# Malaria on the Move: Human Population Movement and Malaria Transmission

**Pim Martens and Lisbeth Hall**
Maastricht University, Maastricht, the Netherlands

Reports of malaria are increasing in many countries and in areas thought free of the disease. One of the factors contributing to the reemergence of malaria is human migration. People move for a number of reasons, including environmental deterioration, economic necessity, conflicts, and natural disasters. These factors are most likely to affect the poor, many of whom live in or near malarious areas. Identifying and understanding the influence of these population movements can improve prevention measures and malaria control programs.

Malaria, the world's most prevalent vector-borne disease, is endemic in 92 countries, with pockets of transmission in an additional eight countries (1). Approximately 41% of the world's population is at risk, and each year 300 million to 500 million clinical cases of malaria, >90% of them in Africa, are reported. Worldwide, approximately 2 million deaths per year can be attributed to malaria, half of these in children under 5 years of age.

Historically, population movement has contributed to the spread of disease (2). Failure to consider this factor contributed to failure of malaria eradication campaigns in the 1950s and 1960s (3). The movement of infected people from areas where malaria was still endemic to areas where the disease had been eradicated led to resurgence of the disease. However, population movement can precipitate or increase malaria transmission in other ways as well. As people move, they can increase their risk for acquiring the disease through the ways in which they change the environment and through the technology they introduce, for example, through deforestation and irrigation systems (4). Such activities can create more favorable habitats for *Anopheles* mosquitoes; at the same time, workers may have increased exposure to the vector. Furthermore, people can inadvertently transport infectious mosquitoes to malaria-free areas, reintroducing disease. Population movement is also increasingly implicated in the spread of drug resistance in malaria (5).

The unprecedented increase in mobility in the last few decades has led to greater concern about the relationship between mobility and malaria. There are a number of reasons for increased mobility. First, sophisticated forms of transport now permit the swift movement of people over huge distances. Air travel has increased by almost 7% a year in the last 20 years and is predicted to increase by >5% a year during the next 20 years (6). Second, in the developing world a rapidly increasing population is putting pressure on scarce resources, leading to major population redistribution. This particularly involves the movement from rural to urban areas. Third, natural disasters such as droughts and floods have created approximately 25 million environmental refugees (7). Finally, conflict, often a result of population pressures and environmental degradation, displaces vast numbers of people. We examine the impact of population movement on malaria transmission.

## A Typology of Population Movement

The decision-making process leading to population movement can best be understood in the light of "push and pull" forces (8). When their needs can no longer be met in a particular environment, people move elsewhere. The "push factor" could be environmental degradation, population pressure on land, droughts, famines, conflict, or loss or lack of employment. When people are satisfied with their situation but

Address for correspondence: Pim Martens, International Centre for Integrative Studies, Maastricht University, P.O. Box 616, 6200 MD Maastricht, the Netherlands; fax: 31-43-388-4916; e-mail: p.martens@icis.unimaas.nl.

believe that a move elsewhere will provide new and attractive opportunities, a "pull factor" is involved. This pull factor could be better political, economic, or social opportunities or improved living conditions. Push and pull factors can operate simultaneously; for example, people can be pushed by environmental deterioration and scarce resources and pulled by the economic opportunities offered by development projects.

Population movements can be differentiated by their temporal and spatial dimensions. Temporal dimensions include circulation and migration. Circulation encompasses a variety of movements, usually short-term and cyclical and involving no longstanding change of residence. Migration involves a permanent change of residence (9). Circulation can be subdivided into daily, periodic, seasonal, and long term (Table) (9). Daily circulation involves leaving a place of residence for up to 24 hours. Periodic circulation may vary from 1 night to 1 year, although it is usually shorter than seasonal circulation. Seasonal circulation is a type of periodic circulation in which the period is defined by marked seasonality in the physical or economic environment. This type of circulation involves persons or groups who are absent from their permanent homes during a season or seasons of the year. Long-term circulation, defined as absence from home for longer than a year, affects groups such as wage laborers and traders, who maintain close social and economic ties with their home area and intend to return.

In terms of spatial dimensions, the movements to and from malarious areas are of epidemiologic importance. People who move can be categorized as either active transmitters or passive acquirers (2). Active transmitters harbor the parasite and transmit the disease when they move to areas of low or sporadic transmission. Passive acquirers are exposed to the disease through movement from one environment to another; they may have low-level immunity or may be nonimmune, which increases their risk for disease.

Based on the above definitions, a typology can be devised that identifies categories of population movement. Different activities can be associated with these categories, and these activities, in turn, can be associated with differing risks for malaria transmission. All types of population movement can be accommodated in this typology, and people may exhibit more than one type of mobility.

## Population Movement and Malaria

In developing countries, activities involving population movement include urbanization, colonization, labor related to agriculture and mining, and conflict. In industrialized countries, the impact of population movements on malaria risk is mainly related to intercontinental travel.

In some regions, malaria risk may increase as a result of a combination of different forms of mobility, as well as other factors unrelated to population movements. For example, in the African highlands, many of the issues described below act concurrently (10). The categorization of the various examples below simplifies a complex issue but is useful for indicating major processes related to mobility and malaria risk.

### Urbanization

The world's urban population is growing at four times the rate of the rural population (11). Urban pull is prevalent throughout the developing world, with rural-to-urban migration taking place faster than ever before (12). Sub-Saharan Africa is the most rapidly urbanizing region in the world (13), and the urban population in India has doubled in the last 2 decades (14). When accompanied by adequate housing and sanitation, urbanization can lead to a decrease in malaria through reductions in human-vector contact and vector breeding sites. However, in developing countries, rapid, unregulated urbanization often leads to an increase in or resumption of malaria transmission because of poor housing and sanitation, lack of proper drainage of surface

Table. A typology of population movement (adapted from [2])

| Circulation | | | | |
|---|---|---|---|---|
| Daily | Periodic | Seasonal | Long-term | Migration |
| Commuting | Trading | Fishing | Laboring | Urbanization |
| Trading | Pilgrimage | Pastoralism | Colonization | Refugees |
| Cultivation | Mining | Laboring | | Colonization |
| Wood-cutting | Tourism | | | |

water, and use of unprotected water reservoirs that increase human-vector contact and vector breeding.

Although water pollution in urban areas usually leads to decreases in vector populations, some vectors, such as *An. arabiensis* in the forest belt of West Africa, may adapt to breeding in polluted waters (15). In Asia, *An. stephensi* is proving adaptable to urban conditions, and in India it is a well-established vector of urban malaria. In urban areas of India, water is not supplied regularly and is stored in houses, providing extensive breeding places for *An. stephensi* in overhead tanks and cisterns. In periurban areas, where 25% to 40% of the urban population live in poor housing without proper water supply and drainage, another vector, *An. culcifacies,* also transmits malaria (14).

In India, the fact that the National Malaria Eradication Program concentrated only on rural areas, ignoring the problem of urban malaria, was one of the factors leading to a resurgence of malaria in the 1970s (14). Several types of population movement contributed to malaria transmission in India. First, circulation from stable rural malaria areas to unstable urban areas had firmly established malaria transmission in urban areas. Then, after the National Malaria Eradication Program, rural areas became free of endemic malaria but were receptive, so circulation from urban areas back to rural areas reintroduced malaria transmission. Changes in vector behavior (exophilic and exophagic behavior limiting the effectiveness of spraying), vector resistance to insecticides, and increasing drug resistance, especially in *Plasmodium falciparum* (14), also played a role. Population movement also contributed to drug resistance, with people of different immune status moving from endemic- to nonendemic-disease areas, accelerating transmission of resistant strains.

## Colonization of New Territory

Through the interaction of a number of factors, the colonization of unpopulated or sparsely populated areas may be accompanied by an increase in malaria. Settlers, who have low-level immunity or are nonimmune, may migrate into a disease-endemic area, spreading the disease. Initially, housing tends to be basic, leading to close human-vector contact. Moreover, housing is often near rivers or lakes to facilitate water collection, increasing the exposure of humans to mosquitoes. Activities to develop an area, such as deforestation and irrigation, can increase the number of vector breeding sites, contributing to an increase in malaria. Colonization may be accompanied by major building projects, such as dams, canals, highways, or mining activities—referred to as the tropical aggregation of labor—which can further enhance malaria transmission.

Reemergence of malaria through mobility related to colonization occurred in Brazil. Malaria had been practically eradicated from most areas of the Amazon region by the national malaria campaign in the 1950s and 1960s (16). Since the 1960s, however, the incidence of malaria has increased dramatically because of massive population movements to colonize new territory. New highways were built in the 1960s, linking the Amazon region to the rest of the country and attracting laborers to work on road construction. In the 1970s, many more people were attracted to the region by agricultural settlements and hydroelectric projects. Finally, in the 1980s, the discovery of gold led to a greater influx of people, along with the establishment of hundreds of mines throughout the region. The population of Rondônia State, which received the greatest number of migrants, increased from 113,000 in 1970 to 1,200,000 in 1990. Malaria cases in Rondônia increased from 20,000 to 174,000 in the same period. In Brazil as a whole, approximately 50,000 cases of malaria were reported in 1970; by 1990, reports had increased to 577,520, representing 10% of the world's reported cases outside Africa (17). Of this total, >98% were recorded in the Amazon region.

The types of population movement involved in the colonization of the Amazons are migration and long-term circulation from malaria-free areas of Brazil to the malaria-endemic Amazon region. The people involved are nonimmune passive acquirers who on becoming infected can become active transmitters. If these active transmitters return to their initial place of residence in a malaria-free but highly receptive area, they can reintroduce the parasite and initiate an outbreak of malaria. For example, in 1985, 26 new active foci of malaria were recorded in Brazilian states outside the Amazon region (16). Settlers in the Amazon region are highly mobile, moving with daily, periodic, and seasonal circulation from settlements in unstable disease-endemic regions to hyperendemic-disease regions of the rainforests. This mobility keeps settlements unstable and at high risk for epidemics through the constant flow of parasitemic laborers (17,18).

## Agricultural Labor

Swaziland provides an example of how agricultural labor has changed the spread of malaria. In the 1950s, control measures (DDT spraying) were successfully implemented in the lowveld so that agricultural development could take place, and by 1959, malaria had been all but eradicated from Swaziland (19). However, agricultural developments in the 1950s involving an irrigation project for the cultivation of sugar cane created conditions favorable for malaria. Vector density increased, along with a high frequency of feeding on humans, as no domestic or wild animals were around the project area to serve as alternative hosts. This resurgence of malaria was catalyzed by the reintroduction of parasite carriers in the form of migrant workers from disease-endemic areas of Mozambique, who were involved in migration or long-term circulation to work on the sugar estates in the 1960s and early 1970s (19).

In Colombia, the annual parasite index (defined as the ratio between the number of cases reported and the population at risk) has increased threefold since the 1960s (20). This increase seems to be related to the migration of nonimmune people to areas such as the Naya basin, where malaria is endemic, and to the circulation of groups within the Naya basin. The circulation is predominantly seasonal, related to agriculture. People descend from hills and terraces, where malaria risk is minimal, to the malarious delta zone to cultivate and harvest their crops. In doing so, they are exposed to the anopheline population of the area and are at high risk for malaria. A large number of people are involved in this circulation (approximately 60% of the area's population is mobile for approximately 4 months of the year), and this population density, combined with the large vector population, maintains transmission at high levels (20).

## Refugees

The number of officially recognized refugees has steadily increased, from approximately 5 million in 1980 to >20 million in late 1994 (21). In addition, an estimated 25 million people have fled their homes but remain internally displaced in their countries of origin (22). The displacement of large numbers of people and their circulation can favor malaria transmission. If refugees are nonimmune, they could travel through or to malarious regions and acquire the infection, and if they are infectious, they could disseminate the disease to other areas.

Malaria is one of the most commonly reported causes of death among refugees and has caused high rates of both illness and death among refugees and displaced persons in disease-endemic countries, such as Thailand, Sudan, Somalia, Burundi, Rwanda, and the Democratic Republic of Congo (23). In recent outbreak among Burundian refugees at a refugee camp in northwestern Tanzania, deaths from malaria and anemia in children under 5 years of age have increased 10-fold since the outbreak, reflecting the lack of immunity in this age group (24). In the Sahel region of Africa, where civil wars and conflicts have occurred for many decades and large numbers of displaced people live in resettlement or refugee camps often located in lowland disease-endemic areas, epidemics are common (25).

As a result of 15 years of continuous war, which displaced hundreds of thousands of people, Luanda, the capital of Angola, underwent an unprecedented population increase in the 1980s. This population movement resulted in a shift in malaria endemicity in Luanda from hypoendemic to mesoendemic level within 5 years (26). As a cause of child deaths, malaria moved from sixth to first place. Increasing parasite resistance to chloroquine also became a major problem. This situation arose because of the enormous influx of displaced people of low socioeconomic status into an environment with stagnant water reservoirs. The population movements that increased malaria transmission in Luanda were long-term circulation and migration from stable rural areas to an unstable urban area.

Besides movements of large numbers of people, wars and civil unrest tend to favor malaria transmission. The disruptive effect of war on agriculture and water management can increase vector breeding sites; the destruction of housing can increase human-vector contact; the destruction of cattle can prompt zoophilic vectors to become anthropophilic if their usual food supply is disrupted (27); and control measures can be seriously diminished if health-care facilities are reduced or unavailable.

## Intercontinental Travel

The intercontinental transfer of malaria can occur through the introduction of an infective vector into a nonendemic-disease area, as in so-called airport malaria, or through the movement of a parasitemic person to a nonendemic-disease area, as in imported malaria. Although the incidence of these cases is low, they account for most malaria transmission in industrialized countries.

### Airport Malaria

Airport malaria is defined as malaria acquired through the bite of an infected tropical anopheline mosquito by persons whose geographic history excludes exposure to this vector in its natural habitat (28). The vector is usually introduced into a nonendemic-disease country on an international flight. For example, random searches of airplanes at Gatwick Airport (London) found that 12 of 67 airplanes from tropical countries contained mosquitoes (29). After a mosquito leaves the aircraft, it may survive long enough to take a blood meal and transmit the disease, usually in the vicinity of an airport. In temperate climates, temperature and humidity can be favorable in the summer for the mosquito not only to survive but also to move around and perhaps lay eggs. With the enormous and continuing increase in air traffic, cases of airport malaria may increase. Several such cases are described below.

During a hot summer in 1994, six cases of airport malaria were identified in and around Roissy-Charles-de-Gaulle Airport (30). Four of the patients were airport workers, and the others lived in Villeparisis, approximately 7.5 km away. Anopheline mosquitoes were thought to have traveled in the cars of airport workers who lived next door to two of the patients. In 1989, two cases of *P. falciparum* malaria were identified in Italy in two persons who lived in Geneva (31). Another five cases of airport malaria were reported in Geneva in the summer of 1989 (32). High minimum temperatures were thought to have allowed the survival of infected anophelines introduced by aircraft. In Britain, two cases of *P. falciparum* malaria were observed in persons living 10 km and 15 km from Gatwick Airport (33). Hot, humid weather in Britain may have facilitated the survival of an imported mosquito.

### Imported Malaria

Throughout the world, many countries are reporting an increasing number of cases of imported malaria (Figure) because of the great increase in long-distance travel in recent decades. For example, cases imported from Africa to the United Kingdom rose from 803 in 1987 to 1,165 in 1993, and the ratio of all imported cases of *falciparum* to *vivax* malaria rose from 0.76 in 1984 to 1.52 in 1993 (36).

Recently, a woman in Italy was infected with malaria through a bite from a local species, *An. labranchiae* (37). This species was a common malaria vector in Italy until the country was declared malaria free in 1970. Local breeding sites, including isolated pools in dried-up irrigation channels, were identified, and the mosquito responsible is thought to have acquired the parasite after biting a parasitemic girl who had acquired malaria in India. Airport malaria was ruled out because of the distance from the nearest airport. This may be the first case of malaria introduced to Europe in 20 years and demonstrates the hazards of population movement (the parasite had been introduced from India) combined with human activities (providing vector breeding sites).

In the United States, recent outbreaks of presumed local mosquito-borne transmission have been reported in California, with migration from a disease-endemic area (38). The people involved were migrant workers from malaria-endemic areas. An outbreak in 1986 involved 28 cases (26 in Mexican migrant workers) of *P. vivax* during a 3-month period (39). The epidemic curve indicated secondary spread, which confirmed local mosquito-borne transmission.

In the early 1990s, outbreaks were identified in neighborhoods of Houston with many immigrants from countries with malaria

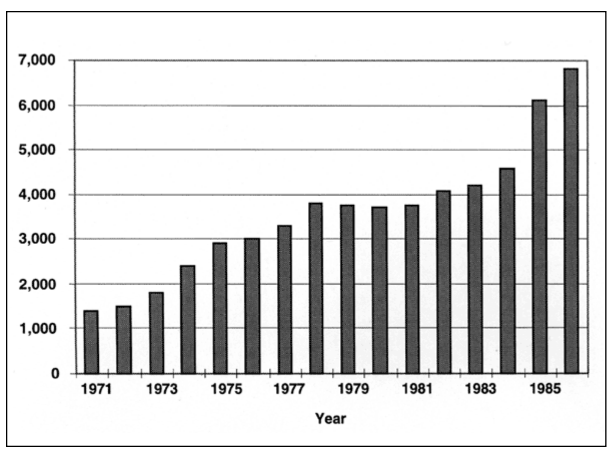


Figure. Imported cases of malaria in Europe (34,35).

transmission. These outbreaks occurred when the weather was hot and humid and thus conducive to the completion of the sporogonic cycle and the survival of female anophelines (38). Given that climate change could lead to more favorable conditions for vector survival in Europe and the United States (40), the increase in incidence in both airport and imported malaria is cause for concern. If temperatures increase, uninfected introduced or local mosquitoes could survive long enough after taking a blood meal from a parasitemic person for the completion of the sporogonic cycle of the parasite, thus enabling transmission.

## Conclusions

Population movements that either place people at risk for malaria or cause them to pose a risk to others cannot be stopped. However, prevention measures can address the causes of these movements which, in developing countries, are often prompted by need rather than choice; if living conditions and opportunities improved in their place of residence, people would not be forced to move. In cases where movements are unavoidable, people should be made aware of the risks and have adequate access to treatment. Epidemics are more likely to take place in areas where health care may be poor or lacking. Areas at risk for epidemics through the influx of infected people should be identified to avoid or control epidemics. Particular attention should be paid to urban areas, given the increasing number of cases of urban malaria and the ongoing trend toward uncontrolled urbanization.

The risk for increased malaria transmission through economic development of an area should be analyzed thoroughly before development begins. For example, sound environmental management can restrict vector breeding and reduce human-vector contact. Such management could include proper maintenance of irrigation systems and adequate water supply and sanitation facilities for workers. Personal vector-control measures, such as bed nets, and antimalarial drugs should be used.

Regarding the risks that airport and imported malaria pose for industrialized countries, measures should be taken to ensure that cases of malaria are promptly diagnosed and treated. Strengthened surveillance would help prevent the reintroduction of malaria transmission by local mosquitoes, which could acquire the infection by biting persons with airport or imported malaria. Given the economic resources and quality of health care in industrialized countries, the likelihood is low that isolated outbreaks of malaria will lead to reestablishment of transmission.

The relationship between malaria transmission and population movement is complex, but future attempts to eradicate or control malaria will be futile if they are not based on understanding of this link. Because the current magnitude and diversity of population movements are unprecedented, this issue is worthy of attention.

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Dr. Martens is director of the Global Assessment Centre, International Centre for Integrative Studies, Maastricht University. His area of expertise includes assessment of the health impact of globalization and global environmental changes. He is editor-in-chief of the journal Global Change and Human Health.

Ms. Hall studied environmental health sciences at Maastricht University and toxicology and pharmacology at the University of London. The focus of her research is behavioral change in relation to environmental impact.

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