3 | HOLDING THE LINE

Justin M. Cohen,[a] David L. Smith,[b] Andrew Vallely,[c] George Taleo,[d] George Malefoasi,[e] and Oliver Sabot[a]

3.1 | Introduction

Once elimination is achieved, the constant threats of reintroduction and reemergence, and thus severe morbidity and mortality, make some malaria control activities necessary. Prevention of transmission reemergence is an integral component of any elimination campaign and must be planned carefully before elimination is attempted. The risk of reintroduction after elimination is highly dependent upon two components:

1. the intrinsic potential for malaria transmission in the region, as determined by its vectors, geography, environment, and social factors
2. the rate at which new sources of malaria infection enter the region from other countries or regions where elimination has not yet been achieved

Even in regions with high intrinsic malaria risk, well-developed health systems and effective interventions can reduce the risk from this baseline prevalence, while measures such as targeted screening of immigrants can permit early identification and treatment. To "hold the line," the MEG recommends

[a]Clinton Foundation, Boston, USA; [b]Department of Zoology and Emerging Pathogens Institute, University of Florida, Gainesville, USA; [c]Pacific Malaria Initiative Support Centre, University of Queensland, Brisbane, Australia; [d]Malaria and Other Vector Borne Diseases, Ministry of Health, Port Vila, Vanuatu; [e]Ministry of Health, Honiara, Solomon Islands

BOX 3.1 | Main Messages

- Countries or regions considering elimination must make detailed assessments of the factors listed below to ensure the feasibility of preventing malaria reemergence:
  1. importation risk, in terms of the number of infected individuals entering the country each year, in order to determine screening requirements
  2. outbreak risk, in terms of the intrinsic potential for reintroduced malaria transmission
  3. surveillance system capacity, in terms of its ability to identify, report, and respond to imported individual malaria cases and outbreaks
- Governments must commit to maintaining resources and encouraging community support for sustainable antimalarial interventions long after malaria has been eliminated.
- It may be appropriate to maintain a central unit with responsibility focused on malaria even after cessation of transmission, to ensure epidemic containment and effective case response, but these activities should be carefully integrated with the health system.
- Each country needs to assess its own needs for the ongoing activities required to deal with outbreaks, and the potential for importation, according to the overall risks to which it is exposed.
- A coordinated multicountry regional approach to elimination will greatly reduce importation and outbreak risks and should strongly be considered before, during, and after an elimination program.
- Screening high-risk individuals at ports of entry may help to reduce importation risk, but implementation and cost-effectiveness are important considerations. Key factors that determine whether port screening is likely to be cost-effective include the expected prevalence of infection in these individuals; the volume of travelers; and the importation risk, surveillance, and case response capabilities of the country to prevent missed cases from developing into epidemics.
- Eliminating vectors is generally not recommended as a strategy for preventing reemergence of malaria, although controlling receptivity through sustained, targeted indoor residual spraying (IRS), or net use may be appropriate.
- Maintaining a strong surveillance and outbreak response system is essential for containing infections before they can spark epidemics.

Mauritius

Achieved elimination: 1973

Malaria recurred: 1975–1976

Contributing cause: Increased migrant labor from endemic areas

Kazakhstan

Achieved elimination: 1980s

Malaria recurred: 1991-1996

Contributing cause: Weakened health system; increased migration (e.g., of soldiers from endemic areas)

South Korea

Achieved elimination: 1979

Malaria recurred: 1993

Contributing cause: Introduction of parasites and vectors from North Korea

interventions tailored to the specifics of a region or country, which should include guarding against the introduction of malaria parasites (to lower the importation risk) and preventing the spread of such parasites should they be introduced (to lower outbreak risk). The ability to identify and respond quickly to introduced cases must be maintained through strong surveillance and outbreak response capacity.

Many countries have successfully eliminated malaria and have instituted sound surveillance programs and policies that hold the line, and they have been able to respond effectively to limited reintroduction. By contrast, as funding for the Global Malaria Eradication Program (GMEP) began to wane, malaria reemerged in other countries that had come close to zero but had not adequately prepared for surveillance and sustained vigilance.[1] Examples of the occurrence of epidemics include, in diverse settings, Sri Lanka (1968-1969),[2] Madagascar (1986-1988),[3] and more recently, Azerbaijan, Tajikistan, and Turkey.[4] After insecticide spraying stopped or was scaled back in these areas, the vector populations recovered, resulting in high rates of transmission and thus severe malaria and mortality due to the waning of immunity.

Reaching zero is not the end of malaria; countries or regions must shift focus from eliminating internal transmission to preventing reemergence from external sources, whether from bordering nations or neighboring regions in which malaria is still endemic. In other words, planning for malaria elimination must consider not only how to get to zero but the equally challenging task of staying there; tactics for prevention of reemergence should be treated as integral components of the overall elimination strategy, and many of the same approaches adopted to reach zero may successfully be maintained to hold the line.

Planning for elimination is based, in part, on the quantitative concepts of outbreak risk and importation risk (Chapter 1). After elimination is achieved, these

BOX 3.2 | Modeling Outbreak Risk

Initial efforts to define outbreak risk semi-quantitatively have been described in Italy[5] and more recently in southern France (below)[6] using detailed entomological transmission risk maps based on meteorological data. Such methods may be useful in assessing risk in places where malaria has already been eliminated and in monitoring and evaluating malariogenic potential in countries considering elimination.

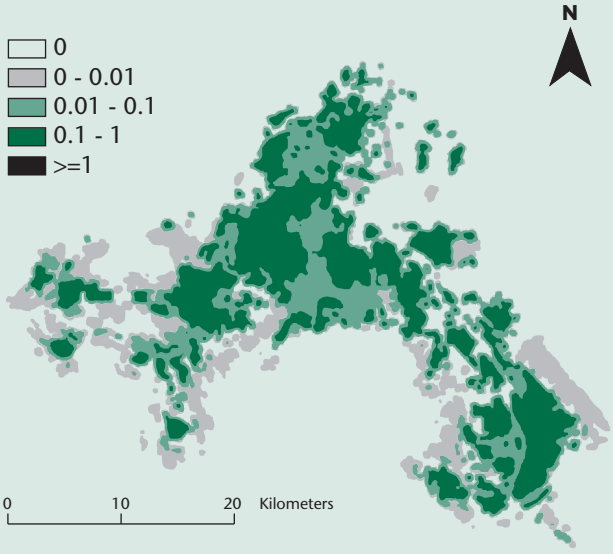

FIGURE 3.1 | Spatial variations in *P. falciparum* transmission risk estimate (ranging from 0 to greater than 1) in August in the Camargue. Corresponding calculations for *P. vivax* showed a much higher risk of outbreaks occurring at this time of year (from Ponçon et al.[6]).

concepts remain highly relevant. The WHO certification of malaria elimination is awarded after 3 years of continued absence of locally acquired cases, but malaria can still return years later. Preventing reemergence of malaria will rely upon a combination of keeping outbreak risk low through maintenance of good health systems, minimizing importation risk, and maintaining a strong surveillance system to monitor and catch cases that do appear. The combination of a region's outbreak risk and importation risk produces a measure called the malariogenic potential, which can be considered an indication of the overall risk that malaria will return.

Despite the widely recognized importance of malariogenic potential, there are no standardized measures for defining levels of outbreak risk or importation risk in any given geographical setting.[7] In the future, mathematical models will play an important role in helping to define quantitative thresholds of acceptability (Box 3.2). Any model will require detailed data on the epidemiological and entomological situation in a given country; collecting specific metrics, including age-specific parasite prevalence, vector density, human biting rate,

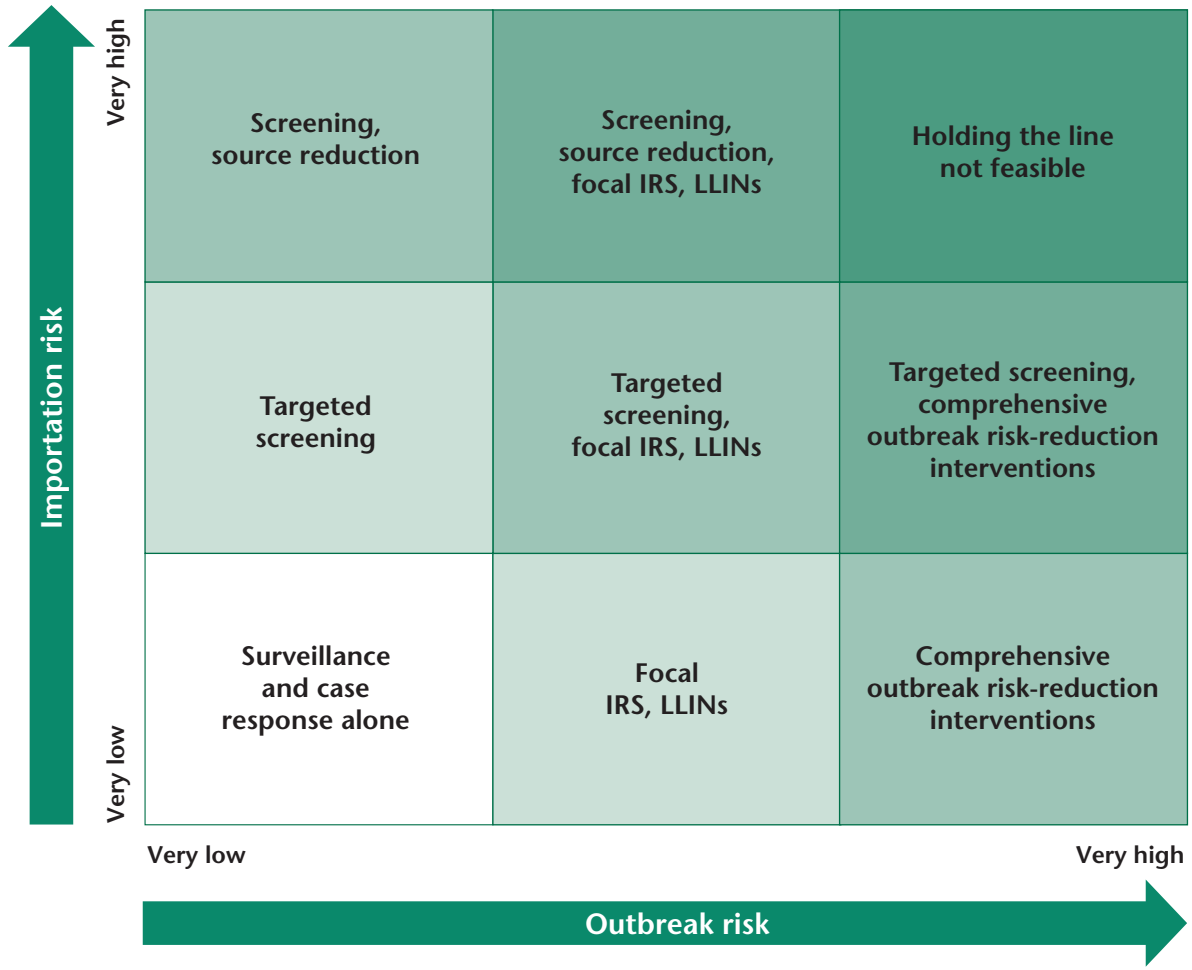

FIGURE 3.2 | An example of how the measures required to prevent reintroduction will vary according to relative levels of outbreak risk and importation risk. Specific interventions must be appropriate to country contexts.

entomological inoculation rates, and other parameters at geo-referenced locations, will help in defining malaria risk. This information can then be used to make maps to inform operations, to identify ongoing transmission foci or hot spots, and to focus elimination efforts.

Collection of this information is something some countries could undertake now. Even without these data, planning for elimination can still proceed while the capacity to obtain detailed risk information is gradually improving.

In the example cited in Box 3.2, the outbreak risk is quite high in certain regions of the Camargue during August; however, the overall malariogenic potential will remain low if there is little importation risk occurring in those areas where outbreak risk is high. In this situation, and also when importation

risk is high but outbreak risk low, it is possible to hold the line (Figure 3.2). In places with high importation risk and high outbreak risk, multiple sustained approaches and interventions will be required if malaria reintroduction is to be avoided. To hold the line, countries must reduce their malariogenic potential to a level that ensures a low risk of reintroduction. Again, there are no absolute standards for defining a low level of risk.

The MEG recommends careful analysis of the outbreak risk and importation risk of a particular region to help determine the relative emphasis that must be placed on different sorts of post-elimination interventions.

3.2 | Management and Implementation

Holding the line, like the campaign to get to zero, will necessitate a combination of strong commitment and effective management and leadership. Additionally, the national or regional health system will need to be sufficiently robust to permit timely identification and treatment of all new malaria cases to prevent an outbreak. Maintaining sufficient political will and capacity to sustain intervention against an invisible opponent will be a difficult task. Historical examples of countries that nearly eliminated malaria, only to suffer severe resurgences when control activities were stopped, illustrate the hazard in not maintaining disease-specific efforts after successful gains have been made.

The MEG recommends that countries attempting to hold the line consider maintaining a central malaria program in some form, integrated into the health system, to ensure sustainability of outbreak risk and importation risk-lowering interventions, as well as rapid and effective case management and epidemic containment (see Chapter 2).

Proactive planning is necessary to ensure that national commitment to malaria elimination does not end with achievement of zero transmission. Getting to zero requires an intensive campaign with defined resources, while holding the line needs an unbounded commitment to continue malaria prevention activities until malaria is completely eradicated. As a result, it is important to note that considerable financial resources may be required to maintain antimalarial operations even after elimination has been achieved (Chapter 4).

The MEG recommends that governments must commit to maintaining resources and encouraging community support for sustainable antimalarial interventions, even long after malaria has been eliminated.

As long as malaria remains endemic elsewhere, preventing its reintroduction requires strong political commitment, active community support, and in many cases, untiring interventions for reducing outbreak risk and importation risk.

BOX 3.3 | The Importance of Maintaining Interventions

In the central highlands of Madagascar, a combination of DDT spraying, IRS, and case detection and treatment successfully prevented reemergence of malaria from 1960 until cessation of control activities in 1980. At that time, the government halted spraying in the highlands, since the lack of malaria seemed to indicate that such activities were no longer necessary. With the discontinuation of spraying, *Anopheles funestus* gradually became firmly reestablished in rice field breeding habitats, and this, coupled with the migration of gametocyte-positive individuals from malaria-endemic lowland areas, resulted in an explosive malaria epidemic among a then-nonimmune highlands population in the late 1980s, causing an estimated 40,000 deaths over 5 years.[3] Although this example is of resurgence in a country that had not yet achieved elimination, it emphasizes that holding the line against reintroduction within a country is often deeply challenging and requires aggressive and sustained intervention.

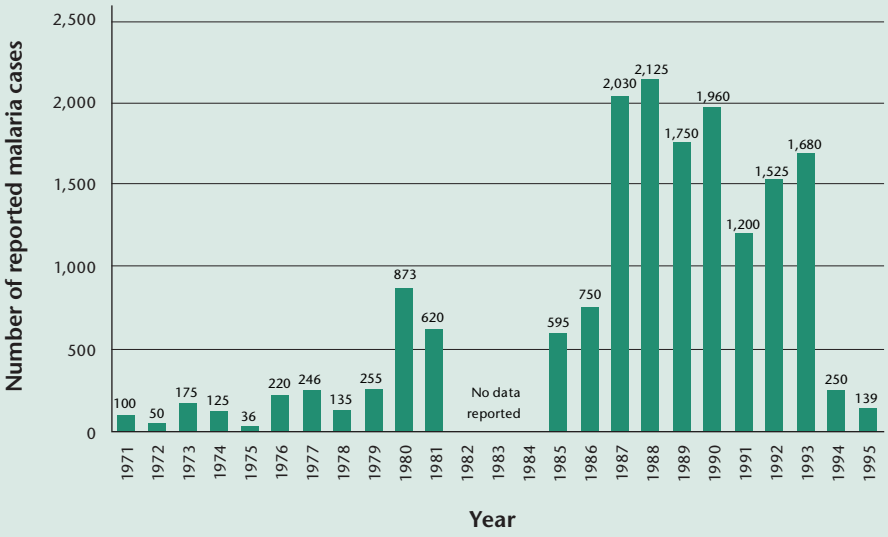

FIGURE 3.3 | Number of malaria cases in the Analaroa Health Center, Madagascar Highlands (no data reported from 1982-1984) (from Mouchet et al.[8])

Approaches that may help maintain such steadfastness include:

- community awareness campaigns, such as periodic "malaria day" reminders of the great economic and health advantages of preventing the potentially devastating reintroduction of malaria
- maintenance of small malaria-specific programs, or a multipurpose program with specific malaria expertise, to ensure vigilance in areas

BOX 3.4 | Sociopolitical Upheaval Can Spark Reemergence

In Tajikistan, malaria transmission had been reduced to very low levels by the 1980s, although occasional seasonal cases still occurred. The situation deteriorated in the 1990s. What changed? Altered agricultural practices associated with the introduction of rice crop irrigation significantly increased outbreak risk by creating favorable breeding habitats for local competent malaria vectors (*A. superpictus, A. pulcherrimus,* and *A. maculipennis*).[9] At the same time, armed conflict, civil unrest, and adverse economic conditions led to large population movements across the border with Afghanistan, where 2 to 3 million people are thought to have been infected in epidemics during the mid-1990s. Finally, malaria control in Tajikistan was disrupted during the 1992-1997 civil war. Although this example is of resurgence in a country that had not yet achieved elimination, it illustrates a central challenge that some eliminating countries will face as they attempt to hold the line.

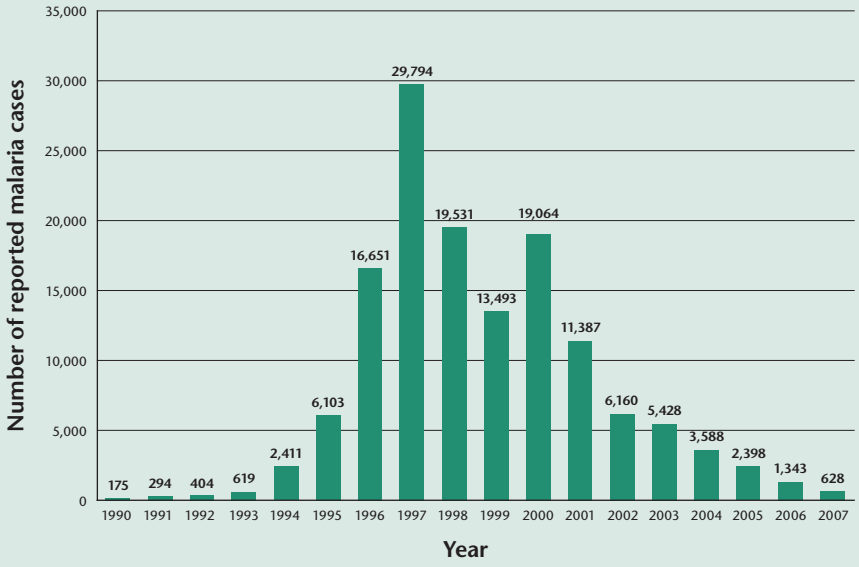

FIGURE 3.4 | Reported malaria cases in Tajikistan between 1990 and 2007 (from Matthys et al.[10])

with high malariogenic potential or weak health systems, even years after the perception of a threat from malaria has vanished

- establishment of innovative financing schemes to ensure that domestic and international resources are set aside for post-elimination antimalarial vigilance

Because a country's or region's importation risk and outbreak risk may change over time, assessments of these indicators must also be dynamic. Such a need

is especially important when development, agriculture, or conflict may cause significant changes in vector habitat or the risk of imported malaria. In areas undergoing major sociopolitical upheaval, rapid and simultaneous changes in importation risk and outbreak risk can result in resurgent malaria that quickly overwhelms available resources. For example, several countries of the former Soviet Union, notably Azerbaijan and Tajikistan, have experienced significant epidemics since indigenous transmission was reestablished in the 1990s.[4,11,12]

3.3 Importation Risk

As discussed in Chapter 1, importation risk, also known as vulnerability, measures the rate at which infected and infectious mosquitoes or humans come into a region each year. Importation risk can be conceived of on a national scale, but it is also a useful concept for malaria elimination within parts of countries, such as the Philippines, where spatially progressive malaria elimination is occurring province by province.

Malaria is constantly being imported and exported around the globe, a fact that was brought into sharp relief after eastern Africa imported chloroquine-resistant parasites from Southeast Asia, and as chloroquine resistance spread throughout the world from a few focal points of origin.[13] In areas with high levels of transmission, importing malaria is a minor public health concern, except, as in eastern Africa, when the imported parasites are much more difficult to treat. As local transmission is reduced, imported malaria becomes a higher priority, and after malaria has been eliminated from a region, importation risk increases to the point where it is of utmost concern. Movement of parasites is facilitated by migration of their mosquito and human hosts, and we consider each of these cases separately.

Mosquitoes typically fly only short distances, but they occasionally travel or get blown much farther, and they can be transported accidentally in the cargo holds of airplanes or in containers on ships. The risk of importing malaria over long distances is real, but a second issue is that countries can import a new vector species and dramatically increase their importation risk. Brazil imported the efficient African vector *A. arabiensis* in 1930, sparking a severe outbreak. In that case, the epidemic was stopped by eliminating the vector, albeit with great difficulty, but malaria persisted. The geographical spread of sub–Saharan African vectors north of the Sahara and the spread of efficient vectors to neighboring countries are important concerns, especially when those countries have eliminated malaria. These risks highlight the need for vector vigilance.

In almost all cases, human introduction of parasites, rather than acciden-

tal transportation of mosquito species, is chiefly to blame in countries where malaria has resurged. Asymptomatic malaria infections in humans can last months, and humans can fly around the world in a few days and cross national borders in an afternoon. Given the numbers of people who move across borders, human movement is the most important component of importation risk. Malaria can be introduced by soldiers, journalists, diplomats, or others who are returning home from foreign service; tourists who have recently visited malaria-endemic areas; migrant labor populations; nomadic populations migrating across borders; people with ethnic or tribal affiliations across arbitrarily drawn political borders; or refugees escaping political instability in their home countries. Quantifying all of these rates is a daunting task.

Certain travelers, however, are likely to be at much higher risk of transporting parasites than others. Poor migrant workers traveling overland from endemic countries are substantially more likely to harbor parasites than wealthy tourists on prophylaxis or business travelers arriving from nonendemic regions by plane and residing primarily in air-conditioned hotels. As a result, the magnitude of importation risk will be affected greatly by the endemicity in regions surrounding the borders of a country, as well as the socioeconomic status of the people in those regions. Elimination may be a tenuous, short-term victory for a nation bordering a poor, highly endemic country, especially if substantial migration occurs across porous borders.

One part of importation risk can be estimated by taking the product of the immigration rate and malaria endemicity in the immigrants' country of origin. This multiplication provides a first-order approximation that can be built upon for planning or comparison purposes. Other more comprehensive assessments of importation risk can be made by sectors of the government that are not typically included in malaria planning, such as the department of immigration.

The MEG recommends a comprehensive evaluation of migration into the region in which malaria is to be eliminated, in order to estimate overall vulnerability and to identify groups at particularly high risk.

Important considerations include the following:

- the magnitude of immigration rates
- the likelihood that migrants carry malaria
- the parasite species carried (e.g., *P. vivax* may be more difficult to detect and uproot)
- where migrants settle (e.g., many immigrants arrive in urban areas, where malaria transmission rates tend to be low, though this is not always so in poor and expanding peri-urban areas)

BOX 3.5 | Screening Travelers to Mauritius

In Mauritius, which has had no indigenous malaria transmission for a decade despite still having competent vectors, all visitors arriving from endemic countries are registered at the port of entry, and their names and addresses are recorded for follow-up by health surveillance officers. These officers may take a blood sample for screening, and private-sector doctors are also encouraged to take blood smears from those with suspected malaria cases. These measures have identified between 35 and 63 imported cases of malaria each year since 2000.

Although risk of reintroduction of malaria transmission will be driven by gametocyte carriers from malaria-endemic areas, in many cases the events necessary to spark a malaria outbreak will not occur despite the entry of an infected individual—that person may not be bitten by an anopheline mosquito during his or her time in the malaria-free country, or that mosquito may not survive long enough to transmit again. However, each additional case of imported malaria introduces the risk that all of these events will happen and that transmission will occur. There is, then, an urgent need to locate and treat the primary and secondary cases in order to stop the development of an outbreak. Knowing the rate of migration by potentially infected individuals from endemic regions allows a possibility to reduce importation risk. Two principal means of reducing importation risk should be evaluated:

1. Identify infected individuals and treat them promptly, ideally before entry, before they can infect competent local vectors and lead to secondary cases and sustained foci of indigenous transmission.[5, 12]
2. Address the source of infection directly by reducing transmission in the regions that are the primary sources of infected travelers.

IDENTIFYING INFECTED INDIVIDUALS AND TREATING THEM PROMPTLY

Screening with malaria rapid diagnostic tests (RDTs) or microscopy at port of entry and/or point of departure and providing follow-up treatment of infected individuals may play an important role in reducing the number of imported cases and outbreaks. For example, all individuals entering the island of Aneityum in Vanuatu have a blood smear at the point of entry with same-

Table 3.1 | Some examples of key populations that could be screened

Source region	Migrant group	Destination region
Mozambique	Migrant sugar laborers	Swaziland
Malaria-endemic regions of Burundi	Refugees from civil war violence	Highlands region of Burundi
Colombian nonendemic regions	Nonimmune agricultural workers	Colombia's malaria-endemic Naya basin

day testing and treatment, as appropriate. When migration rates are high, efforts should focus on screening high-risk groups, such as migrant laborers from endemic regions. Large influxes of laborers for agriculture or mining are a well-known source of imported malaria. As demonstrated in Table 3.1, targeted screening and treating of high-risk populations has been an effective tool for decreasing vulnerability in certain regions.

Countries generally adopt different border-entry procedures for their own citizens; in developed countries, citizens returning from malaria-endemic countries represent a dominant source of imported malaria. Citizens who plan to visit malaria-endemic countries should be encouraged to take prophylaxis while traveling and continue prophylaxis to control early-stage infections that appear after returning home. As malaria disappears from a country, doctors will tend to overlook malaria, so it is worth reminding doctors that they, too, need to remain vigilant and to ask patients whether they have been traveling and, if so, where.

Establishing effective internal border control measures to reduce the movement of malaria within a country is a particular challenge when planning to stage spatially progressive elimination (e.g., province by province). Legal and ethical acceptability must be considered carefully. In addition, screening internal migration may be an enormous burden for a country already fully engaged with preventing introduction of malaria parasites from external sources; for example, uncontrolled internal migration was a major factor in the resurgence of malaria within Indian states, such as Kerala, during the GMEP. However, when geographically feasible, countries pursuing spatially progressive elimination should monitor movement within their own borders just as if they were reducing reimportation from a neighboring country. Generally, the problems of staged progressive elimination are more difficult for large contiguous countries like India than for multi-island nations like the Philippines, where internal migration is more easily screened.

In resource-poor settings, it is unclear how much countries should rely on malaria screening at international ports of entry. Border screening can be costly and can entail direct monetary requirements, such as paying for RDT procurement and the human resources needed to conduct the tests, and nonmonetary costs, including the inconvenience to the individuals being screened. Some of these costs can be passed on to immigrants, but such charges will also increase the incentives to bypass official border crossings.

The MEG recommends that countries conduct effectiveness and cost-effectiveness analyses to determine whether and where screening measures should be implemented.

Total costs must be weighed against the potential benefits to determine the cost-effectiveness of screening programs. The following points should be considered:

1. Screening groups of travelers at very low risk of malaria infection will prove inefficient because a large number of individuals will need to be tested to find a single positive case.
2. Border screening is unlikely to be cost-effective in settings with high immigration rates but low importation risk, as large numbers of malaria-free individuals will have to be screened to find the few cases, as in the first point.
3. For a test with a given sensitivity and specificity, positive predictive value (PV^+, which indicates the probability that infection is truly present) will be lower if the population being screened has a low prevalence of infection (Figure 3.5).
4. The specificity of the screening test should be considered to ensure an acceptable rate of false negative results. In some cases, combining two tests—one highly specific and the other highly sensitive—may be appropriate.
5. The costs of screening can be reduced by focusing on high-risk groups, with calculations depending upon existing levels of outbreak risk and the capabilities for strong surveillance and outbreak response.

It is important to balance screening with other measures. For example, in the case of overland migration across a porous border, countries should increase the level of vigilance at the clinics in regions where migrants are likely to settle. The farms, mines, or other regions drawing migrant workers from endemic countries, for example, should be closely scrutinized for imported cases. If

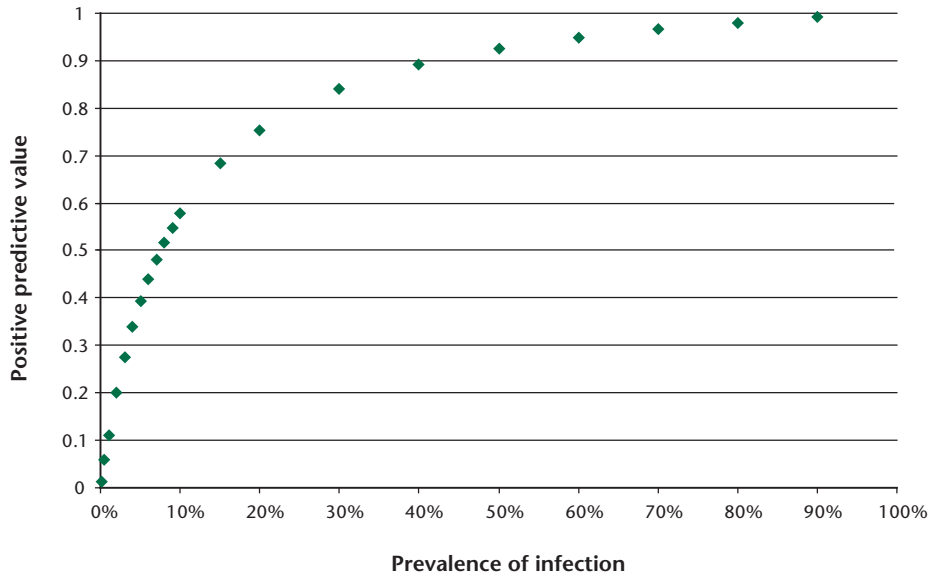

FIGURE 3.5 | Positive predictive value (shown here for a test with 95% sensitivity and specificity) increases as prevalence of infection increases in the population. At lower prevalence, a smaller fraction of positive test results is actually due to infections. Among groups of people crossing borders, overall prevalence rates may be low, so assessment of particularly high-prevalence subgroups will facilitate a more specific and cost-effective screening program.

screening is inherently inefficient, it may be more effective to focus resources on surveillance and outbreak risk reduction measures. There is no hard and fast rule for determining how valuable screening will be, but as a rule of thumb, the higher the malariogenic potential, the greater the need for all measures, including screening.

REDUCING TRANSMISSION IN SOURCE REGIONS

Risk of infection for a given migrant is dependent upon the endemicity of malaria in the region from which he or she travels. Oman, for example, reported importing less malaria after Zanzibar, a source of many travelers, controlled malaria with artemisinin-based combination therapy (ACT) and IRS and therefore greatly decreased transmission rates. Similarly, the burden of malaria in South Africa was reduced after Mozambique improved control of malaria. In resource-poor areas that share a border with endemic regions, zero transmission is unlikely to be sustainable without significant investment in cross-border initiatives. In addition, importation risk will increase if malaria

interventions falter or weaken in countries connected by national borders or immigration routes, emphasizing that countries have an interest in not only achieving control in neighboring countries but also sustaining it.

Importation risk is thus, to some extent, a factor that can be modified by coordinating national and international malaria control programs. Regional benefits of malaria control through transnational initiatives are what justify spatially progressive approaches to elimination.

The MEG recommends working with neighboring countries and those from which migrants originate whenever possible, to reduce importation risk.

Working with neighbors to reduce malaria in a multi-country region will increase the sustainability of malaria elimination. Because malaria control has regional implications for the public good, it should be incorporated into the international financing of malaria control (Chapter 4). Contributing resources to ensure sustained reductions in malaria in neighboring countries may prove to be a cost-effective investment toward preventing reintroduction following elimination.

3.4 Outbreak Risk

Outbreak risk, also known as receptivity, is essentially a measure of potential transmissibility that takes into account the two components described below:

1. the intrinsic potential for malaria transmission, as determined by the vectors and by geographic, environmental, and social factors (Chapter 7)
2. the interventions that reduce potential transmission from this baseline, including IRS, long-lasting insecticide-treated nets (LLINs), and well-developed health systems that treat malaria promptly with effective antimalarial drugs such as ACTs

The MEG recommends assessing intrinsic potential for malaria transmission to determine the need for maintaining interventions that lower outbreak risk.

Assessing potential transmission is important because many places in the world have suitable vectors and a history of malaria transmission. Some long-term changes in the intrinsic potential for transmission come about naturally as a consequence of socioeconomic growth, environmental modification, and climate change (Table 3.2).

The effect on malaria transmission of interventions to achieve elimination is discussed in Chapter 7. In planning for elimination, it is important to evaluate whether it will be necessary to sustain high coverage levels of nets and spraying

Table 3.2 | Factors affecting outbreak risk

Factors increasing outbreak risk	Factors decreasing outbreak risk
Evolution of vector resistance to insecticides or parasite resistance to antimalarial drugs	Economic development
Increased poverty and deteriorating living conditions	High-quality housing, screened windows
Increased agriculture or other land-cover/land-use changes (which may also decrease potential)	Paved streets, with gutters to improve drainage
Civil strife	Increased urbanization

even after reaching zero. Given that such operations will likely have been vital to the success of interrupting transmission, maintaining them should create an environment hostile to reemergence.

In countries where baseline outbreak risk is low, it will not be necessary to continue specific interventions to reduce outbreak risk further. The decision to maintain intervention coverage will depend upon the overall malariogenic potential: if baseline suitability for transmission or importation risk (or both) is high, reducing outbreak risk will be necessary to diminish reemergence risk to an acceptable level (Figure 3.2). At present, it is difficult to prescribe precisely what level of outbreak risk is "acceptable."

Outbreak-risk-reducing activities in a post-elimination region may involve regular and targeted vector control in previously persistent transmission foci identified during the elimination campaign:

- Regions in which final cases persisted before elimination are very likely to be the same regions in which risk of resurgent malaria is highest.
- New transmission foci may be identified by factors such as the influx of a large population of migrant workers or changes in the environment and geography.

In some cases, distribution of insecticide-treated nets (ITNs) may be warranted to ensure that outbreak risk does not return to baseline levels, while in other cases, larviciding and/or environmental management may be appropriate to control key vector breeding sites (Chapter 9).

In cases where analysis of outbreak risk and importation risk indicate the need to continue activities that lower outbreak risk, the MEG recommends that

such interventions should be conducted in a spatially targeted way that concentrates on previously identified foci.

Some countries have eliminated or come close to eliminating locally important anopheline vectors as part of their malaria campaigns, but the persistence of suitable breeding habitats and failure of malaria vigilance systems have allowed vectors to reestablish and create a suitable environment for malaria to reemerge. In some cases, the vectors have returned decades after malaria transmission was first interrupted. Countries where malaria parasites have been eradicated but where competent mosquito vectors remain—such as Australia,[15] France,[6] Italy,[5] Mauritius,[16] Réunion,[17] and Singapore (and nearly every eliminating country shown in Figure 1.1)[18]—can be said to exist in a state of "anophelism without malaria." Rather than attempt to further diminish outbreak risk, such countries have focused largely on ensuring that importation risk is minimized. Due to the proven resiliency of anopheline species, only in special circumstances should complete elimination of the vector be considered. In other areas, sustainable mosquito control measures may succeed in reducing anopheline levels and thus decreasing outbreak risk.

3.5 Surveillance: From Case Detection to Case Investigation and Response

Effective surveillance, efficient contact tracing, and aggressive response may be able to compensate for some weaknesses in other programs that reduce importation risk and outbreak risk. Surveillance for malaria in a region where malaria has been eliminated for a considerable time is somewhat facilitated by the loss of immunity in the population, because infections are more likely to manifest clinically, rather than remain asymptomatic. There is some hope of controlling outbreaks, even in areas with high outbreak risk, because of the length of time required for parasites to develop in the mosquito and in the human.

Even in the case of a country where the probability of local transmission is low, a strong and effective surveillance system (Figure 3.6) will be essential for ensuring the continued sustainability of malaria elimination, as long as humans and mosquitoes continue to cross borders freely:

Passive case detection Surveillance begins by examining a high fraction of people with suspicious fevers who show up at the clinic, either with microscopy or RDTs.

Active case detection Some transmission may have already occurred, whether or not the person in question was the index case; serological

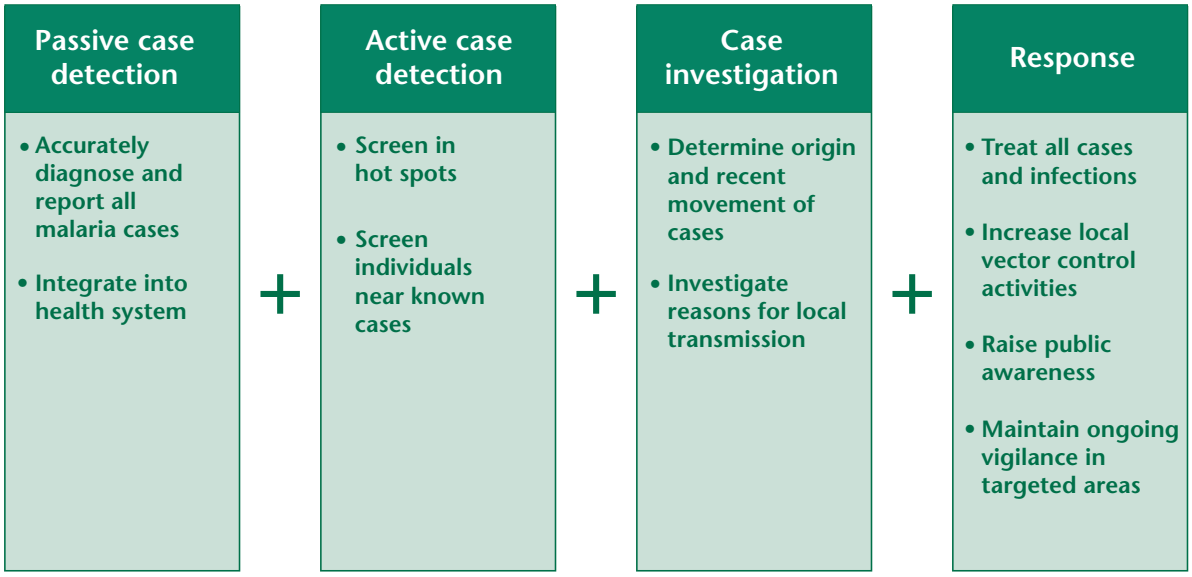

FIGURE 3.6 | Components of the surveillance and response safety net. Most surveillance activities should be integrated into the public health system.

sampling of individuals in the surrounding area can help define the history of infection, and increased testing for malaria in incident fevers may identify other malaria infections.

Case investigation When malaria is detected inside a country, follow-up procedures should be established. A history of travel should be taken to ascertain the source of the case—did the person travel to a malaria-endemic country? A travel history can also help to identify other places where malaria may have spread.

Response If there is any evidence of transmission, mass spraying with insecticides can help to reduce the reservoir of malaria in the adult vector population and reduce the level of immediate risk; identification and focal elimination of local breeding sites may also prove useful. Enhanced vigilance for malaria should continue for several months.

Surveillance for very rare occurrences of malaria is unlikely to succeed if it is conducted as a vertical system. Preventing isolated malaria cases from flaring into epidemics or endemic transmission requires identifying cases as they occur and ensuring that further transmission is prevented. In Oman, for example, strong interaction with the community encourages reporting of malaria cases even among illegal immigrants who might generally fear contact with

BOX 3.6 | Post-elimination Surveillance in Action

In the United States, around 1,000 to 1,500 cases of malaria are reported to the Centers for Disease Control and Prevention (CDC) annually, the great majority of which are imported cases among travelers and visitors from malaria-endemic regions. Although the United States received certification of malaria eradication in 1969, there have been 20 cases of probable local transmission reported to the CDC since 1992. The CDC's National Malaria Surveillance System collects information on cases reported by state health departments, laboratories, and health care providers, using a standardized form, and the CDC maintains a hotline to assist health departments in confirming malaria diagnoses with microscopy, serology, or PCR. Following identification of malaria cases in 2003, there were 300,000 residents living in the same county as identified cases who were urged to use prevention measures through telephoned warnings, while other residents were warned through mailing of informational postcards and posting of flyers. Additionally, enhanced mosquito spraying was implemented within a 3-mile radius of the homes of the malaria patients.

government agencies. Those cases can then be investigated. Case investigation is likely to be a cornerstone of post-elimination malaria programs, since maintaining a strong surveillance and treatment system is essential for containing infections before they can spark epidemics. Countries should be prepared to respond to imported malaria, regardless of the precautions taken to prevent it.

The MEG recommends that malaria surveillance needs to be integrated into the public health system for it to succeed.

It is also recommended that, until malaria is finally eradicated, every country should develop a case response plan with appropriate human capital and resource capacity to hold the line.

Following identification of malaria cases, screening of people in the surrounding area should be paired with rapid, targeted vector control to diminish the probability of local transmission. Because any infected individuals must be treated promptly, it is essential to maintain sufficient stockpiles of effective ACTs. These ACT stocks must be monitored, old drugs must be replaced as they expire, and an appropriate mix of pediatric and adult dosages must remain on hand.

3.6 | Conclusion

As long as malaria exists, countries free of transmission must be prepared to hold the line against reintroduction. Every country will have its own set of challenges to overcome in order to do so. This risk of reemergence must be

weighed against a country's surveillance and outbreak response capabilities. Assessing reemergence risk will require a careful assessment of importation risk and outbreak risk; ideally, an initial assessment should be conducted as a part of planning for malaria elimination. National malaria elimination programs should also develop surveillance to collect data about outbreak risk and importation risk, including historical patterns of endemicity and a record of imported malaria cases that have been investigated. Countries should weigh the value of reducing outbreak risk or importation risk. As a general rule, wherever the intrinsic potential for transmission is high, a combination of the following will be required to reduce the malariogenic potential:

- border screening to reduce importation risk
- ongoing malaria control to reduce outbreak risk
- rapid and robust response to identified cases

As malaria control succeeds in surrounding countries, importation risk will decline, but the need for vigilance will remain until malaria has been eradicated.

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