Chapter 9

Ending Malaria Transmission in the Asia Pacific Malaria Elimination Network (APMEN) Countries: Challenges and the Way Forward

Kinley Wangdi and Archie CA Clements

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75405

Abstract

Member countries in the Asia Pacific Malaria Elimination Network (APMEN) are pursuing the global goal of malaria elimination by 2030. Different countries are in various phases of malaria elimination and this review aims to present a compilation of available evidence on the challenges and way forward for malaria elimination in APMEN countries. Malaria transmission in these States is complex. APMEN member countries include the largest populations living in areas of malaria transmission risk outside Africa. They are a global source for spread of artemisinin-based combination therapy (ACT) resistance, include the biggest burden of *Plasmodium vivax* and zoonotic malaria, and face many geopolitical and socio-economic factors that will challenge malaria elimination efforts. These challenges can be addressed in part through operational research to identify country-specific solutions, making better use of operational data such as through spatial decision support system (SDSS) approaches, strengthening surveillance, and cross-border initiative for coordinated action.

Keywords: *Plasmodium falciparum*, *P. vivax*, drug-resistance, malaria elimination, APMEN, challenges

1. Background

Malaria imposes great health and socio-economic burden on humanity, with an estimated 3.2 billion people at risk of being infected with malaria [1]. In 2016, there were approximately 216 million cases with 445,000 deaths, most of which were in children aged under 5 years in Africa [2, 3]. However, substantial progress has been made in fighting malaria, with global

Figure 1. Member countries of the Asia Pacific Malaria Elimination Network countries (APMEN).

incidence reducing by 41% and mortality rates by 62% between 2000 and 2015 [1]. In 2016, malaria remained endemic in 91 countries and territories as compared to 108 in 2000 [2]. It is estimated that most (90%) of total malaria cases were in the World Health Organisation (WHO) African Region, followed by the South-East Asian Region (SEAR) (7%) and the Eastern Mediterranean Region (2%) [4]. A number of factors have been attributed for this reduction, including wide-scale deployment of malaria control interventions, economic development in endemic countries, urbanisation, and unprecedented financial support for malaria control interventions [5–8]. In 2016, an estimated US$ 2.7 billion was invested in malaria control and elimination efforts globally by governments of malaria endemic countries and international partners [1, 9].

Recognising the need to hasten progress in reducing the burden of malaria, WHO developed the *Global Technical Strategy for Malaria 2016–2030* (GTS) [5], which sets out a vision for accelerating progress towards malaria elimination. The WHO strategy is complemented by the Roll Back Malaria advocacy plan, *Action and Investment to Defeat Malaria 2016–2030* (AIM) [10]. GTS and AIM set an ambitious global target of eliminating malaria in at least 21 countries by 2020, identified as E-2020 countries by WHO and 35 countries by 2030 [1, 2, 10].

In line with the global efforts to eliminate malaria, the Asia Pacific Malaria Elimination Network (APMEN) was established in 2009, initially including 10 countries (Bhutan, China,

No. of cases/year Country	2010	2011	2012	2013	2014	2015	2016
Bangladesh	79,300	69,700	13,750	5000	12,990	8000	6000
Bhutan	400	190	≤100	≤100	≤100	≤100	≤100
Cambodia	175,000	203,600	146,000	76,500	89,700	120,300	83,300
China	5000	3000	240	≤100	≤100	≤100	≤10
DPR Korea	13,520	16,760	21,850	14,410	10,540	800	2700
India	21,090,000	17,930,000	14,640,000	11,540,000	11,850,000	12,670,000	13,170,000
Indonesia	2,715,000	2,469,000	2,453,000	2,017000	1,479,000	1,274,000	1,281,000
Lao PDR	51,000	42,800	112,700	93,500	117,300	87,900	27,390
Malaysia	5000	4000	4000	2900	3100	240	270
Nepal	43,400	32,700	20,520	16,230	8000	7000	4000
Philippines	53,200	25,970	18,630	16,290	12,210	20,580	16,630
PNG*	1,342,000	1,130,000	1,452,000	1,617,000	1,260,000	1,014000	1,407,000
Republic of Korea	1300	500	400	400	600	600	600
Solomon Islands	95,900	66,200	55,000	56,400	30,780	39,400	86,000
Sri Lanka	—	—	—	—	—	—	—
Thailand	32,500	24,900	32,600	33,300	37,900	8000	11,520
Vanuatu	13,780	10,000	7000	5000	1900	600	4000
Vietnam	25,460	22,630	26,610	23,140	21,200	12,560	6000

Source: World malaria report 2017 (WHO [1, 16])*PNG, Papua New Guinea.

Table 1. Malaria transmission trends in the Asia Pacific Malaria Elimination Network (APMEN) countries based on the estimated malaria cases during 2010–2016.

http://dx.doi.org/10.5772/intechopen.75405

Democratic People's Republic of Korea (DPR Korea), Indonesia, Malaysia, the Philippines, Republic of Korea, Solomon Islands, Sri Lanka, and Vanuatu) that now have expanded to 18 countries (adding Bangladesh, Cambodia, Lao People's Democratic Republic (Lao PDR), India, Nepal, Papua New Guinea, Thailand, and Vietnam) [11] (**Figure 1**). APMEN countries encompass the largest malaria reporting area outside the African region. APMEN serves the country partners and together with regional partners from the academic, development, non-governmental and private sectors, and global agencies including the WHO, collaboratively address the unique challenges of malaria elimination in the region through leadership, advocacy, capacity building, knowledge exchange and building evidence to support more effective, sustained malaria elimination programmes across the region [12].

Each member State has defined elimination goals based on malaria transmission trends (**Table 1**). Countries with low incidence of malaria are targeting elimination at the national level, while countries with higher incidence are planning to eliminate malaria at the sub-national level before pursuing elimination at the national level. However, all countries are committed to eliminating malaria in the Asia Pacific region by 2030 [13]. Sri Lanka eliminated malaria in 2012 and WHO certified Sri Lanka malaria free nation in 2016 [14]. Bhutan and the Republic of Korea have targeted to eliminate malaria in 2018 and 2019 respectively [15, 16]. Bangladesh, China, Malaysia, Philippines, and Vanuatu plan to eliminate malaria by 2020; DPR Korea, Cambodia, Lao People's Demographic Republic (Lao PDR), and Papua New Guinea (PNG) are planning to eliminate by 2025, and Nepal by 2026; finally India, Indonesia, Thailand, and Vietnam plan to eliminate malaria by 2030 [15]. The success of malaria elimination in APMEN States will greatly enhance the global drive towards malaria elimination. Therefore, the aim of this review is to present a compilation of available evidence on the challenges and way forward for malaria elimination in APMEN countries.

2. Epidemiological drivers of malaria in APMEN countries

Malaria elimination in APMEN countries faces many challenges. The challenges include large numbers of people living in malaria risk areas; presence of all forms of human malaria: *Plasmodium falciparum*, *P. vivax*, *P. ovale, P. malariae*, and *P. knowlesi*; the high incidence of *P. vivax* malaria, which is particularly difficult to control due to the dormant stages of its life cycle within the human host, and zoonotic malaria caused by *P. knowlesi*, which has animal reservoirs; anti-malarial drug resistance in *P. falciparum* and *P. vivax* parasites; diverse vectors with different feeding behaviour and insecticide resistance; forest malaria; human migration across porous international borders and cross-border malaria; and inadequacies in health systems in the region.

2.1. *Plasmodium vivax* Malaria

Plasmodium vivax is an important but relatively neglected malaria parasite globally [17]. This form of malaria is more widespread than *P. falciparum* malaria with 2.9 billion people at risk of infection, of which 90% live in the Asia Pacific region [18–22]. *P. vivax* is more difficult to treat than *P. falciparum* due to dormant liver stages (hypnozoites) [23–25], and the development of transmissible blood stages (gametocytes) before clinical symptoms [26]. These characteristics enable the parasite to adapt to environmental challenges and evade control interventions in place and time.

http://dx.doi.org/10.5772/intechopen.75405

In many countries embarking on malaria elimination, *P. falciparum* incidence declines more rapidly than *P. vivax* incidence, due to the greater effectiveness of interventions for the former. Treating all stages of the parasite (radical cure) is a critical strategy for the successful control and ultimate elimination of *P. vivax*. In order to achieve radical cure of *P. vivax*, blood stage parasites, as well as the hypnozoites, need to be cleared. The only current widely available drug against hypnozoites is the 8-aminoquinoline compound, primaquine [27]. Unfortunately, individuals who have a genetic deficiency for glucose-6-phosphate dehydrogenase (G6PD) enzyme are at risk of severe haemolysis when treated with the drug [28–30]. In addition, primaquine requires prolonged daily administration over seven to 14 days. The complexities of prescribing reliable, safe and effective radical cure of *P. vivax* highlights the urgent need for innovative new approaches to assure schizonticidal and hypnozoiticidal treatment; without which, *P. vivax* elimination is unlikely in most settings.

2.2. Zoonotic malaria

Plasmodium knowlesi infections have been reported in a number of Asian Pacific countries [31–34]. This zoonotic species of malaria, which also infects macaque monkeys that form the main animal reservoir, was probably present in humans but was undiagnosed until molecular detection methods were developed that could distinguish *P. knowlesi* from the morphologically similar human malaria parasite *Plasmodium malariae* [35, 36]. Recently, the first case of human infection with *Plasmodium cynomolgi* was reported in Peninsular Malaysia that resembles *P. vivax* morphologically [37]. The role of animal reservoirs of malaria transmittable to humans is an almost wholly neglected question in the elimination agenda in the Asia-Pacific region [38].

2.3. Characteristics of populations at risk

Nearly 2.1 billion people in the Asia-Pacific region live in areas where there is risk of malaria transmission of which 16.8% live in high-risk areas [2, 39] (**Figure 2**). These high-risk areas include settlements located in remote parts of endemic countries including border areas. Many of these high-risk areas are characterised by forest and forest fringe environment with high malaria transmission, poor geographical accessibility, high population mobility, and low human density. In addition, most of these areas are inhabited by ethnic minorities, refugees and displaced people who are difficult to access and often experience high degree of poverty [40, 41]. Furthermore, these areas are frequented by people engaged in activities with increased risk of malaria exposure, such as tourism and pilgrimages, forest-related work such as logging, gem-mining, latex harvesting, fishing, road construction and other industrial occupations [41–45].

2.4. Antimalarial drug-resistance

Historically, countries in the Mekong Region including Cambodia and Thailand are global epicentres of emerging antimalarial drug resistance [46]. Chloroquine resistance was first reported in this area in the 1970s, followed by resistance to other anti-malarial drugs [47]. Over the past decade, artemisinin-based combination therapy (ACT) became the first-line protocol for the management of *P. falciparum* infections world over. However, parasites that

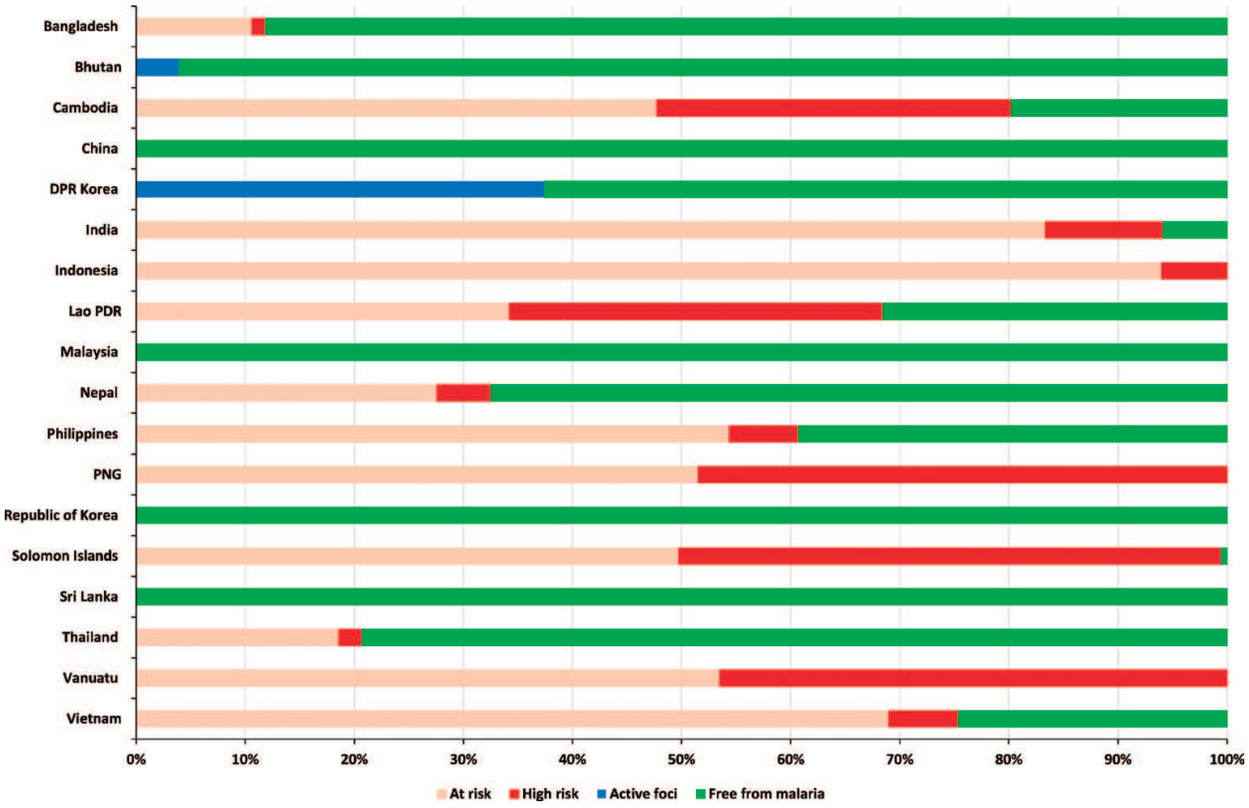

Figure 2. Population at risk of malaria in Asia Pacific Malaria Elimination Network (APMEN) countries for data based on 2016. (at risk- low risk + high risk). Source: World malaria report 2017 [1].

are drug-resistant to artemisinin and its derivatives have recently emerged in various parts of Southeast Asia challenging all control strategies for treatment and elimination efforts [48–51]. Presently, resistance to mefloquine continues to be a concern in Thailand and Cambodia, where artesunate-mefloquine is used as first line treatment [47]. Artemether-lumefantrine remains highly effective in most parts of the world, with the exception of Cambodia [52, 53]. There are evidences of resistance to ACT in Vietnam [2, 54]. In India, ACT is used universally across the country yet declining efficacy to artesunate plus sulphadoxine-pyrimethamine has already been reported in its northeastern region [55–57] however, there have been no reports of ACT resistance in other APMEN member States (**Figure 3**).

Chloroquine has remained the main choice of treatment for *P. vivax* blood stage infections, however, this policy is under threat from emerging drug resistant *P. vivax* strains [58]. A number of APMEN countries have reported *P. vivax* resistance to chloroquine. There are reports of resistance in some States of India [59–62], central Vietnam [63], and Thai-Myanmar border [64]. However, *P. vivax* is still sensitive to chloroquine in Cambodia [65], border area of Yunnan Province of China and Myanmar [66], central China [67], and Nepal [68, 69].

2.5. Vector control

Vector control remains one of the main preventive strategies of containing malaria transmission in APMEN countries. However, a lack of technical capacity in entomology and vector control represents a key gap in elimination programmes. In addition, the diversity of malaria vectors in the

http://dx.doi.org/10.5772/intechopen.75405

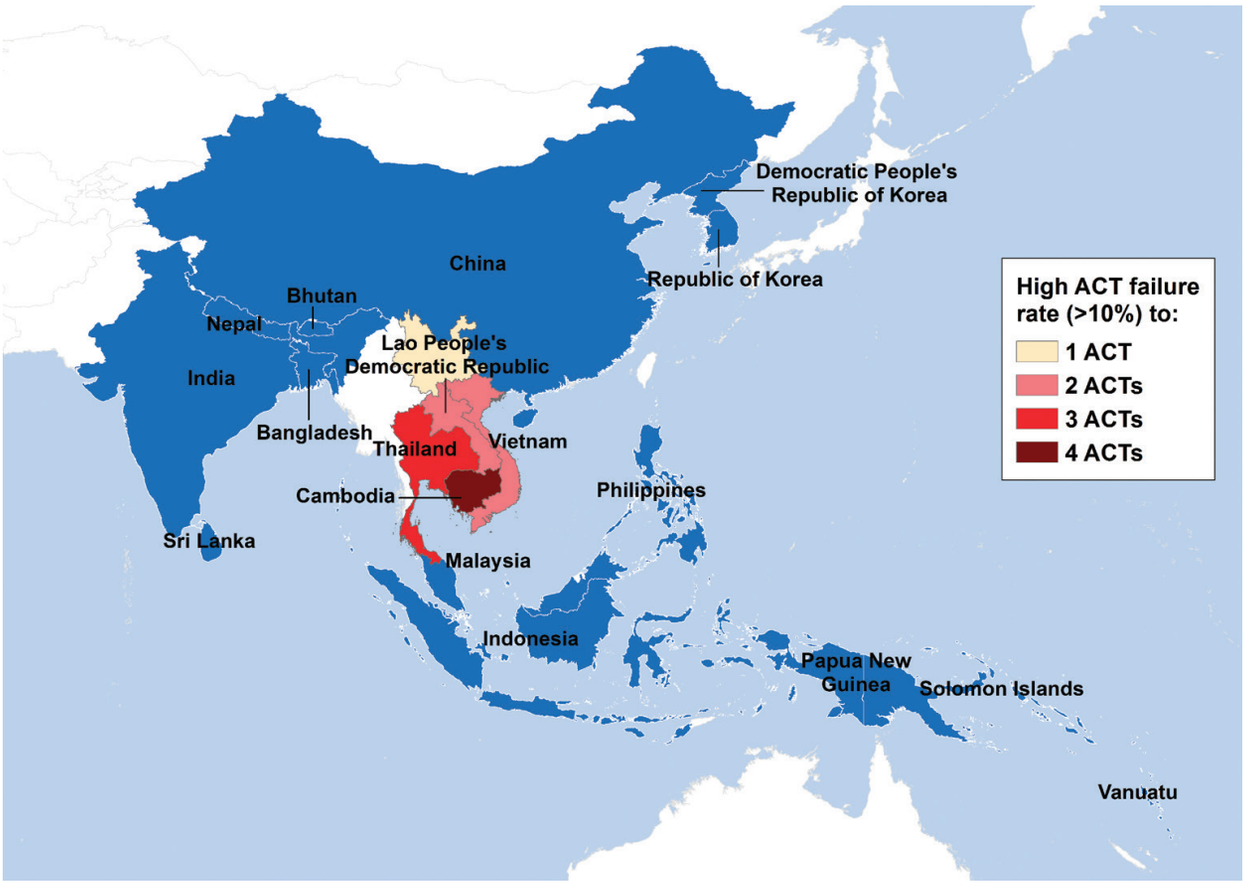

Figure 3. Distribution of malarial multidrug resistance for data based on 2016. ACT- artemisinin-based combination therapy; 1 ACT- resistance to one ACT; 2 ACT- resistance to two ACTs; 3 ACTs- resistance to three ACTs; 4 ACTs- resistance to four ACTs. Source: World malaria report 2017 [1].

Asia-Pacific region (19 different species) poses unique challenges for elimination [70, 71] (**Table 2**). There is considerable variation in bionomical characteristics of mosquito vectors making control efforts difficult. The commonest malaria vector species in the region, including *Anopheles dirus, An. baimaii,* and *An. minimus* [72, 73], are able to avoid indoor sprayed surfaces because of their exophilic and exophagic characteristics [70, 74, 75] rendering most domicile-based interventions, like long-lasting insecticidal nets (LLIN) and indoor residual spraying (IRS), less effective [74, 76]. Other challenges include insecticide resistance [77] and absence of local vector surveillance [78]. To address these challenges, APMEN instituted the APMEN Vector Control Working Group (VcWG) in 2010 [79]. The working group fosters information exchange between vector control experts and national programme managers of APMEN countries to formulate strategies to counter the challenges faced in the region. The Working Group has supported a range of activities to build vector control capacity in the region, including providing training fellowships to vector control officers in priority areas, supporting community efficacy studies of interventions, and consolidating information on vector management practices in the region [78].

2.6. Forest malaria

Forest malaria constitutes bulk of transmission in APMEN countries [42, 43, 80–83]. Many species of *Anopheles* mosquitoes that transmit malaria agents are abundant in natural forests

Country°	Main vectors*
Bangladesh [210]	*An. dirus, An. minimus, An. aconitus, An. philippinensis, An. sundaicus, An. barbirostris, An. subpictus, An. culicifacies, An. fluviatilis, An. maculatus*
Bhutan [210]	*An. minimus*
Cambodia [211]	*An. dirus, An. minimus, An. maculatus, An. epiroticus*
China [73, 212]	*An. sinensis, An. lesteri, An. dirus, An. minimus, An. maculatus*
DPR Korea [210]	*An. lesteri, An. sinensis, An. sineroides, An. kleini, An. yatsus hiroensis, An. lindesayi japonicas, An. koreicus*
India [213]	*An. culicifacies, An. baimaii, An. fluviatilis, An. minimus, An. stephensi, An. maculatus, An. sundaicus*
Indonesia [214]	*An. aconitus, An. balabacensis, An. bancrofti, An. barbirostris, An. barbumbrosus, An. farauti, An. flavirostris, An. karwari, An. kochi, An. koliensis, An. leucosphyrus, An. maculatus, An. nigerrimus, An. parangensis, An. punctulatus, An. sinensis, An. subpictus, An. sundaicus, An. tessellatus, An. vagus*
Lao PDR [211]	*An. dirus, An. minimus, An. maculatus, An. jeyporiensis*
Malaysia [211]	*An. balabacensis, An. campestris, An. cracens, An. donaldi, An. flavirostris, An. latens, An. letifer, An. maculatus, An. sundaicus*
Nepal [210]	*An. fluviatilis, An. annularis, An. maculatus*
Philippines [215]	*An. flavirostris, An. balabacensis, An. maculatus, An. litoralis, An. mangyanus*
PNG [216, 217]	*An. farauti, An. koliensis, An. punctulatus, An. bancroftii, An. karwari*
Republic of Korea [218]	*An. kleini, An. pullus, An. belenrae, An. sineroides, An. sinensis, An. lesteri*
Solomon Islands [217]	*An. punctulatus, An. koliensis, An. farauti*
Sri Lanka [210, 219]	*An. culicifacies, An. annularis, An. subpictus, An. tessellatus, An. stephensi*
Thailand [210]	*An. dirus, An. minimus, An. maculatus, An. aconitus, An. epiroticus*
Vanuatu [217]	*An. farauti*
Vietnam [211]	*An. dirus, An. minimus, An. maculatus, An. aconitus, An. jeyporiensis, An. subpictus, An. sinensis, An. pampanai, An. epiroticus*

*An., *Anopheles* names refer either to the group, complex or species when specific identifications have been done.
°Corresponding references are in brackets.

Table 2. List of the main malaria vectors in the Asia Pacific Malaria Elimination Network (APMEN) countries.

and forested plantations. Both the forests and occurrence of deforestation impact increasing malaria risk and transmission, particularly in border areas. Forested areas provide conducive environment for vector proliferation and survival [84, 85]. Forest vectors usually prefer tree canopy coverage and are known to take shelter in tree holes [86–88]. Forest flora and sugar availability have also been shown to be crucial determinants of vectorial capacity [89]. In addition, leaves falling into larval habitats assure sustainable micro-climatic conditions for larvae of vectors like *An. dirus,* which is a dominant vector in Southeast Asia [90]. Further, there are usually abundant bodies of water including ponds, streams, and rivers in forested areas supporting vector multiplication and survival thereby sustaining malaria transmission

in the region [80, 90–93]. Deforestation increases the risk of malaria through a number of favourable conditions for the *Anopheles* mosquito by creating mosquito-breeding sites in the stumps of trees, ditches and puddles on the ground. The direct sunlight on the pools of water increases temperatures promoting mosquito breeding. Increased human activities in deforested areas such as logging, increased large-scale agricultural activities, mining, building of hydropower projects, and the collection of wood for fuel, all enhance contact with mosquitoes and thereby increased malaria transmission [94–96].

Populations in border areas are at greater risk of malaria infections because they frequently visit forests, forest fringe areas, or forested plantations at or near the border [42, 75, 97, 98]. Occupational exposures affect malarial receptivity by age group–for example, in forest fringe villages, adult infections are more prevalent due to forest-related activities such as logging, rubber tapping, bamboo cutting, charcoaling, foraging, and overnight stays in the forests [99]. Migration of the population working in the forest and forest fringe results in spread via carriers to new areas previously free from malaria transmission [100]. Despite high coverage of preventive measures such as LLIN or insecticide-treated nets (ITNs) and IRS in the member States of APMEN, populations working and staying overnight in the forest are not protected [43, 82, 101]. A lack of infrastructure such as roads and healthcare facilities hinder malaria control activities and delayed treatment.

2.7. Migration and cross-border malaria

One of the main challenges that continues thwart malaria elimination is cross-border malaria [94, 102]. People migrate across international borders for a number of reasons including work opportunities, visiting friends and relatives, and displacement as a result of natural and manmade calamities (such as ethnic conflicts) and major development projects. Malaria control in border areas is often difficult for being heavily forested, mountainous and inaccessible terrain, and unregulated population movements across the borders [103, 104]. Open porous international borders allow unchecked movement of people [105–111]. Such cross-border migration is likely to derail the malaria control activities of the neighbouring countries and risk introduction of drug-resistant parasites [112]. Mobile populations along the border areas often live in poverty and have poor access to healthcare services. Movement of people across international borders has contributed to maintaining high transmission hotspots adjacent to border points [73, 105, 113].

2.8. Misalignment of programmatic approaches

There are differences in programmatic approaches among neighbouring countries in the APMEN region making the coordination of control and preventive measures challenging [114, 115]. For example, there are differences in malaria control activities across Laos-Vietnam border. In Laos, the mainstay of malaria control is distribution of LLINs but on the Vietnamese side there is a stronger focus on IRS [114, 115]. Even where the approaches are similar, the specific antimalarial drugs or insecticides used can influence effectiveness due to parasite or vector resistance. Deltamethrin (synthetic pyrethroid) is used for IRS in Bhutan, however, DDT is used in the neighbouring State of Assam in India [116–118]. Effective control or elimination requires coordinated efforts for control interventions.

3. Way forward

In light of the aforementioned challenges in the APMEN member States, some of the possible solutions for way forward include carrying out operational research (OR) to understand the micro-epidemiology of malaria in each country, the use of technologically-assisted solutions for managing operational data (including spatial decision support systems (SDSS)), strengthening surveillance and initiating cross-border initiative.

3.1. Operational research (OR)

As countries move forward with malaria elimination, this effort requires adjustments on the way national malaria programmes operate. For example, the strategies for case detection and surveillance are radically different in control and elimination programmes. Countries may face constraints or bottlenecks as they make the transition from control to elimination for which OR can help to remove these bottlenecks, thereby enabling countries to make the transition from control to elimination phases more rapidly [119, 120]. OR in health is defined as search for knowledge on interventions, strategies, or tools that can enhance the quality, effectiveness, or coverage of programmes [121], and results in improved policy-making, better design and implementation of health systems, and more efficient methods of service delivery [122–125]. The goal is to strengthen health services and improve healthcare delivery in disease-endemic countries and it has an additional critical role to play in helping solve major implementation problems [121, 126–128]. The key elements of OR are that the research questions are generated by identifying the constraints and challenges encountered during the implementation of programme activities, thus can be imbedded into routine programmatic activities [129]. The WHO and Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) have been encouraging programmes to conduct OR as part of their donor-funded activities [119, 130].

A significant limitation of national programmes has been the poor ability, even inability, to manage operational data collected through surveillance and other health information systems [131]. OR can be used to address these knowledge gaps and provide solutions to this limitation. OR has been under-utilised in APMEN member States [132, 133]. However, some countries including China [134], Bhutan [108], India [135, 136], Nepal [137], Solomon Islands [138], and countries in the Greater Mekong Sub-region (GMS) [120] are starting to address the challenges in malaria elimination efforts through OR in areas such as artemisinin resistance.

A key challenge is a lack of operational research capacity of member States [133]. One of the ways to overcome this shortcoming is to develop research capacity through the Structured Operational Research and Training Initiative (SORT IT), a global partnership-based initiative led by the Special Programme for Research and Training in Tropical Diseases (TDR) of WHO [131, 139, 140].

3.2. Role of geospatial data analysis

Malaria has a focal spatial distribution in pre-elimination and elimination phases, with hotspots of transmission in which the risk of malaria (including asymptomatic parasitaemias) and number of cases are higher than in surrounding areas [141, 142]. The scale at which spatial

http://dx.doi.org/10.5772/intechopen.75405

heterogeneity occurs ranges from micro-geographical setting beginning with household or village level [143–149] to municipalities [150], sub-districts [111], district [151–153], subnational [105, 154–156], national [40], regional [157], and global scales [70]. These spatial clusters of malaria have the potential to be sources of spread into neighbouring regions and countries if there is no focused intervention in the hotspot areas. Given the spatial heterogeneity of the disease, focused interventions in areas with higher incidence of disease are likely to have greater impact than uniform resource allocation [158]. Therefore, the spatial distribution of malaria and its interventions should be taken into account in national malaria elimination plans.

Risk mapping and temporal forecasting of malaria using environmental and climatic factors as spatial and/or temporal risk predictors has been routinely undertaken [107, 159, 160]. Environmental data for geospatial and temporal analysis can be collected through satellite sensors or meteorological stations [159–162]. Image analysis techniques can be applied to satellite data to derive useful variables for the investigation of environmental drivers of malaria, such as land surface temperature, cold cloud duration (an indirect measure of rainfall), land use or land cover class, and normalised difference vegetation index (NDVI) [85, 161]. The NDVI can be used as proxy for rainfall through the measure of the greenness of the earth's surface and hence vegetation cover [163]. Meteorological data can be interpolated with statistical techniques to estimate values of climatic variables, such as rainfall, temperature, and humidity, for locations where meteorological data are not available [164]. Currently these approaches have mainly been used in research context, and more research including OR needs to be conducted to establish how these approaches can be of practical benefit to malaria control and elimination programmes.

3.3. Spatial decision support systems

In recent years, spatial decision support systems (SDSSs) have been increasingly used in malaria elimination programmes in some countries of Asia-Pacific region to support planning, monitoring and evaluation, including Vanuatu, Solomon Islands and Bhutan [110, 165]. SDSSs have also been employed for other vector-borne disease control programmes such as dengue in Thailand and Singapore [166–168].

SDSSs are technology-driven systems for the collection, mapping, displaying and dissemination of disease data. They provide computerised support for decision making that helps spatially-explicit resource allocation decisions [107, 169]. Key elements of SDSS include: (i) data inputs from a variety of sources (including geospatial data layers), (ii) automated outputs to guide informed and strategic decision making for designated applications, (iii) enabling application/intervention outcomes re-entered back into the SDSS as a cyclical input, and (iv) expert knowledge integrated throughout all stages of the spatial decision support process [170] (**Figure 4**). In most recent examples, data are fed into the SDSS in the field using personal digital assistants (PDAs). The SDSS contains modules for planning, monitoring and evaluating coverage of target populations with IRS and LLINs, and for mapping malaria surveillance data. A mechanism is provided to link routinely collected data with associated spatial information. Spatial queries and analyses can be conducted and cartographic maps and reports of the areas of interest can be produced. Summary statistics of key indicators and maps are fed back to field teams to enhance implementation of interventions.

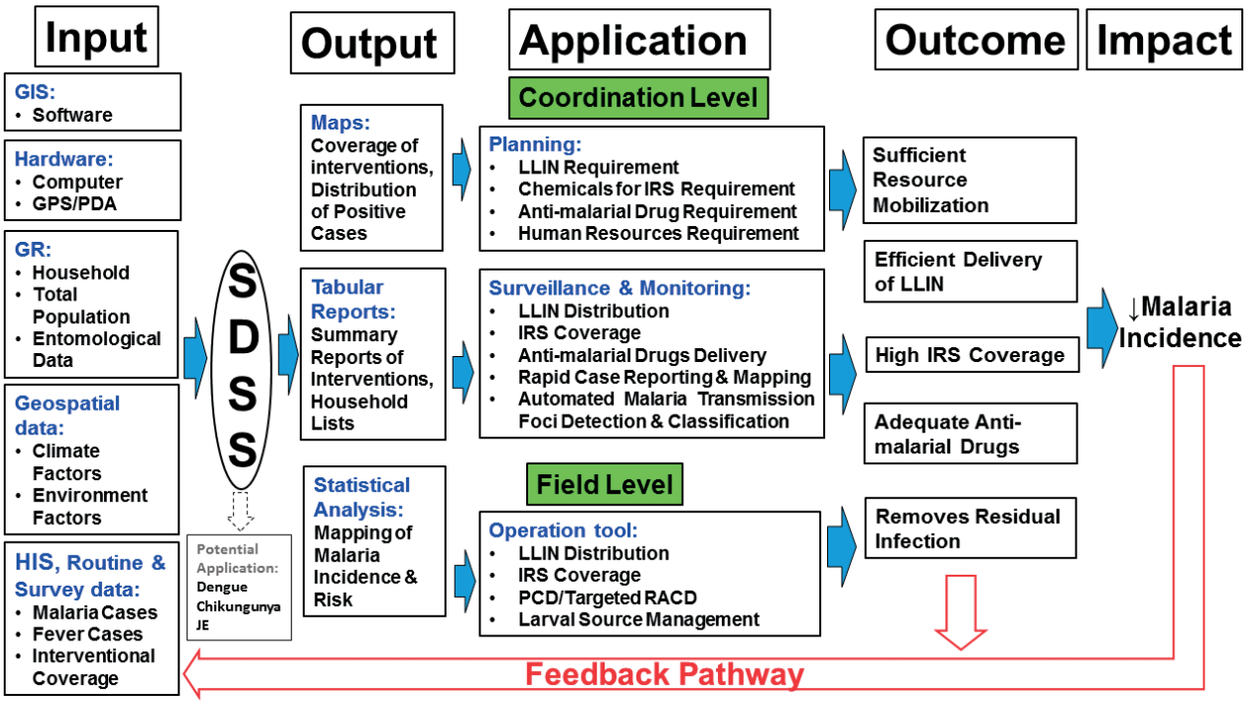

Figure 4. Framework of spatial decision support system for malaria control and prevention with potential use in other vector borne diseases. (GIS geographical information system, PDA personnel digital assistant, GPS global positioning system, SDSS spatial decision support system, GR geographic reconnaissance, LLIN long-lasting insecticidal net, IRS indoor residual spraying, PCD passive case detection, RACD active case detection, JE Japanese encephalitis) (Wangdi et al. [110]).

Limited evaluation to date suggests that these systems support health programmes with a powerful and user-friendly operational tool for evidence-based decision making. Maps are an important SDSS output that provide a visual aid for decision making [170]. An example of map used to monitor LLIN coverage during a mass LLIN distribution in Bhutan is shown in **Figure 5**. This map can inform programme officials of the progress of the campaign and more importantly identifies areas that require catch up activities to achieve target coverage. Malaria incidence maps provide important inputs to policy makers to implement targeted interventions aimed at disease prevention and management. Spatial targeting of malaria interventions, supported by SDSS, will result in more efficient and effective allocation of intervention resources in transmission hotspots helping achieve substantial transmission reduction [135, 156, 158, 171].

3.4. Strengthening surveillance-response and cross-border initiatives

For countries embarking on malaria elimination, malaria surveillance systems need revamping. The main objectives of surveillance in malaria elimination are to detect infections (both symptomatic and asymptomatic), and ensure radical cure. This is in contrast to the malaria control phase in which the main objectives of surveillance is to quantify the level of malaria transmission and to support preventive action at the population level [172, 173]. In most countries, malaria surveillance is based on passive case detection. Passive surveillance involves reporting malaria cases by a health facility, which can be limited by incomplete reporting, healthcare seeking in the private sector (not captured by government systems), and poor diagnostic capacity, particularly in low transmission settings [174]. Prompt detection and radical treatment of

http://dx.doi.org/10.5772/intechopen.75405

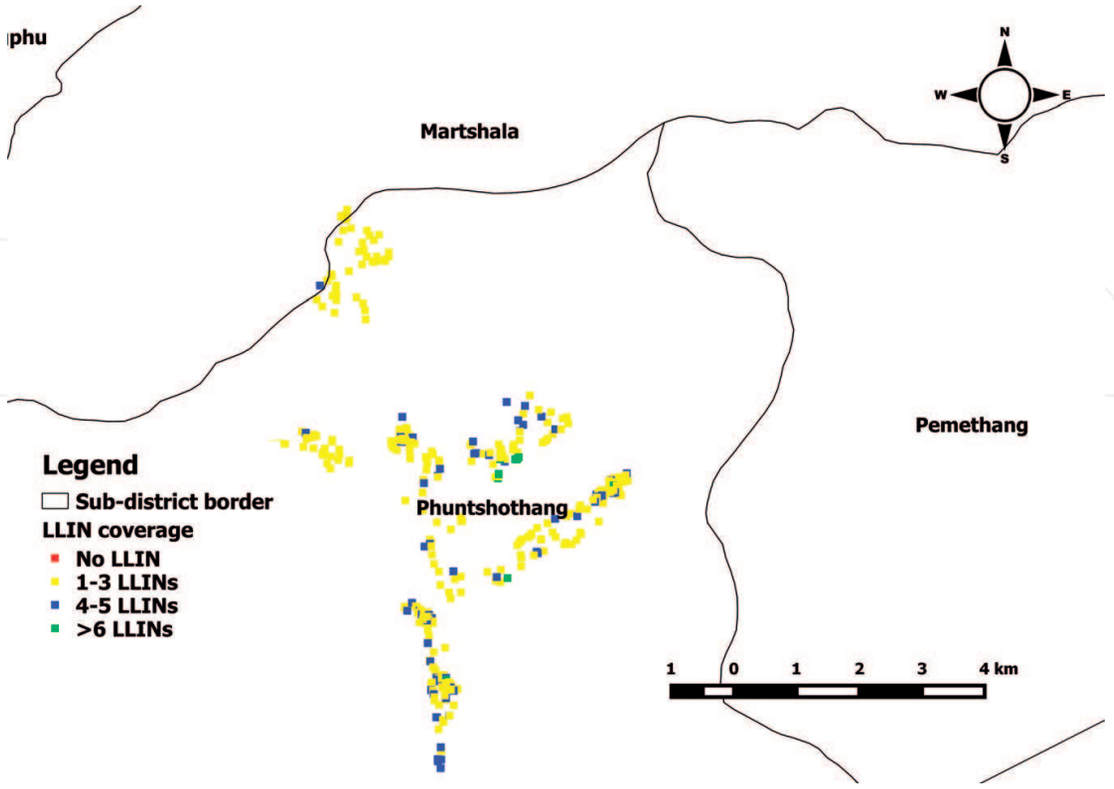

Figure 5. Sample output map for monitoring the coverage of long-lasting insecticidal net in Bhutan (Samdrup Jongkhar) (in this map there was no households without LLIN) (Wangdi et al. [110]).

imported malaria cases is critical for malaria elimination for sustaining the malaria elimination efforts. However, importation of malaria is inevitable, even in countries that have eliminated malaria. Passive case detection (PCD) could capture imported cases and allow interventions that would prevent resurgence in the presence of robust health system [175]. However, in areas with high transmission intensities in APMEN countries [70, 176], and unchecked migration across borders [103–111], there is likely to be significant transmission even in low transmission settings. Therefore, imported infections must be prevented through border screening, regional and cross-border initiatives and dialogue, proactive case detection, and treatment in high-risk population groups and travellers preventing resurgence of the disease [177].

Active surveillance addresses some of the limitations of PCD and generally involves cross-sectional surveys of defined sample populations, where the primary malaria indicator is the proportion of persons infected with malaria parasites (parasite prevalence) [178]. These surveys enable detection of asymptomatic infections that perpetuate transmission [179], and provide an opportunity to concurrently assess coverage of malaria interventions [180], but they are expensive and difficult to implement, and are not efficient in low-transmission settings.

One of the most efficient ways to enhance passive surveillance is through reactive case detection (RACD). When an index case of clinical malaria is detected in a community, RACD is carried out in all the households located within a certain distance of the index case. During the RACD, follow-up activities differ widely and can include testing of fever using RDTs or microscopy for any residual malaria infection and treating those who test positive. In addition, vector control activities including IRS and LLINs are intensified. RACD has been implemented in Africa and

Asia with mixed results [110, 181–186]. Nevertheless, RACD provides an opportunity for public health workers to concurrently assess coverage of malaria interventions including LLINs, and should be advocated and practised. Another efficient way to evaluate the efficacy of vector control methods, also applied in Africa and Asia, is to estimate the human antibody response to *Anopheles* saliva in human populations [187–189].

Diagnostic techniques used for testing blood during RACD will significantly impact the programme effectiveness. Estimating parasite prevalence using microscopy is time and labour intensive, and often inaccurate in operational settings [190]. Newly available rapid diagnostic tests (RDTs) offer on-the-spot results, but have limitations in specificity, sensitivity, quality, and cost [190–193]. Both methods (microscopy and RDTs) may fail to detect a substantial proportion of low-density parasitaemias [186, 194, 195]. Polymerase chain reaction (PCR) provides enhanced sensitivity but results are not available immediately [196], instead Real-time PCR may present a consistent, accurate, and efficient tool for surveillance to assist malaria elimination in the future [196].

Cross-border movement of populations impacts the maintenance of 'hotspots' of high transmission along international borders [77, 94, 97, 108, 137, 197–200], and spread of drug-resistance seen along the international border of Thailand and Cambodia [201]. Then, cross-border initiatives should be initiated through sharing of programme data including insecticide resistance, blood testing at the border areas, and treatment of symptomatic cases [177, 202–208]. Such successful cross-border case studies in the region have led to significant reduction in malaria burden in the study areas [209].

4. Conclusions

Successful malaria elimination in the APMEN member States will greatly enhance the global drive to eliminate malaria. Malaria transmission in these States is complex. APMEN member States include the largest populations living in areas of malaria transmission risk outside Africa. They are a global source of ACT resistance, highest burden of *P. vivax* and zoonotic malaria, and face many geopolitical and socioeconomic factors that will challenge malaria elimination efforts. These challenges can be addressed in part through operational research to identify country specific solutions, making better use of operational data such as through implementing SDSS approaches, and strengthening surveillance and cross-border collaborations.

Abbreviations

ACT	artemisinin-based combination therapy
AIM	action and investment to defeat malaria 2016–2030
APMEN	Asia Pacific Malaria Elimination Network
DDT	dichlorodiphenyltrichloroethane

http://dx.doi.org/10.5772/intechopen.75405

DPR Korea	Democratic People's Republic of Korea
G6PD	glucose-6-phosphate dehydrogenase
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GIS	geographic information systems
GMS	Greater Mekong Sub-region
GST	Global Technical Strategy for Malaria
IRS	indoor residual spraying
ITN	insecticide-treated nets
Lao PDR	Lao People's Demographic Republic
LLIN	long-lasting insecticidal nets
MIS	malaria indicator survey
NDVI	normalised difference vegetation index
OR	operational research
PCD	passive case detection
PCR	polymerase chain reaction
RACD	reactive case detection
RDT	rapid diagnostic test
PNG	Papua New Guinea
SDSS	spatial decision support systems
SEAR	South-East Asian Region
SORT IT	Structured Operational Research and Training Initiative
TDR	Research and Training in Tropical Diseases
VcWG	Vector Control Working Group
WHO	World Health Organisation

Author details

Kinley Wangdi* and Archie CA Clements

*Address all correspondence to: kinley.wangdi@anu.edu.au

Department of Global Health, Research School of Population Health, The Australian National University, Canberra, ACT, Australia

References

[1] WHO. World Malaria Report 2017. Geneva, Switzerland: WHO Library Cataloguing-in-Publication Data; 2017

[2] WHO. World Malaria Report 2016. Switzerland: WHO Library Cataloguing-in-Publication Data Geneva; 2016

[3] Malaria; 2016. [http://www.who.int/malaria/media/world-malaria-report-2016/en/]

[4] WHO. World Malaria Report 2014. Switzerland: World Health Organization, Geneva, Switzerland, Geneva; 2014

[5] WHO. Global Technical Strategy for Malaria 2016-2030. WHO Library Cataloguing-in-Publication Data; 2015

[6] Wang SQ, Li YC, Zhang ZM, Wang GZ, Hu XM, Qualls WA, Xue RD. Prevention measures and socio-economic development result in a decrease in malaria in Hainan, China. Malaria Journal. 2014;**13**:362

[7] Tusting LS, Willey B, Lucas H, Thompson J, Kafy HT, Smith R, Lindsay SW. Socioeconomic development as an intervention against malaria: A systematic review and meta-analysis. Lancet. 2013;**382**:963-972

[8] Datta SC, Reimer JJ. Malaria and economic development. Review of Development Economics. 2013;**17**:1-15

[9] Malaria; 2017. [http://www.who.int/malaria/media/world-malaria-report-2017/en/]

[10] Action and Investiment to Defeat Malaria 2016-2030; 2015. [https://rollbackmalaria.com/about-rbm/aim-2016-2030/]

[11] Gosling RD, Whittaker M, Gueye CS, Fullman N, Baquilod M, Kusriastuti R, Feachem RG. Malaria elimination gaining ground in the Asia Pacific. Malaria Journal. 2012;**11**:346

[12] APMEN: Elimination 2030: Working Together for a Malria-free Aisa Pacific. 2014;**2017**. [http://apmen.org/web/1/elimination/]

[13] Chairman's Statement of 9th East Asia Summit; 2014. [http://dfat.gov.au/international-relations/regional-architecture/eas/Pages/chairmans-statement-of-the-9th-east-asia-summit.aspx]

[14] WHO certifies Sri Lanka malaria-free; 2016. [http://www.searo.who.int/mediacentre/releases/2016/1631/en/]

[15] Malaria elimination goals; 2015. [http://apmen.org/web/1/elimination/]

[16] WHO: Malaria Control and Elimination in the Western Pacific (2016-2020). (Pacific WHOROftW ed. Manila, Philippines. 2017

[17] Feachem RG, Phillips AA, Hwang J, Cotter C, Wielgosz B, Greenwood BM, Sabot O, Rodriguez MH, Abeyasinghe RR, Ghebreyesus TA, Snow RW. Shrinking the malaria map: Progress and prospects. Lancet. 2010;**376**:1566-1578

[18] Baird JK. Neglect of *Plasmodium vivax* malaria. Trends in Parasitology. 2007;**23**:533-539

[19] Ballut PC, Siqueira AM, Orlando AC, Alexandre MA, Alecrim MG, Lacerda MV. Prevalence and risk factors associated to pruritus in *Plasmodium vivax* patients using chloroquine in the Brazilian Amazon. Acta Tropica. 2013;**128**:504-508

[20] Mendis K, Sina BJ, Marchesini P, Carter R. The neglected burden of *Plasmodium vivax* malaria. The American Journal of Tropical Medicine and Hygiene. 2001;**64**:97-106

[21] Sharma VP, Dev V, Phookan S. Neglected *Plasmodium vivax* malaria in northeastern states of India. The Indian Journal of Medical Research. 2015;**141**:546-555

[22] Waheed AA, Ghanchi NK, Rehman KA, Raza A, Mahmood SF, Beg MA. Vivax malaria and chloroquine resistance: A neglected disease as an emerging threat. Malaria Journal. 2015;**14**:146

[23] Gray KA, Dowd S, Bain L, Bobogare A, Wini L, Shanks GD, Cheng Q. Population genetics of *Plasmodium falciparum* and *Plasmodium vivax* and asymptomatic malaria in Temotu Province, Solomon Islands. Malaria Journal. 2013;**12**:429

[24] Noviyanti R, Coutrier F, Utami RA, Trimarsanto H, Tirta YK, Trianty L, Kusuma A, Sutanto I, Kosasih A, Kusriastuti R, et al. Contrasting transmission dynamics of co-endemic *Plasmodium vivax* and *P. falciparum*: Implications for malaria control and elimination. PLoS Neglected Tropical Diseases. 2015;**9**:e0003739

[25] Jennison C, Arnott A, Tessier N, Tavul L, Koepfli C, Felger I, Siba PM, Reeder JC, Bahlo M, Mueller I, Barry AE. *Plasmodium vivax* populations are more genetically diverse and less structured than sympatric *Plasmodium falciparum* populations. PLoS Neglected Tropical Diseases. 2015;**9**:e0003634

[26] Bousema T, Drakeley C. Epidemiology and infectivity of *Plasmodium falciparum* and *Plasmodium vivax* gametocytes in relation to malaria control and elimination. Clinical Microbiology Reviews. 2011;**24**:377-410

[27] Domingo GJ, Satyagraha AW, Anvikar A, Baird K, Bancone G, Bansil P, Carter N, Cheng Q, Culpepper J, Eziefula C, et al. G6PD testing in support of treatment and elimination of malaria: Recommendations for evaluation of G6PD tests. Malaria Journal. 2013;**12**:391

[28] von Seidlein L, Auburn S, Espino F, Shanks D, Cheng Q, McCarthy J, Baird K, Moyes C, Howes R, Menard D, et al. Review of key knowledge gaps in glucose-6-phosphate dehydrogenase deficiency detection with regard to the safe clinical deployment of 8-aminoquinoline treatment regimens: A workshop report. Malaria Journal. 2013;**12**:112

[29] Cappellini MD, Fiorelli G. Glucose-6-phosphate dehydrogenase deficiency. Lancet. 2008; **371**:64-74

[30] Howes RE, Battle KE, Satyagraha AW, Baird JK, Hay SI. G6PD deficiency: Global distribution, genetic variants and primaquine therapy. Advances in Parasitology. 2013;**81**: 133-201

[31] Moyes CL, Henry AJ, Golding N, Huang Z, Singh B, Baird JK, Newton PN, Huffman M, Duda KA, Drakeley CJ, et al. Defining the geographical range of the *Plasmodium knowlesi* reservoir. PLoS Neglected Tropical Diseases. 2014;**8**:e2780

[32] Khim N, Siv S, Kim S, Mueller T, Fleischmann E, Singh B, Divis PC, Steenkeste N, Duval L, Bouchier C, et al. *Plasmodium knowlesi* infection in humans, Cambodia, 2007-2010. Emerging Infectious Diseases. 2011;**17**:1900-1902

[33] Ta TT, Salas A, Ali-Tammam M, Martinez Mdel C, Lanza M, Arroyo E, Rubio JM. First case of detection of *Plasmodium knowlesi* in Spain by real time PCR in a traveller from Southeast Asia. Malaria Journal. 2010;**9**:219

[34] Lubis IND, Wijaya H, Lubis M, Lubis CP, Divis PCS, Beshir KB, Sutherland CJ. Contribution of *Plasmodium knowlesi* to multispecies human malaria infections in north Sumatera, Indonesia. The Journal of Infectious Diseases. 2017;**215**:1148-1155

[35] Singh B, Kim Sung L, Matusop A, Radhakrishnan A, Shamsul SS, Cox-Singh J, Thomas A, Conway DJ. A large focus of naturally acquired *Plasmodium knowlesi* infections in human beings. Lancet. 2004;**363**:1017-1024

[36] Singh B, Daneshvar C. Human infections and detection of *Plasmodium knowlesi*. Clinical Microbiology Reviews. 2013;**26**:165-184

[37] Ta TH, Hisam S, Lanza M, Jiram AI, Ismail N, Rubio JM. First case of a naturally acquired human infection with *Plasmodium cynomolgi*. Malaria Journal. 2014;**13**:68

[38] Baird JK. Asia-Pacific malaria is singular, pervasive, diverse and invisible. International Journal for Parasitology. 2017;**47**:371-377

[39] Overview: Malaria in the Asia-Pacific; 2014. [un.org.au/files/2014/04/Malaria-in-the-Asia-Pacific-WMD-2014.pdf]

[40] Bui HM, Clements AC, Nguyen QT, Nguyen MH, Le XH, Hay SI, Tran TH, Wertheim HF, Snow RW, Horby P. Social and environmental determinants of malaria in space and time in Viet Nam. International Journal for Parasitology. 2011;**41**:109-116

[41] Erhart A, Ngo DT, Phan VK, Ta TT, Van Overmeir C, Speybroeck N, Obsomer V, Le XH, Le KT, Coosemans M, D'Alessandro U. Epidemiology of forest malaria in Central Vietnam: A large scale cross-sectional survey. Malaria Journal. 2005;**4**:58

[42] Erhart A, Thang ND, Hung NQ, Toi le V, Hung le X, Tuy TQ, Cong le D, Speybroeck N, Coosemans M, D'Alessandro U. Forest malaria in Vietnam: A challenge for control. American Journal of Tropical Medicine and Hygiene. 2004;**70**:110-118

[43] Grietens KP, Xuan XN, Ribera J, Duc TN, Bortel W, Ba NT, Van KP, Xuan HL, D'Alessandro U, Erhart A. Social determinants of long lasting insecticidal hammock use among the Ra-glai ethnic minority in Vietnam: Implications for forest malaria control. PLoS One. 2012;**7**:e29991

[44] Liu Y, Hsiang MS, Zhou H, Wang W, Cao Y, Gosling RD, Cao J, Gao Q. Malaria in overseas labourers returning to China: An analysis of imported malaria in Jiangsu Province, 2001-2011. Malaria Journal. 2014;**13**:29

[45] Pichainarong N, Chaveepojnkamjorn W. Malaria infection and life-style factors among hilltribes along the Thai-Myanmar border area, northern Thailand. The Southeast Asian Journal of Tropical Medicine and Public Health. 2004;**35**:834-839

[46] WHO: Containment of Malaria Multi-Drug Resistance on the Cambodia-Thailand Border. WHO-Mekong Malaria Programme; 2007

[47] Satimai W, Sudathip P, Vijaykadga S, Khamsiriwatchara A, Sawang S, Potithavoranan T, Sangvichean A, Delacollette C, Singhasivanon P, Kaewkungwal J, Lawpoolsri S. Artemisinin resistance containment project in Thailand. II: Responses to mefloquine-artesunate combination therapy among falciparum malaria patients in provinces bordering Cambodia. Malaria Journal. 2012;**11**:300

[48] Dondorp AM, Fairhurst RM, Slutsker L, Macarthur JR, Breman JG, Guerin PJ, Wellems TE, Ringwald P, Newman RD, Plowe CV. The threat of artemisinin-resistant malaria. The New England Journal of Medicine. 2011;**365**:1073-1075

[49] Enserink M. Malaria's drug miracle in danger. Science. 2010;**328**:844-846

[50] Dondorp AM, Nosten F, Yi P, Das D, Phyo AP, Tarning J, Lwin KM, Ariey F, Hanpithakpong W, Lee SJ, et al. Artemisinin resistance in *Plasmodium falciparum* malaria. The New England Journal of Medicine. 2009;**361**:455-467

[51] Ashley EA, Dhorda M, Fairhurst RM, Amaratunga C, Lim P, Suon S, Sreng S, Anderson JM, Mao S, Sam B, et al. Spread of artemisinin resistance in *Plasmodium falciparum* malaria. The New England Journal of Medicine. 2014;**371**:411-423

[52] WHO. Global report on antimalarial drug efficacy and drug resistance: 2000-2010. WHO Library Cataloguing-in-Publication Data; 2010

[53] Noedl H, Se Y, Schaecher K, Smith BL, Socheat D, Fukuda MM. Evidence of artemisinin-resistant malaria in western Cambodia. The New England Journal of Medicine. 2008;**359**:2619-2620

[54] Hien TT, Thuy-Nhien NT, Phu NH, Boni MF, Thanh NV, Nha-Ca NT, Thai le H, Thai CQ, Toi PV, Thuan PD, et al. In vivo susceptibility of *Plasmodium falciparum* to artesunate in Binh Phuoc Province, Vietnam. Malaria Journal. 2012;**11**:355

[55] Mishra N, Prajapati SK, Kaitholia K, Bharti RS, Srivastava B, Phookan S, Anvikar AR, Dev V, Sonal GS, Dhariwal AC, et al. Surveillance for artemisinin resistance in *Plasmodium falciparum* in India using the kelch13 molecular marker. Antimicrobial Agents and Chemotherapy. 2015;**59**:2548-2553

[56] Saha P, Guha SK, Das S, Mullick S, Ganguly S, Biswas A, Bera DK, Chattopadhyay G, Das M, Kundu PK, et al. Comparative efficacies of artemisinin combination therapies in *Plasmodium falciparum* malaria and polymorphism of pfATPase6, pfcrt, pfdhfr, and pfdhps genes in tea gardens of Jalpaiguri District, India. Antimicrobial Agents and Chemotherapy. 2012;**56**:2511-2517

[57] Patel P, Bharti PK, Bansal D, Ali NA, Raman RK, Mohapatra PK, Sehgal R, Mahanta J, Sultan AA, Singh N. Prevalence of mutations linked to antimalarial resistance in *Plasmodium falciparum* from Chhattisgarh, Central India: A malaria elimination point of view. Scientific Reports. 2017;**7**:16690

[58] Price RN, von Seidlein L, Valecha N, Nosten F, Baird JK, White NJ. Global extent of chloroquine-resistant *Plasmodium vivax*: A systematic review and meta-analysis. The Lancet Infectious Diseases. 2014;**14**:982-991

[59] Srivastava HC, Yadav RS, Joshi H, Valecha N, Mallick PK, Prajapati SK, Dash AP. Therapeutic responses of *Plasmodium vivax* and *P. falciparum* to chloroquine, in an area of western India where *P. vivax* predominates. Annals of Tropical Medicine and Parasitology. 2008;**102**:471-480

[60] Adak T, Sharma VP, Orlov VS. Studies on the *Plasmodium vivax* relapse pattern in Delhi, India. The American Journal of Tropical Medicine and Hygiene. 1998;**59**:175-179

[61] Yadav RS, Ghosh SK. Radical curative efficacy of five-day regimen of primaquine for treatment of *Plasmodium vivax* malaria in India. The Journal of Parasitology. 2002; **88**:1042-1044

[62] Singh RK. Emergence of chloroquine-resistant vivax malaria in South Bihar (India). Transactions of the Royal Society of Tropical Medicine and Hygiene. 2000;**94**:327

[63] Thanh PV, Hong NV, Van NV, Louisa M, Baird K, Xa NX, Peeters Grietens K, Hung le X, Duong TT, Rosanas-Urgell A, et al. Confirmed *Plasmodium vivax* resistance to chloroquine in Central Vietnam. Antimicrobial Agents and Chemotherapy. 2015;**59**:7411-7419

[64] Rungsihirunrat K, Muhamad P, Chaijaroenkul W, Kuesap J, Na-Bangchang K. *Plasmodium vivax* drug resistance genes; Pvmdr1 and Pvcrt-o polymorphisms in relation to chloroquine sensitivity from a malaria endemic area of Thailand. The Korean Journal of Parasitology. 2015;**53**:43-49

[65] Amaratunga C, Sreng S, Mao S, Tullo GS, Anderson JM, Chuor CM, Suon S, Fairhurst RM. Chloroquine remains effective for treating *Plasmodium vivax* malaria in Pursat province, Western Cambodia. Antimicrobial Agents and Chemotherapy. 2014;**58**:6270-6272

[66] Liu H, Yang HL, Tang LH, Li XL, Huang F, Wang JZ, Li CF, Wang HY, Nie RH, Guo XR, et al. Monitoring *Plasmodium vivax* chloroquine sensitivity along China-Myanmar border of Yunnan Province, China during 2008-2013. Malaria Journal. 2014;**13**:364

[67] Lu F, Wang B, Cao J, Sattabongkot J, Zhou H, Zhu G, Kim K, Gao Q, Han ET. Prevalence of drug resistance-associated gene mutations in *Plasmodium vivax* in Central China. The Korean Journal of Parasitology. 2012;**50**:379-384

[68] Ranjitkar S, Schousboe ML, Thomsen TT, Adhikari M, Kapel CM, Bygbjerg IC, Alifrangis M. Prevalence of molecular markers of anti-malarial drug resistance in *Plasmodium vivax* and *Plasmodium falciparum* in two districts of Nepal. Malaria Journal. 2011;**10**:75

[69] Pant DK, Joshi AB, Lekhak B. Assessment of therapeutic efficacy of anti malarial drug (Chloroquine) against *Plasmodium vivax* malaria in Kanchanpur District. Journal of Nepal Health Research Council. 2006;**4**:41-45

[70] Sinka ME, Bangs MJ, Manguin S, Rubio-Palis Y, Chareonviriyaphap T, Coetzee M, Mbogo CM, Hemingway J, Patil AP, Temperley WH, et al. A global map of dominant malaria vectors. Parasites & Vectors. 2012;**5**:69

[71] Morgan K, Somboon P, Walton C. Understanding *Anopheles* diversity in Southeast Asia and its applications for malaria control. In: Manguin S, editor. *Anopheles* Mosquitoes - New Insights into Malaria Vectors. Rijeka: InTech; 2013. Ch. 11

[72] Dev V, Manguin S. Biology, distribution and control of *Anopheles (Cellia) minimus* in the context of malaria transmission in northeastern India. Parasites & Vectors. 2016;**9**:585

[73] Zhang S, Guo S, Feng X, Afelt A, Frutos R, Zhou S, Manguin S. *Anopheles* vectors in mainland China while approaching malaria elimination. Trends in Parasitology. 2017;**33**:889-900

[74] Trung HD, Bortel WV, Sochantha T, Keokenchanh K, Briet OJ, Coosemans M. Behavioural heterogeneity of *Anopheles* species in ecologically different localities in Southeast Asia: A challenge for vector control. Tropical Medicine & International Health. 2005;**10**:251-262

[75] Manh CD, Beebe NW, Van VN, Quang TL, Lein CT, Nguyen DV, Xuan TN, Ngoc AL, Cooper RD. Vectors and malaria transmission in deforested, rural communities in north-Central Vietnam. Malaria Journal. 2010;**9**:259

[76] Somboon P, Lines J, Aramrattana A, Chitprarop U, Prajakwong S, Khamboonruang C. Entomological evaluation of community-wide use of lambdacyhalothrin-impregnated bed nets against malaria in a border area of north-West Thailand. Transactions of the Royal Society of Tropical Medicine and Hygiene. 1995;**89**:248-254

[77] Dhiman S, Goswami D, Rabha B, Gopalakrishnan R, Baruah I, Singh L. Malaria epidemiology along indo-Bangladesh border in Tripura state, India. The Southeast Asian Journal of Tropical Medicine and Public Health. 2010;**41**:1279-1289

[78] Vector control; 2010. [http://apmen.org/focus-areas/vector-control/]

[79] APMEN: APMEN Vector Working Group (VcWG): Vector Control Working Group Objectives and Governance. APMEN; 2010. [http://apmen.org/focus-areas/vector-control/]

[80] Bharti PK, Chand SK, Singh MP, Mishra S, Shukla MM, Singh R, Singh N. Emergence of a new focus of *Plasmodium malariae* in forest villages of district Balaghat, Central India: Implications for the diagnosis of malaria and its control. Tropical Medicine & International Health. 2013;**18**:12-17

[81] Sharma SK, Tyagi PK, Padhan K, Upadhyay AK, Haque MA, Nanda N, Joshi H, Biswas S, Adak T, Das BS, et al. Epidemiology of malaria transmission in forest and plain ecotype villages in Sundargarh District, Orissa, India. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2006;**100**:917-925

[82] Van Bortel W, Trung HD, Hoi le X, Van Ham N, Van Chut N, Luu ND, Roelants P, Denis L, Speybroeck N, D'Alessandro U, Coosemans M. Malaria transmission and vector behaviour in a forested malaria focus in Central Vietnam and the implications for vector control. Malaria Journal. 2010;**9**:373

[83] Durnez L, Mao S, Denis L, Roelants P, Sochantha T, Coosemans M. Outdoor malaria transmission in forested villages of Cambodia. Malaria Journal. 2013;**12**:329

[84] O'Loughlin SM, Okabayashi T, Honda M, Kitazoe Y, Kishino H, Somboon P, Sochantha T, Nambanya S, Saikia PK, Dev V, Walton C. Complex population history of two *Anopheles dirus* mosquito species in Southeast Asia suggests the influence of Pleistocene climate change rather than human-mediated effects. Journal of Evolutionary Biology. 2008;**21**:1555-1569

[85] Haque U, Hashizume M, Glass GE, Dewan AM, Overgaard HJ, Yamamoto T. The role of climate variability in the spread of malaria in Bangladeshi highlands. PLoS One. 2010;**5**:e14341

[86] Zhou G, Munga S, Minakawa N, Githeko AK, Yan G. Spatial relationship between adult malaria vector abundance and environmental factors in western Kenya highlands. The American Journal of Tropical Medicine and Hygiene. 2007;**77**:29-35

[87] Yadav RS, Sharma VP, Chand SK. Mosquito breeding and resting in treeholes in a forest ecosystem in Orissa. Indian Journal of Malariology. 1997;**34**:8-16

[88] Gunasekaran K, Sahu SS, Parida SK, Sadanandane C, Jambulingam P, Das PK. Anopheline fauna of Koraput district, Orissa state, with particular reference to transmission of malaria. The Indian Journal of Medical Research. 1989;**89**:340-343

[89] Manda H, Gouagna LC, Foster WA, Jackson RR, Beier JC, Githure JI, Hassanali A. Effect of discriminative plant-sugar feeding on the survival and fecundity of *Anopheles gambiae*. Malaria Journal. 2007;**6**:113

[90] Obsomer V, Defourny P, Coosemans M. The *Anopheles dirus* complex: Spatial distribution and environmental drivers. Malaria Journal. 2007;**6**:26

[91] Sahu SS, Parida SK, Sadanandane C, Gunasekaran K, Jambulingam P, Das PK. Breeding habitats of malaria vectors: *A. fluviatilis*, *A. annularis* and *A. culicifacies*, in Koraput district, Orissa. Indian Journal of Malariology. 1990;**27**:209-216

[92] Kumar DS, Andimuthu R, Rajan R, Venkatesan MS. Spatial trend, environmental and socioeconomic factors associated with malaria prevalence in Chennai. Malaria Journal. 2014;**13**:14

[93] Sharma VP, Dev V. Biology & control of *Anopheles culicifacies* Giles 1901. The Indian Journal of Medical Research. 2015;**141**:525-536

[94] Wangdi K, Gatton ML, Kelly GC, Clements AC. Cross-border malaria: A major obstacle for malaria elimination. Advances in Parasitology. 2015;**89**:79-107

[95] Hahn MB, Gangnon RE, Barcellos C, Asner GP, Patz JA. Influence of deforestation, logging, and fire on malaria in the Brazilian Amazon. PLoS One. 2014;**9**:e85725

[96] Guerra CA, Snow RW, Hay SI. A global assessment of closed forests, deforestation and malaria risk. Annals of Tropical Medicine and Parasitology. 2006;**100**:189-204

[97] Chaveepojnkamjorn W, Pichainarong N. Malaria infection among the migrant population along the Thai-Myanmar border area. The Southeast Asian Journal of Tropical Medicine and Public Health. 2004;**35**:48-52

[98] Tangena JA, Thammavong P, Wilson AL, Brey PT, Lindsay SW. Risk and control of mosquito-borne diseases in southeast Asian rubber plantations. Trends in Parasitology. 2016;**32**:402-415

[99] Dysoley L, Kaneko A, Eto H, Mita T, Socheat D, Borkman A, Kobayakawa T. Changing patterns of forest malaria among the mobile adult male population in Chumkiri District, Cambodia. Acta Tropica. 2008;**106**:207-212

[100] Wisit Chaveepojnkamjorn D. Behavioral factors and malaria infection among the migrant population, Chiang Rai province. Journal of the Medical Association of Thailand. 2005;**88**:1293-1301

[101] Singh N, Singh OP, Sharma VP. Dynamics of malaria transmission in forested and deforested regions of Mandla District, Central India (Madhya Pradesh). Journal of the American Mosquito Control Association. 1996;**12**:225-234

[102] Hlongwana KW, Tsoka-Gwegweni J. Towards the implementation of malaria elimination policy in South Africa: The stakeholders' perspectives. Global Health Action. 2017;**10**:1288954

[103] Stern A. International population movements and public health in the Mekong region: An overview of some issues concerning mapping. The Southeast Asian Journal of Tropical Medicine and Public Health. 1998;**29**:201-212

[104] Xu J, Liu H. The challenges of malaria elimination in Yunnan Province, People's Republic of China. The Southeast Asian Journal of Tropical Medicine and Public Health. 2012;**43**:819-824

[105] Clements A, Barnett AG, Cheng ZW, Snow RW, Zhou HN. Space-time variation of malaria incidence in Yunnan province, China. Malaria Journal. 2009;**8**:18

[106] Hu H, Singhasivanon P, Salazar NP, Thimasarn K, Li X, Wu Y, Yang H, Zhu D, Supavej S, Looarecsuwan S. Factors influencing malaria endemicity in Yunnan Province, PR China (analysis of spatial pattern by GIS). Geographical information system. The Southeast Asian Journal of Tropical Medicine and Public Health. 1998;**29**:191-200

[107] Reid H, Haque U, Clements AC, Tatem AJ, Vallely A, Ahmed SM, Islam A, Haque R. Mapping malaria risk in Bangladesh using Bayesian geostatistical models. The American Journal of Tropical Medicine and Hygiene. 2010;**83**:861-867

[108] Wangdi K, Banwell C, Gatton ML, Kelly GC, Namgay R, Clements AC. Malaria burden and costs of intensified control in Bhutan, 2006-14: An observational study and situation analysis. The Lancet Global Health. 2016;**4**:e336-e343

[109] Mohapatra PK, Narain K, Prakash A, Bhattacharyya DR, Mahanta J. Risk factors of malaria in the fringes of an evergreen monsoon forest of Arunachal Pradesh. National Medical Journal of India. 2001;**14**:139-142

[110] Wangdi K, Banwell C, Gatton ML, Kelly GC, Namgay R, Clements AC. Development and evaluation of a spatial decision support system for malaria elimination in Bhutan. Malaria Journal. 2016;**15**:180

[111] Wangdi K, Kaewkungwal J, Singhasivanon P, Silawan T, Lawpoolsri S, White NJ. Spatio-temporal patterns of malaria infection in Bhutan: A country embarking on malaria elimination. Malaria Journal. 2011;**10**:89

[112] Childs DZ, Cattadori IM, Suwonkerd W, Prajakwong S, Boots M. Spatiotemporal patterns of malaria incidence in northern Thailand. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2006;**100**:623-631

[113] Carme B. Substantial increase of malaria in inland areas of eastern French Guiana. Tropical Medicine & International Health. 2005;**10**:154-159

[114] Anh NQ, Hung le X, Thuy HN, Tuy TQ, Caruana SR, Biggs BA, Morrow M. KAP surveys and malaria control in Vietnam: Findings and cautions about community research. The Southeast Asian Journal of Tropical Medicine and Public Health 2005;**36:**572-577

[115] Hung le Q, Vries PJ, Giao PT, Nam NV, Binh TQ, Chong MT, Quoc NT, Thanh TN, Hung LN, Kager PA. Control of malaria: A successful experience from Viet Nam. Bulletin of the World Health Organization. 2002;**80**:660-666

[116] Dev V, Phookan S, Sharma VP, Dash AP, Anand SP. Malaria parasite burden and treatment seeking behavior in ethnic communities of Assam, northeastern India. The Journal of Infection. 2006;**52**:131-139

[117] Mittal PK, Wijeyaratne P, Pandey S. Status of insecticide resistance of malaria, Kala-azar and Japanese encephalitis vectors in Bangladesh, Bhutan, India and Nepal (BBIN). Environmental Health Project Activity Report. 2004;**129**:44-48

[118] Wangdi K, Singhasivanon P, Silawan T, Lawpoolsri S, White NJ, Kaewkungwal J. Development of temporal modelling for forecasting and prediction of malaria infections using time-series and ARIMAX analyses: A case study in endemic districts of Bhutan. Malaria Journal. 2010;**9**:251

[119] WHO. Planning Meeting for Operational Research on Malaria Elimination. Geneva, Switzerland; 2014

[120] Guyant P, Corbel V, Guerin PJ, Lautissier A, Nosten F, Boyer S, Coosemans M, Dondorp AM, Sinou V, Yeung S, White N. Past and new challenges for malaria control and elimination: The role of operational research for innovation in designing interventions. Malaria Journal. 2015;**14**:279

[121] Zachariah R, Harries AD, Ishikawa N, Rieder HL, Bissell K, Laserson K, Massaquoi M, Van Herp M, Reid T. Operational research in low-income countries: What, why, and how? The Lancet Infectious Diseases. 2009;**9**:711-717

[122] Nunn P, Harries A, Godfrey-Faussett P, Gupta R, Maher D, Raviglione M. The research agenda for improving health policy, systems performance, and service delivery for tuberculosis control: A WHO perspective. Bulletin of the World Health Organization. 2002;**80**:471-476

[123] Reynolds J. Introduction. Socio-Economic Planning Sciences. 1987;**21**:73-77

[124] Datta S. Applications of O.R. in health in developing countries: A review. Social Science & Medicine. 1993;**37**:1441-1450

[125] Harries AD. Integration of operational research into National Tuberculosis Control Programmes. Tuberculosis (Edinburgh, Scotland). 2003;**83**:143-147

[126] Operational and Implementation research; 2016. [http://www.who.int/tdr/diseases-topics/operational-implementation-research/en/]

[127] Malhotra S, Zodpey SP. Operations research in public health. Indian Journal of Public Health. 2010;**54**:145-150

[128] Monks T. Operational research as implementation science: Definitions, challenges and research priorities. Implementation Sci. 2016;**11**:1-10

[129] Mahendradhata Y, Probandari A, Widjanarko B, Riono P, Mustikawati D, Tiemersma EW, Alisjahbana B. Embedding operational research into national disease control programme: Lessons from 10 years of experience in Indonesia. Global Health Action. 2014;**7**:25412

[130] WHO. Guide to Operational Research in programs supported by the global fund; 2016. [http://www.who.int/hiv/pub/operational/globalfund/en/]

[131] Zachariah R, Ford N, Maher D, Bissell K, Van den Bergh R, van den Boogaard W, Reid T, Castro KG, Draguez B, von Schreeb J, et al. Is operational research delivering the goods? The journey to success in low-income countries. The Lancet Infectious Diseases. 2012;**12**:415-421

[132] Zhou SS, Rietveld AE, Velarde-Rodriguez M, Ramsay AR, Zhang SS, Zhou XN, Cibulskis RE. Operational research on malaria control and elimination: A review of projects published between 2008 and 2013. Malaria Journal. 2014;**13**:473

[133] Ramsay A, Olliaro P, Reeder JC. The need for operational research and capacity-building in support of the global technical strategy for malaria 2016-2030. Malaria Journal. 2016;**15**:235

[134] Chen SB, Ju C, Chen JH, Zheng B, Huang F, Xiao N, Zhou X, Ernest T, Zhou XN. Operational research needs toward malaria elimination in China. Advances in Parasitology. 2014;**86**:109-133

[135] Srivastava A, Nagpal B, Joshi P, Paliwal J, Dash A. Identification of malaria hot spots for focused intervention in tribal state of India: A GIS based approach. International Journal of Health Geographics. 2009;**8**:30

[136] Dev V, Sangma BM, Dash AP. Persistent transmission of malaria in Garo hills of Meghalaya bordering Bangladesh, north-East India. Malaria Journal. 2010;**9**:263

[137] Dhimal M, O'Hara RB, Karki R, Thakur GD, Kuch U, Ahrens B. Spatio-temporal distribution of malaria and its association with climatic factors and vector-control interventions in two high-risk districts of Nepal. Malaria Journal. 2014;**13**:457

[138] Atkinson JA, Johnson ML, Wijesinghe R, Bobogare A, Losi L, O'Sullivan M, Yamaguchi Y, Kenilorea G, Vallely A, Cheng Q, et al. Operational research to inform a sub-national surveillance intervention for malaria elimination in Solomon Islands. Malaria Journal. 2012;**11**:101

[139] Ramsay A, Harries AD, Zachariah R, Bissell K, Hinderaker SG, Edginton M, Enarson DA, Satyanarayana S, Kumar AM, Hoa NB, et al. The structured operational research and training initiative for public health programmes. Public Health Action. 2014;**4**:79-84

[140] Zachariah R, Rust S, Berger SD, Guillerm N, Bissell K, Delaunois P, Reid AJ, Kumar AM, Olliaro PL, Reeder JC, et al. Building global capacity for conducting operational research using the SORT IT model: Where and who? PLoS One. 2016;**11**:e0160837

[141] Bousema T, Griffin JT, Sauerwein RW, Smith DL, Churcher TS, Takken W, Ghani A, Drakeley C, Gosling R. Hitting hotspots: Spatial targeting of malaria for control and elimination. PLoS Medicine. 2012;**9**:e1001165

[142] Ernst KC, Adoka SO, Kowuor DO, Wilson ML, John CC. Malaria hotspot areas in a highland Kenya site are consistent in epidemic and non-epidemic years and are associated with ecological factors. Malaria Journal. 2006;**5**:78

[143] Alemu K, Worku A, Berhane Y, Kumie A. Spatiotemporal clusters of malaria cases at village level, Northwest Ethiopia. Malaria Journal. 2014;**13**:223

[144] Rosas-Aguirre A, Ponce OJ, Carrasco-Escobar G, Speybroeck N, Contreras-Mancilla J, Gamboa D, Pozo E, Herrera S, Llanos-Cuentas A. *Plasmodium vivax* malaria at households: Spatial clustering and risk factors in a low endemicity urban area of the northwestern Peruvian coast. Malaria Journal. 2015;**14**:176

[145] Pinchoff J, Henostroza G, Carter BS, Roberts ST, Hatwiinda S, Hamainza B, Hawela M, Curriero FC. Spatial patterns of incident malaria cases and their household contacts in a single clinic catchment area of Chongwe District, Zambia. Malaria Journal. 2015;**14**:305

[146] Ayele DG, Zewotir TT, Mwambi HG. Spatial distribution of malaria problem in three regions of Ethiopia. Malaria Journal. 2013;**12**:207

[147] Rosas-Aguirre A, Speybroeck N, Llanos-Cuentas A, Rosanas-Urgell A, Carrasco-Escobar G, Rodriguez H, Gamboa D, Contreras-Mancilla J, Alava F, Soares IS, et al. Hotspots of malaria transmission in the Peruvian Amazon: Rapid assessment through a parasitological and serological survey. PLoS One. 2015;**10**:e0137458

[148] Rulisa S, Kateera F, Bizimana JP, Agaba S, Dukuzumuremyi J, Baas L, de Dieu Harelimana J, Mens PF, Boer KR, de Vries PJ. Malaria prevalence, spatial clustering and risk factors in a low endemic area of eastern Rwanda: A cross sectional study. PLoS One. 2013;**8**:e69443

[149] Wen L, Li C, Lin M, Yuan Z, Huo D, Li S, Wang Y, Chu C, Jia R, Song H. Spatio-temporal analysis of malaria incidence at the village level in a malaria-endemic area in Hainan, China. Malaria Journal. 2011;**10**:88

[150] Braz RM, Guimaraes RF, Carvalho Junior OA, Tauil PL. Spatial dependence of malaria epidemics in municipalities of the Amazonian ecosystem. Revista Brasileira de Epidemiologia. 2014;**17**:615-628

[151] Brooker S, Clarke S, Njagi JK, Polack S, Mugo B, Estambale B, Muchiri E, Magnussen P, Cox J. Spatial clustering of malaria and associated risk factors during an epidemic

in a highland area of western Kenya. Tropical Medicine & International Health. 2004;**9**: 757-766

[152] Haque U, Huda M, Hossain A, Ahmed SM, Moniruzzaman M, Haque R. Spatial malaria epidemiology in Bangladeshi highlands. Malaria Journal. 2009;**8**:185

[153] Ahmed S, Galagan S, Scobie H, Khyang J, Prue CS, Khan WA, Ram M, Alam MS, Haq MZ, Akter J, et al. Malaria hotspots drive hypoendemic transmission in the Chittagong Hill districts of Bangladesh. PLoS One. 2013;**8**:e69713

[154] Kohara Melchior LA, Chiaravalloti Neto F. Spatial and spatio-temporal analysis of malaria in the state of acre, western Amazon, Brazil. Geospatial Health. 2016;**11**:443

[155] Sluydts V, Heng S, Coosemans M, Van Roey K, Gryseels C, Canier L, Kim S, Khim N, Siv S, Mean V, et al. Spatial clustering and risk factors of malaria infections in Ratanakiri Province, Cambodia. Malaria Journal. 2014;**13**:387

[156] Zhang W, Wang L, Fang L, Ma J, Xu Y, Jiang J, Hui F, Wang J, Liang S, Yang H, Cao W. Spatial analysis of malaria in Anhui province, China. Malaria Journal. 2008;**7**:206

[157] Gething PW, Casey DC, Weiss DJ, Bisanzio D, Bhatt S, Cameron E, Battle KE, Dalrymple U, Rozier J, Rao PC, et al. Mapping *Plasmodium falciparum* mortality in Africa between 1990 and 2015. The New England Journal of Medicine. 2016;**375**:2435-2445

[158] Clements ACA, Reid HL, Kelly GC, Hay SI. Further shrinking the malaria map: How can geospatial science help to achieve malaria elimination? The Lancet Infectious Diseases. 2013;**13**:709-718

[159] Hay SI, Tatem AJ, Graham AJ, Goetz SJ, Rogers DJ. Global environmental data for mapping infectious disease distribution. Advances in Parasitology. 2006;**62**:37-77

[160] Yang GJ, Gao Q, Zhou SS, Malone JB, McCarroll JC, Tanner M, Vounatsou P, Bergquist R, Utzinger J, Zhou XN. Mapping and predicting malaria transmission in the People's Republic of China, using integrated biology-driven and statistical models. Geospatial Health. 2010;**5**:11-22

[161] Dlamini SN, Franke J, Vounatsou P. Assessing the relationship between environmental factors and malaria vector breeding sites in Swaziland using multi-scale remotely sensed data. Geospatial Health. 2015;**10**:302

[162] Kamanga A, Renn S, Pollard D, Bridges DJ, Chirwa B, Pinchoff J, Larsen DA, Winters AM. Open-source satellite enumeration to map households: Planning and targeting indoor residual spraying for malaria. Malaria Journal. 2015;**14**:345

[163] Sudre B, Rossi M, Van Bortel W, Danis K, Baka A, Vakalis N, Semenza JC. Mapping environmental suitability for malaria transmission, Greece. Emerging Infectious Diseases. 2013;**19**:784-786

[164] Hay SI, Lennon JJ. Deriving meteorological variables across Africa for the study and control of vector-borne disease: A comparison of remote sensing and spatial interpolation of climate. Tropical Medicine & International Health. 1999;**4**:58-71

[165] Kelly GC, Seng CM, Donald W, Taleo G, Nausien J, Batarii W, Iata H, Tanner M, Vestergaard LS, Clements AC. A spatial decision support system for guiding focal indoor residual interventions in a malaria elimination zone. Geospatial Health. 2011;**6**:21-31

[166] Sithiprasasna R, Patpoparn S, Attatippaholkun W, Suvannadabba S, Srisuphanunt M. The geographic information system as an epidemiological tool in the surveillance of dengue virus-infected *Aedes* mosquitos. The Southeast Asian Journal of Tropical Medicine and Public Health. 2004;**35**:918-926

[167] Teng TB. New initiatives in dengue control in Singapore. Dengue Bulletin. 2001;**25**:1-6

[168] Ai-Leen GT, Song RJ. The use of GIS in ovitrap monitoring for dengue control in Singapore. Dengue Bulletin. 2000;**24**:110-116

[169] Keenan PB. Spatial Decision Support Systems: Decision Making Support Systems: Achievements and Challenges for the New Decade. Idea Group Publishing; 2003

[170] Kelly GC, Tanner M, Vallely A, Clements A. Malaria elimination: Moving forward with spatial decision support systems. Trends in Parasitology. 2012;**28**:297-304

[171] Mendis K. Spatial technology & malaria control. The Indian Journal of Medical Research. 2009;**130**:498-500

[172] WHO. Disease Surveillance for Malaria Elimination: An Operational Manual. World Health Organization. Switzerland: Geneva; 2012

[173] WHO. Disease Surveillance for Malaria Control. Geneva, Switzerland: World Health Organization; 2012

[174] Singh N, Bharti PK, Kumre NS. Active v. Passive surveillance for malaria in remote tribal belt of Central India: Implications for malaria elimination. Pathogens and Global Health. 2016;**110**:178-184

[175] Moonen B, Cohen JM, Snow RW, Slutsker L, Drakeley C, Smith DL, Abeyasinghe RR, Rodriguez MH, Maharaj R, Tanner M, Targett G. Operational strategies to achieve and maintain malaria elimination. Lancet. 2010;**376**:1592-1603

[176] Walton C, Handley JM, Tun-Lin W, Collins FH, Harbach RE, Baimai V, Butlin RK. Population structure and population history of *Anopheles dirus* mosquitoes in Southeast Asia. Molecular Biology and Evolution. 2000;**17**:962-974

[177] Sturrock HJ, Roberts KW, Wegbreit J, Ohrt C, Gosling RD. Tackling imported malaria: An elimination endgame. The American Journal of Tropical Medicine and Hygiene. 2015;**93**:139-144

[178] Hay SI, Smith DL, Snow RW. Measuring malaria endemicity from intense to interrupted transmission. The Lancet Infectious Diseases. 2008;**8**:369-378

[179] Alves FP, Gil LH, Marrelli MT, Ribolla PE, Camargo EP, Da Silva LH. Asymptomatic carriers of *Plasmodium* spp. as infection source for malaria vector mosquitoes in the Brazilian Amazon. Journal of Medical Entomology. 2005;**42**:777-779

[180] WHO. Malaria indicator survey: basic documentation for survey design and implementation/Roll Back Malaria Monitoring and Evaluation Reference Group. 1211 Geneva 27, Switzerland; 2005

[181] Cotter C, Sudathip P, Herdiana H, Cao Y, Liu Y, Luo A, Ranasinghe N, Bennett A, Cao J, Gosling RD. Piloting a programme tool to evaluate malaria case investigation and reactive case detection activities: Results from 3 settings in the Asia Pacific. Malaria Journal. 2017;**16**:347

[182] Hustedt J, Canavati SE, Rang C, Ashton RA, Khim N, Berne L, Kim S, Sovannaroth S, Ly P, Menard D, et al. Reactive case-detection of malaria in Pailin Province, western Cambodia: Lessons from a year-long evaluation in a pre-elimination setting. Malaria Journal. 2016;**15**:132

[183] Larsen DA, Chisha Z, Winters B, Mwanza M, Kamuliwo M, Mbwili C, Hawela M, Hamainza B, Chirwa J, Craig AS, et al. Malaria surveillance in low-transmission areas of Zambia using reactive case detection. Malaria Journal. 2015;**14**:465

[184] Parker DM, Landier J, von Seidlein L, Dondorp A, White L, Hanboonkunupakarn B, Maude RJ, Nosten FH. Limitations of malaria reactive case detection in an area of low and unstable transmission on the Myanmar-Thailand border. Malaria Journal. 2016;**15**:571

[185] Rossi G, Van den Bergh R, Nguon C, Debackere M, Vernaeve L, Khim N, Kim S, Menard D, De Smet M, Kindermans JM. Adapting reactive case detection strategies for falciparum malaria in a low-transmission area in Cambodia. Clinical Infectious Diseases. 2017

[186] Sturrock HJ, Novotny JM, Kunene S, Dlamini S, Zulu Z, Cohen JM, Hsiang MS, Greenhouse B, Gosling RD. Reactive case detection for malaria elimination: Real-life experience from an ongoing program in Swaziland. PLoS One. 2013;**8**:e63830

[187] Brosseau L, Drame PM, Besnard P, Toto JC, Foumane V, Le Mire J, Mouchet F, Remoue F, Allan R, Fortes F, et al. Human antibody response to *Anopheles* saliva for comparing the efficacy of three malaria vector control methods in Balombo, Angola. PLoS One. 2012;**7**:e44189

[188] Drame PM, Poinsignon A, Marie A, Noukpo H, Doucoure S, Cornelie S, Remoue F. New salivary biomarkers of human exposure to malaria vector bites. In: Manguin S, editor. *Anopheles* Mosquitoes - New Insights into Malaria Vectors. Rijeka: InTech; 2013 Ch. 23

[189] Ya-Umphan P, Cerqueira D, Parker DM, Cottrell G, Poinsignon A, Remoue F, Brengues C, Chareonviriyaphap T, Nosten F, Corbel V. Use of an *Anopheles* salivary biomarker to assess malaria transmission risk along the Thailand-Myanmar border. The Journal of Infectious Diseases. 2017;**215**:396-404

[190] Wongsrichanalai C, Barcus MJ, Muth S, Sutamihardja A, Wernsdorfer WH. A review of malaria diagnostic tools: Microscopy and rapid diagnostic test (RDT). The American Journal of Tropical Medicine and Hygiene. 2007;**77**:119-127

[191] Chiodini PL, Bowers K, Jorgensen P, Barnwell JW, Grady KK, Luchavez J, Moody AH, Cenizal A, Bell D. The heat stability of *Plasmodium* lactate dehydrogenase-based and

histidine-rich protein 2-based malaria rapid diagnostic tests. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2007;**101**:331-337

[192] Maltha J, Gillet P, Jacobs J. Malaria rapid diagnostic tests in endemic settings. Clinical Microbiology and Infection. 2013;**19**:399-407

[193] Murray CK, Gasser RA Jr, Magill AJ, Miller RS. Update on rapid diagnostic testing for malaria. Clinical Microbiology Reviews. 2008;**21**:97-110

[194] Littrell M, Sow GD, Ngom A, Ba M, Mboup BM, Dieye Y, Mutombo B, Earle D, Steketee RW. Case investigation and reactive case detection for malaria elimination in northern Senegal. Malaria Journal. 2013;**12**:331

[195] Lin JT, Saunders DL, Meshnick SR. The role of submicroscopic parasitemia in malaria transmission: What is the evidence? Trends in Parasitology. 2014;**30**:183-190

[196] Rogawski ET, Congpuong K, Sudathip P, Satimai W, Sug-aram R, Aruncharus S, Darakapong A, Kitchakarn S, Meshnick SR. Active case detection with pooled real-time PCR to eliminate malaria in Trat province, Thailand. The American Journal of Tropical Medicine and Hygiene. 2012;**86**:789-791

[197] Delacollette C, D'Souza C, Christophel E, Thimasarn K, Abdur R, Bell D, Dai TC, Gopinath D, Lu S, Mendoza R, et al. Malaria trends and challenges in the Greater Mekong subregion. The Southeast Asian Journal of Tropical Medicine and Public Health. 2009;**40**:674-691

[198] Haque U, Overgaard HJ, Clements AC, Norris DE, Islam N, Karim J, Roy S, Haque W, Kabir M, Smith DL, Glass GE. Malaria burden and control in Bangladesh and prospects for elimination: An epidemiological and economic assessment. The Lancet Global Health. 2014;**2**:e98-105

[199] Dev V, Sharma VP, Hojai D. Malaria transmission and disease burden in Assam: Challenges and opportunities. Journal of Parasitic Diseases. 2009;**33**:13-22

[200] Jitthai N. Migration and malaria. The Southeast Asian Journal of Tropical Medicine and Public Health. 2013;**44**(Suppl 1):166-200 discussion 306-167

[201] Bhumiratana A, Intarapuk A, Sorosjinda-Nunthawarasilp P, Maneekan P, Koyadun S. Border malaria associated with multidrug resistance on Thailand-Myanmar and Thailand-Cambodia borders: Transmission dynamic, vulnerability, and surveillance. BioMed Research International. 2013;**2013**:363417

[202] Edwards HM, Canavati SE, Rang C, Ly P, Sovannaroth S, Canier L, Khim N, Menard D, Ashton RA, Meek SR, Roca-Feltrer A. Novel cross-border approaches to optimise identification of asymptomatic and Artemisinin-resistant *Plasmodium* infection in mobile populations crossing Cambodian Borders. PLoS One. 2015;**10**:e0124300

[203] Yangzom T, Gueye CS, Namgay R, Galappaththy GN, Thimasarn K, Gosling R, Murugasampillay S, Dev V. Malaria control in Bhutan: Case study of a country embarking on elimination. Malaria Journal. 2012;**11**:9

[204] Blumberg L, Frean J, Moonasar D. Successfully controlling malaria in South Africa. South African Medical Journal. 2014;**104**:224-227

[205] Gueye CS, Teng A, Kinyua K, Wafula F, Gosling R, McCoy D. Parasites and vectors carry no passport: How to fund cross-border and regional efforts to achieve malaria elimination. Malaria Journal. 2012;**11**:344

[206] Wen S, Harvard KE, Gueye CS, Canavati SE, Chancellor A, Ahmed BN, Leaburi J, Lek D, Namgay R, Surya A, et al. Targeting populations at higher risk for malaria: A survey of national malaria elimination programmes in the Asia Pacific. Malaria Journal. 2016;**15**:271

[207] Wondji CS, Coleman M, Kleinschmidt I, Mzilahowa T, Irving H, Ndula M, Rehman A, Morgan J, Barnes KG, Hemingway J. Impact of pyrethroid resistance on operational malaria control in Malawi. Proceedings of the National Academy of Sciences of the United States of America. 2012;**109**:19063-19070

[208] Sonkong K, Chaiklieng S, Neave P, Suggaravetsiri P. Factors affecting delay in seeking treatment among malaria patients along Thailand-Myanmar border in Tak Province, Thailand. Malaria Journal. 2015;**14**:3

[209] Xu JW, Li Y, Yang HL, Zhang J, Zhang ZX, Yang YM, Zhou HN, Havumaki J, Li HX, Liu H, et al. Malaria control along China-Myanmar border during 2007-2013: An integrated impact evaluation. Infectious Diseases of Poverty. 2016;**5**:75

[210] SEARO: Malaria vectors of South-East Asia. SEARO W ed. 2017

[211] Suwonkerd W, Ritthison W, Ngo CT, Tainchum K, Bangs MJ, Chareonviriyaphap T. Vector biology and malaria transmission in Southeast Asia. In: Manguin S, editor. *Anopheles* Mosquitoes - New Insights into Malaria Vectors. Rijeka: InTech; 2013 Ch. 10

[212] Huang JX, Xia ZG, Zhou SS, Pu XJ, Hu MG, Huang DC, Ren ZP, Zhang SS, Yang MN, Wang DQ, Wang JF. Spatio-temporal analysis of malaria vectors in national malaria surveillance sites in China. Parasites & Vectors. 2015;**8**:146

[213] Wangdi K, Gatton ML, Kelly GC, Banwell C, Dev V, Clements AC. Malaria elimination in India and regional implications. The Lancet Infectious Diseases. 2016;**16**:e214-e224

[214] Elyazar IR, Sinka ME, Gething PW, Tarmidzi SN, Surya A, Kusriastuti R, Winarno BJK, Hay SI, Bangs MJ. The distribution and bionomics of *Anopheles* malaria vector mosquitoes in Indonesia. Advances in Parasitology. 2013;**83**:173-266

[215] WHO. Case Study on Malaria Elimination in the Philippines Launched. Geneva 27, Switzerland: WHO; 2015

[216] Cooper RD, Waterson DG, Frances SP, Beebe NW, Pluess B, Sweeney AW. Malaria vectors of Papua New Guinea. International Journal for Parasitology. 2009;**39**:1495-1501

[217] Beebe NW, Russell TL, Burkot TR, Lobo NF, Cooper RD. The systematics and bionomics of malaria vectors in the Southwest Pacific. In: Manguin S, editor. *Anopheles* Mosquitoes - New Insights into Malaria Vectors. Rijeka: InTech; 2013. Ch. 12

[218] Chang KS, Yoo DH, Ju YR, Lee WG, Roh JY, Kim HC, Klein TA, Shin EH. Distribution of malaria vectors and incidence of vivax malaria at Korean army installations near the demilitarized zone, Republic of Korea. Malaria Journal. 2016;**15**:259

[219] Gayan Dharmasiri AG, Perera AY, Harishchandra J, Herath H, Aravindan K, Jayasooriya HTR, Ranawaka GR, Hewavitharane M. First record of *Anopheles stephensi* in Sri Lanka: A potential challenge for prevention of malaria reintroduction. Malaria Journal. 2017;**16**:326