peak in the beginning of the year, whereas towards the south a second peak around June becomes more pronounced.

These maps may be useful for the planning of malaria control activities. They also may be useful to health professionals, travellers and travel medicine professionals in their assessment of malaria risk in Sri Lanka. However, as incidence of malaria changes over time, regular updates of these maps are necessary.

Authors' contributions

DMG collected the malaria data and helped mapping the MOH areas. OJTB cleaned the data, calculated incidence, made the maps and wrote the article. WVDH and FPA conceived of the study, and participated in its design and coordination. All authors read and approved the final manuscript.

Additional material

Additional File 1

Divisional Secretariat Divisions. Map of Divisional Secretariat Divisions in Sri Lanka (Adobe Acrobat format). Source: The Survey Department, Sri Lanka.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S1.pdf]

Additional File 2

Divisional Secretariat Divisions. DSDs.xls: List of Divisional Secretariat Division names and their number corresponding to the number printed in additional file 1 (Microsoft Excel format).
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S2.xls]

Additional File 3

Population. Map of population by divisional secretariat division in Sri Lanka (Adobe Acrobat format). One dot represents 1000 people. Sources: Department of Census and Statistics http://www.statistics.gov.lk/ and North East Provincial Council http://www.nepc.lk/index.htm.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S3.pdf]

Additional File 4

Temperature. Maps of monthly average temperature in Sri Lanka (Adobe Acrobat format). Source: IWMI World Water and Climate Atlas http://www.iwmi.cgiar.org/WAtlas/atlas.htm.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S4.pdf]

Additional File 5

Altitude. Map of altitude in Sri Lanka (Adobe Acrobat format). Colour shading as recommended by the GLOBE project (except white background). Green contour line: 500 m, black contour lines: 1000 m. Source: GLOBE project http://www.ngdc.noaa.gov/seg/topo/globe.shtml.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S5.pdf]

Additional File 6

Rainfall. Maps of monthly rainfall (75% probability) in Sri Lanka (Adobe Acrobat format). Source: IWMI World Water and Climate Atlas http://www.iwmi.cgiar.org/WAtlas/atlas.htm.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S6.pdf]

Additional File 7

Rivers and lakes. Map of river network and lakes / tanks in Sri Lanka (Adobe Acrobat format). Source: The Survey Department, Sri Lanka.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1475-2875-2-22-S7.pdf]

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