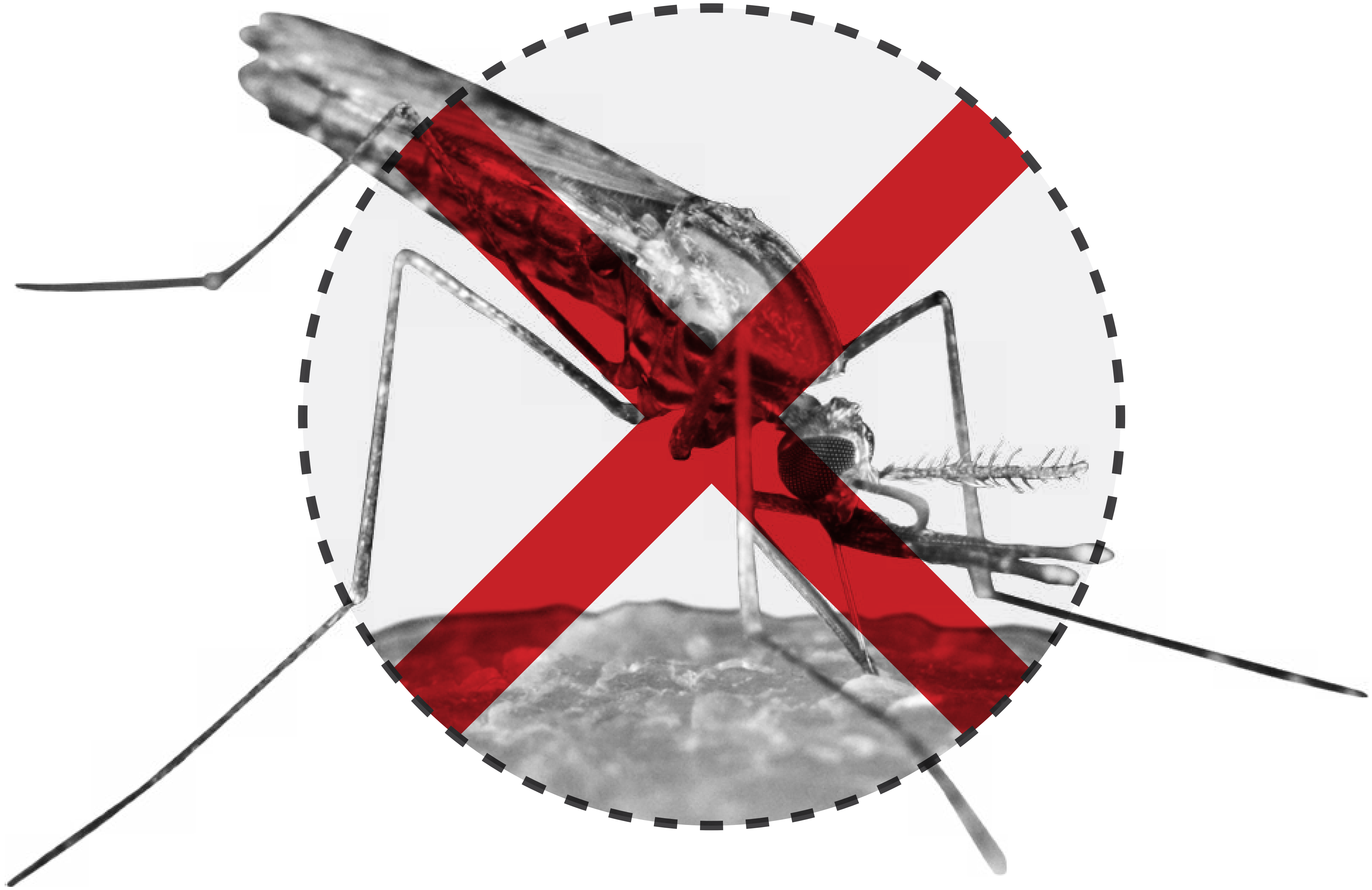
HANDBOOK ON VECTOR CONTROL

in malaria elimination for the WHO African Region



World Health Organization
REGIONAL OFFICE FOR Africa

WHO REGIONAL OFFICE FOR AFRICA HEALTH PROMOTION PROTECTION OF HEALTH AND ENVIRONMENT 1ST EDITION

World Health Organization
REGIONAL OFFICE FOR Africa

WHO/AFRO Library Cataloguing – in – Publication Data

Handbook on vector control in malaria elimination

1. Malaria – prevention and control
2. Disease Vectors
3. Communicable Disease Control – methods
4. Disease Eradication – methods – organization and administration
5. Handbooks

I. World Health Organization. Regional Office for Africa II. Title

ISBN: 978-929023306-0 (NLM Classification: **WC 765**)

CONTENTS

ACRONYMS

GIS	geographic information systems
GPS	global positioning system
GR	geographical reconnaissance
IRS	indoor residual spraying
IVM	integrated vector management
LLINs	long-lasting insecticidal nets
LSM	larval source management
NMCP	national malaria control programmes
NMEP	national malaria eradication programme
VBD	vector-borne disease
VC	vector control
VS	vector surveillance
WHO	World Health Organization

ACKNOWLEDGEMENTS

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FOREWORD

Strong political commitments and the provision and sustenance of resources and technical capacity for programme management, including surveillance, are crucial to deliver effective interventions in both malaria control and elimination programmes. The core strategies are the same for malaria control and elimination, but the goals and objectives of the two differ.

Malaria control programmes aim to reduce malaria burdens across a wide range of epidemiological areas, while malaria elimination targets the removal of residual transmission foci and the interruption of transmission. This requires not only the strengthening of disease and vector surveillance, but also the making of important changes to the way vector control interventions are implemented.

A guiding handbook was required to define the indicators for systematically scaling down vector control interventions; to propose the most appropriate vector control methods and how they are to be combined; to describe the focus areas for vector control, and to define the links between case-based surveillance, including entomological surveillance and the implementation of vector control interventions, in the context of malaria elimination.

This handbook was produced with the purpose of providing a comprehensive package to guide malaria vector control managers in the World Health Organization (WHO) African Region in their aims of eliminating the disease and ensuring that it is not reintroduced. It has been developed out of the need to provide answers to specific questions on vector control in malaria elimination raised by many national malaria control programmes such as when and how to scale down indoor residual spraying and distribution of long lasting insecticidal nets, which type of transmission foci are targeted for vector control in elimination, and how and when vector control is conducted in transmission foci. It covers the salient features of vector control in malaria elimination and post-elimination phases.

Once malaria elimination goals have been achieved, the main task will be to maintain the malaria-free status. It is crucial to mention that after malaria elimination, the programmes may want to consider scaling down or even completely ceasing interventions, depending on the level of vulnerability and the receptivity of the area under elimination. It is the purpose of this handbook to give clear guidance on how managers can do this, or can implement vector control strategies designed to eliminate the disease and maintain malaria-free status in the post-elimination period.

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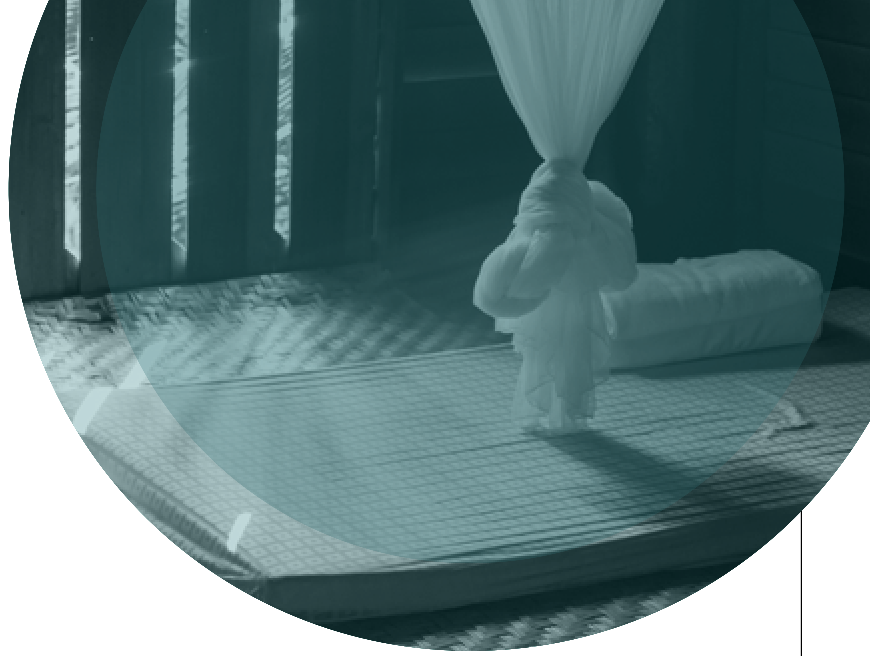


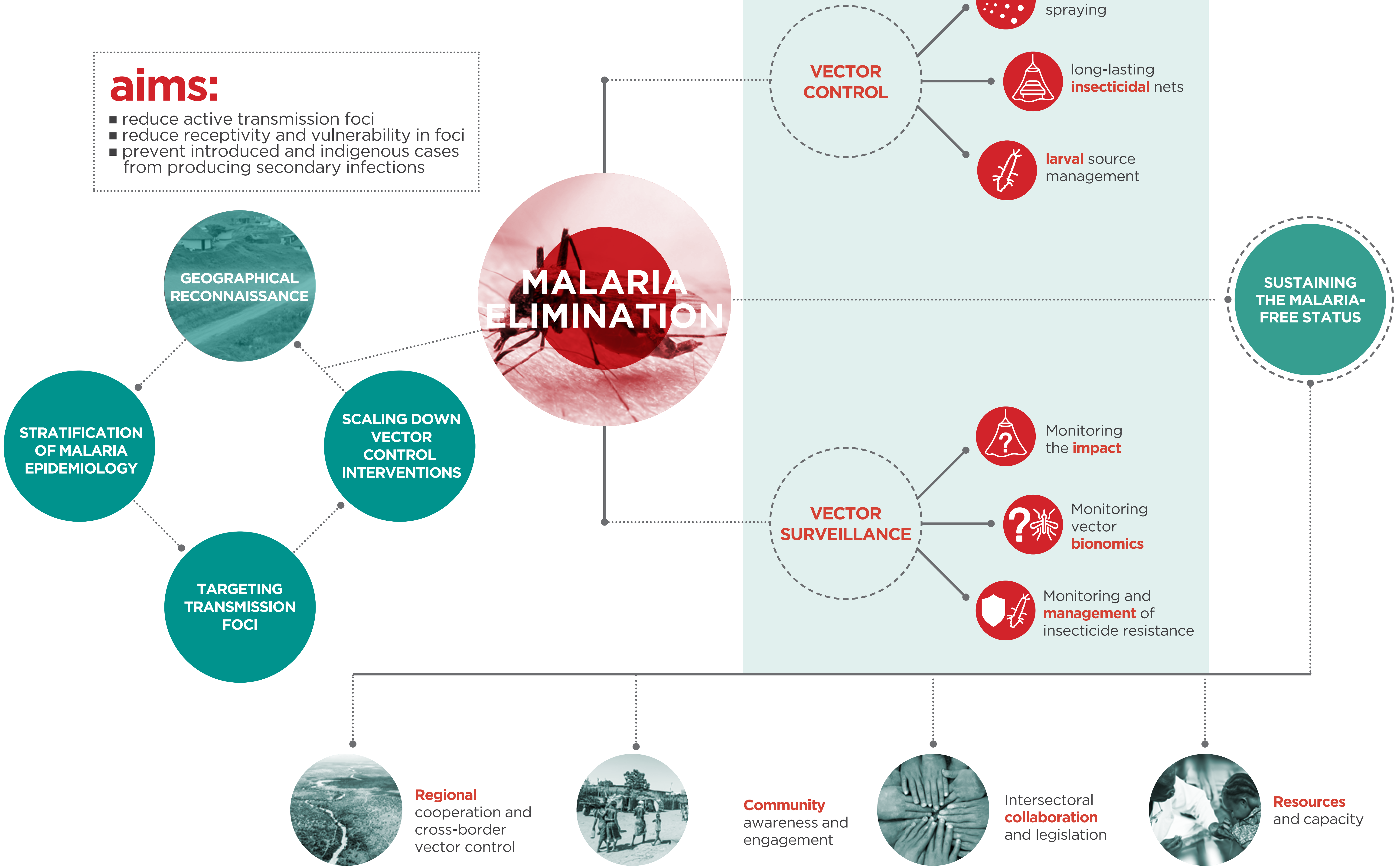
SUMMARY

Vector control, together with case management, is the most effective method for malaria control and elimination. Vector control interventions need to attain universal coverage for malaria control programmes in order to achieve significant reduction in the malaria burden and to transform from control to the elimination phase. Indoor residual spraying (IRS) of insecticides and the use of long-lasting insecticidal nets (LLINs) remain the most important vector control methods in both the control and elimination of malaria. Over the decade, countries in the World Health Organization (WHO) African Region, with the support of the global malaria community, have scaled up these two interventions extensively, resulting in an unprecedented increase in the size of the population at risk of malaria that is now protected through the interventions. The increase in access to and the use of malaria control interventions has led to a significant reduction in malaria transmission in many countries, even those with a high burden. Countries that originally had low transmission rates have seen significant shrinking of the geographical distribution and burden of the disease. These are mainly the countries in the northern and southern fringes of the malaria distribution areas in the Region. Encouraged by this success, some of these countries have decided to embark on malaria elimination.

The reorientation from malaria control to elimination does not entail changing entire vector control strategies or interventions, but rather refocusing and intensifying those already in use, for the purpose of malaria control. One of the greatest distinctions between malaria control and elimination efforts is the importance of the geographical focus in the key vector control interventions such as IRS and LLINs, which in malaria control programmes are deployed widely in a country, targeting universal coverage, but in elimination they become increasingly localized as malaria cases decline and become more localized. Vector control interventions during malaria elimination should, therefore, be targeted at and intensified in the residual foci of malaria transmission. Local malaria transmission and the vulnerability and receptivity levels in the foci will be key factors influencing the decision on the vector control strategy to be implemented in the elimination programme in a country.

The aim of vector control in malaria elimination is to completely interrupt local transmission and eliminate all transmission foci. In this phase, all locally acquired malaria cases, even a single one, are considered as epidemics. Timely and high coverage of vector control interventions are required in all foci with such cases, to reduce the risk of further malaria transmission and ensure its elimination. Consequently, vector control programmes in the elimination phase are organized and delivered in an epidemic-response manner.
This changes how, where and when vector control interventions are implemented, and so programmatic and strategic reorientation will be needed as programmes transform from control to elimination phases.

SUMMARY IN PICTURES

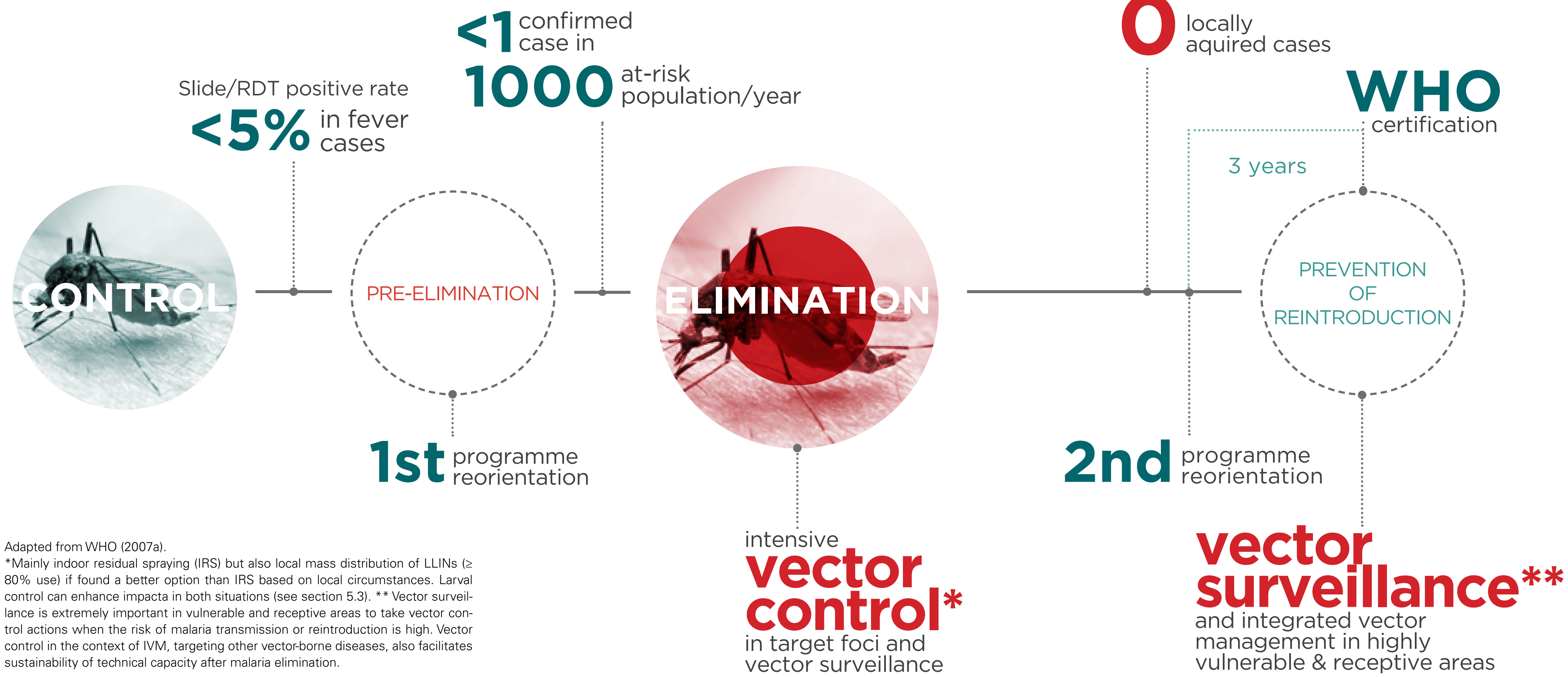


1 INTRODUCTION

Malaria control efforts have expanded and intensified globally in the last two decades. Mortality levels from the disease went down from about one million per year in 2000 to about 627 000 in 2013 (WHO, 2013a). For the first time since the global malaria eradication campaign ceased in the 1970s, a significant reduction in the malaria burden has been documented in the World Health Organization (WHO) African Region.
Some countries, particularly those in the northern and southern fringes of the malaria distribution area, are attempting to move to disease pre-elimination and elimination phases. These countries have developed malaria elimination plans and are now in the process of reorienting their malaria control programmes and strategies.

FIGURE 1

Programme phases and milestones in the path to malaria elimination in low and unstable malaria transmission areas



Adapted from WHO (2007a).
*Mainly indoor residual spraying (IRS) but also local mass distribution of LLINs (≥ 80% use) if found a better option than IRS based on local circumstances. Larval control can enhance impacta in both situations (see section 5.3). ** Vector surveillance is extremely important in vulnerable and receptive areas to take vector control actions when the risk of malaria transmission or reintroduction is high. Vector control in the context of IVM, targeting other vector-borne diseases, also facilitates sustainability of technical capacity after malaria elimination.

“Evolving from malaria **control to elimination** does not entail changing the entire vector control strategy and interventions but just the **focus and intensity of the malaria control strategies** already in place.”

Universal coverage by vector control interventions is needed for impact and to reduce malaria transmission levels to less than one confirmed case per 1000 population at risk per year, which is the level at which elimination should be considered (WHO, 2007a).
At that level, vector control programmes can to be reorganized or restructured in order to respond to malaria case notifications and outcomes of case surveillance. The gradual scaling down of vector control interventions and their transformation from universal coverage to targeted implementation guided by effective disease and vector surveillance are two of the strategic reorientations needed for malaria elimination. Interventions need to be targeted to eliminate local malaria transmission and the risk of its onward transmission. The areas of focus for vector control in the elimination phase are localities where low malaria transmission exists, where local transmission of the disease has been eliminated but then reintroduced, and where the risk of malaria reintroduction is high.

WHO has developed a definition for malaria programme phases and possible landmarks in the transition from control to the elimination of the disease (Fig. 1) . Evolving from malaria control to elimination does not entail changing the entire vector control strategy and interventions but just the focus and intensity of the malaria control strategies already in place. The main strategic shift is in the emphasis on transmission foci instead of the deployment of interventions across wide areas with varied transmission intensity aiming for universal coverage, which is the case in malaria control. As malaria cases decline, they become increasingly localized, and so vector control interventions get targeted to, and intensified in, the residual foci of malaria transmission.

2 AIMS AND OBJECTIVES OF VECTOR CONTROL IN MALARIA ELIMINATION

Vector control in malaria elimination aims to contribute to the total interruption of local transmission of the disease by targeting transmission foci, and to eliminate the risk of onward transmission of the disease from such localities to other receptive areas.

A **TRANSMISSION FOCUS** is a defined locality situated in a currently or formerly malarious area where continuous or intermittent malaria transmission occurs.

aims:

- Contribute to reducing the number of active transmission foci to zero
- Help reduce receptivity and vulnerability in recent foci
- Prevent introduced and indigenous malaria cases from producing secondary infections
- Prevent the re-establishment of local transmission from imported cases

3 STRATIFICATION OF MALARIA EPIDEMIOLOGY IN ELIMINATION

In malaria elimination, stratification is the dynamic process of identifying the areas to which interventions should be targeted to tackle residual and new foci transmission. The interventions during elimination programmes are based on the assumption that transmission is localized in foci. A focus is a defined locality situated in a currently or formerly malarious area where continuous or intermittent malaria transmission occurs. Foci in the malaria elimination phase can be classified into six types: endemic, new potential, new active, residual active, residual non-active and cleared up (WHO, 2012a). As malaria transmission is interrupted in various localities in the process towards its elimination nationally, the type and distribution of foci will change continuously. Therefore, a process for continuously stratifying and microstratifying malaria epidemiology is crucial in targeting vector control interventions. The status and type of primary vector control interventions to be implemented can be unique for each type of focus, based on the local circumstances. Box 1 presents definitions of the classes of foci as described by WHO (2012a).

BOX 1

Types of transmission foci in the malaria elimination phase

ENDEMIC: Transmission is occurring and is not effectively controlled; if malaria control interventions are being implemented, the effect has not yet been sufficient to reduce transmission to low levels.

RESIDUAL ACTIVE: Transmission is occurring in an area that has had transmission within the past 2 years (or past two transmission seasons); it is effectively controlled, with major reductions in malariological indicators after interventions.

NEW ACTIVE: Transmission is occurring in an area that has had transmission for less than 2 years or has never had local transmission. New active foci can be further subdivided into first degree, in which only the first generation of transmission has taken place (i.e. only introduced cases are present) and second degree, in which second- or later-generation malaria and indigenous cases are present.

NEW POTENTIAL: Isolated imported, induced or relapsing cases are occurring during the transmission season in a receptive area that had no transmission in the past 2 years or more. If there is no evidence of renewed local transmission after 1 year, these areas would cease to be new potential foci and would become 'cleared up'.

RESIDUAL NON-ACTIVE: There is no local transmission in an area with a history of local transmission within the past 2 years. Relapses or delayed primary infections with *P. vivax* or a recrudescence (treatment failure) of an infection acquired before transmission ceased may occur.

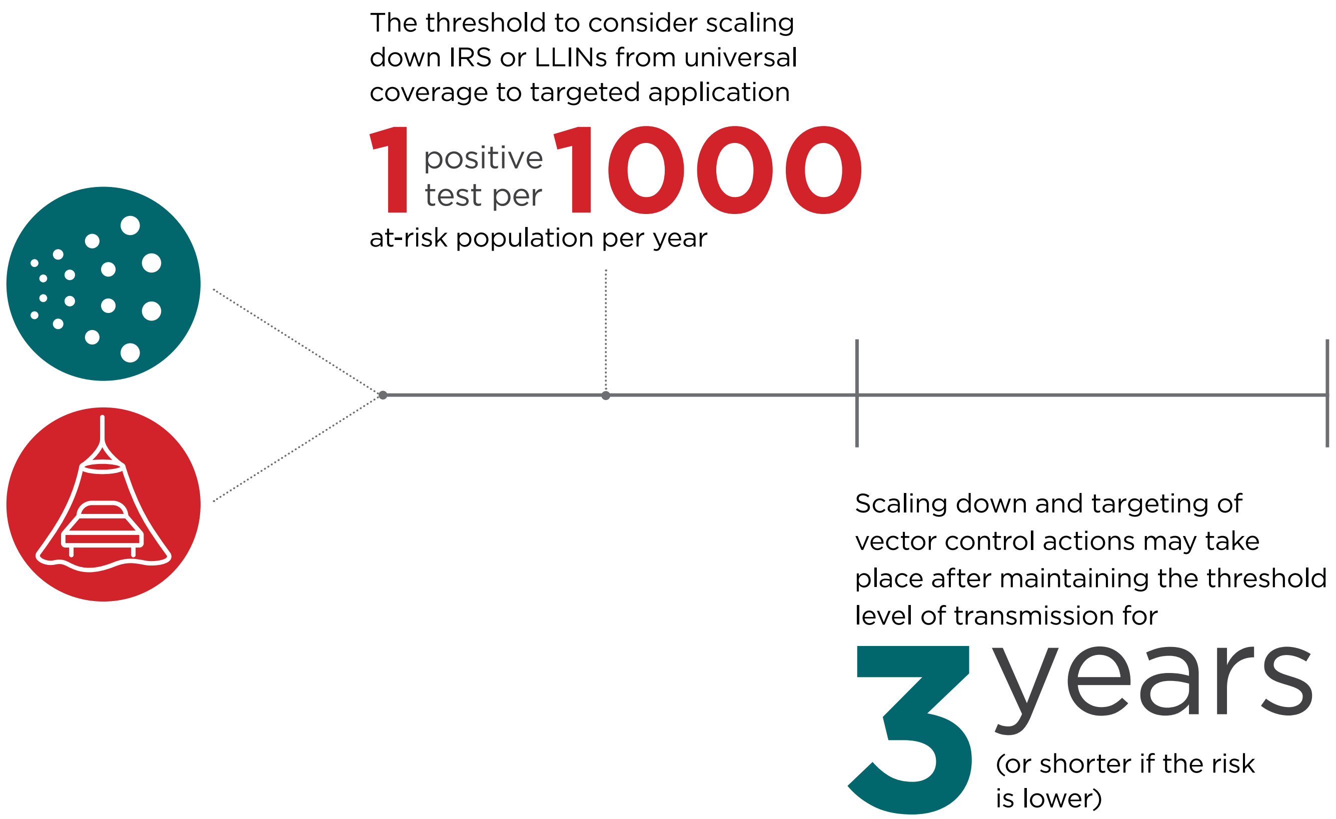
CLEARED UP: No local transmission has been recorded during the past 2 years in an area with a history of malaria and conditions that are suitable for transmission.

Foci may transform from one type to another as progress towards complete elimination of the disease is achieved due to elimination interventions, environmental, climatic and socioeconomic changes.

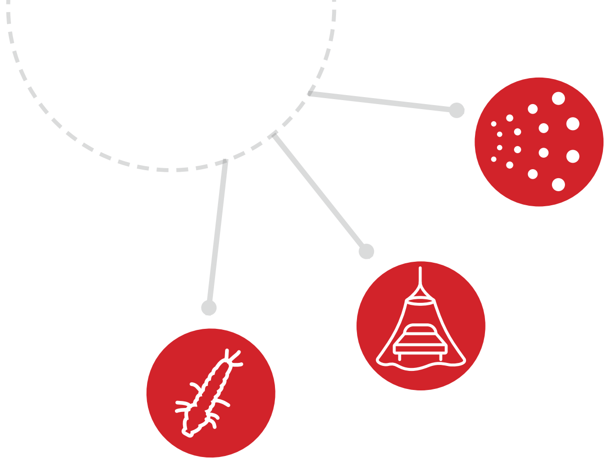
Continuous restratification and microstratification of malaria epidemiology are important, therefore, to guide the implementation of the vector control interventions.

4 SCALING DOWN VECTOR CONTROL INTERVENTIONS WHEN TRANSFORMING FROM MALARIA CONTROL TO ELIMINATION

Malaria control programmes contemplating elimination will need to considerably strengthen their entomological capacity and vector surveillance in addition to scaling up disease surveillance to be able to make evidence-based decisions on issues of implementation of vector control interventions. Information gathered through disease and vector surveillance and monitoring and evaluation should guide the malaria elimination programmes on when to scale down or stop vector control interventions in the target foci. The threshold to consider in scaling down IRS or LLINs from universal coverage to targeted application is one test positive case per 1000 at-risk population per year, which is also the level regarded as the point to consider transforming the malaria programme from control to the elimination phase (Fig. 1). Depending on the risk of resurgence of transmission of the disease, scaling down and targeting of vector control actions may take place after maintaining the threshold level of transmission for three consecutive years, or a shorter period if the risk of malaria transmission reintroduction is minimal and the receptivity is very low. Targeted vector control in identified foci would continue until interruption of transmission is confirmed.



5 VECTOR CONTROL IN MALARIA ELIMINATION



Implementation of vector control interventions will be guided by the reactive or proactive detection and investigation of cases accompanied with vector surveillance. Data generated from investigations can be used to map cases; to identify risk factors for transmission, particularly the presence of the vector, and to target appropriate vector control interventions. A confirmed malaria case that is not associated with travel to an endemic area, or the presence of a larval or adult stage vector may suggest existence of local transmission of the disease. Confirmation of local transmission in such cases must be followed by rapid implementation of a focal vector control intervention to eliminate the vector and prevent further transmission of the parasite. Consequently, sustained vector surveillance (see Section 8) is a crucial component of malaria surveillance in elimination programmes.

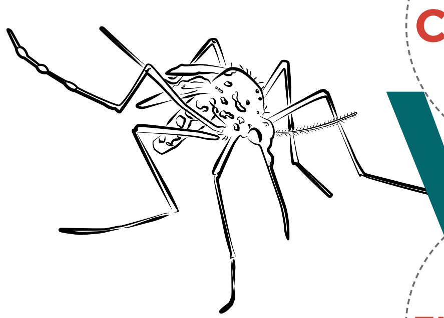
The main vector control interventions used in malaria elimination are the same as those used in malaria control, only that interventions in the elimination setting are guided by case-based surveillance to identify and target transmission foci. Therefore, interventions in the elimination setting are implemented any time the situation requires, but in control programmes they are planned and delivered during approximately the same period each year or season.

5.1

INDOOR RESIDUAL SPRAYING (IRS)

IRS is the main vector control intervention in malaria elimination. The fact that IRS is usually undertaken as an institutional activity makes its high coverage achievable, which is not the case with long-lasting insecticidal nets (LLINs). The impact of good quality IRS with the recommended high coverage levels is felt quickly. IRS can dramatically reduce malaria prevalence from low baseline to zero transmission levels, particularly in localities where vector populations are highly endophagic and endophilic (feeding and resting indoors). IRS plays an important role in interrupting malaria transmission in targeted foci. In a malaria elimination programme, IRS is planned and delivered in an epidemic preparedness and response manner.

Efficient planning and a good level of preparedness is key to the success of IRS, as each identified local case is considered an epidemic and is given an immediate and appropriate response. The frequency and timing of IRS applications, however, is determined by the level and extent of malaria transmission detected and the type of foci the programme is dealing with.



CONTROL – Interventions are planned and delivered during approximately the **same period each year or season**

VS

ELIMINATION – Interventions are implemented **any time the situation requires**

INDICATORS OF COVERAGE OF IRS IN MALARIA ELIMINATION

The WHO recommended optimum IRS coverage guidelines of at least **85 PER CENT** of the households or population in a targeted area is the requirement in all cases. Achieving that level of coverage with good quality and timely IRS is crucial to realize the full potential of the method. However, the proportion of sprayed residual active and new active foci out of the total reported serves as an additional indicator that is critical in monitoring the coverage of IRS in malaria **ELIMINATION**. The recommended optimum coverage in that case is **100 PER CENT**. In malaria elimination, **no focus with a confirmed locally acquired malaria case should be left unsprayed.**

85% in all cases

100% in **ELIMINATION**

In **ENDEMIC FOCI** interventions should be preceded by parasitological, entomological and social investigation to identify the reasons malaria transmission is persistent despite implementation of interventions. The focus of investigations should be on the status of the susceptibility of the vector population(s) to the insecticide(s) in use, quality of IRS or LLINs, compliance of the communities, and existence of significant levels of outdoor resting and biting by the vectors. If insecticide resistance is found to exist, particularly to the type used for IRS, an effective insecticide should be used and a long-term management plan for insecticide resistance put in place. If the vector is resistant to pyrethroids where LLINs are the intervention used, IRS with an effective non-pyrethroid insecticide should be used to manage resistance and sustain the programme's effectiveness. Problems relating to community compliance with the interventions and sub-standard implementation of vector control interventions should be addressed through intensive communication and education activities in the community and staff training, respectively.

In **RESIDUAL ACTIVE** and **NEW ACTIVE FOCI**, IRS is targeted and intensified to interrupt malaria transmission, where appropriate, combined with other vector control methods such as larval source management (LSM). The aim in that case is to stop local malaria transmission and prevent its onward expansion to other receptive areas. When IRS has been implemented in specific foci and when no locally-transmitted case is reported for two consecutive years, the intervention can cease. However, the programme should maintain the preparedness and response capacity at the lowest possible administration level, preferably the district, until malaria elimination from the country is confirmed.

NEW POTENTIAL FOCI are not normally targeted for IRS but one or two rounds of IRS are recommended if an increased vector density is observed in the continued presence of imported or relapsing cases, in order to reduce the risk of establishment of local transmissions.

IRS is not recommended for **RESIDUAL NON-ACTIVE** or **CLEARED UP FOCI**. Nevertheless, if such foci become highly vulnerable from sustained importation of cases, and if local vector surveillance indicates increases in vector density, IRS may be used to reduce receptivity and to avoid the risk of establishment of local transmission. In some situations it might be necessary to complement IRS with the distribution of LLINs locally to avoid applying IRS more than once over a short period, such as a year, if the threat of malaria transmission seems likely to be drawn-out as a consequence of existing risk factors.

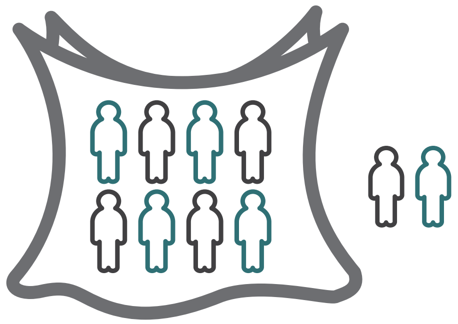
As programmes approach elimination and the number of foci decreases, the scope of IRS will be reduced and ultimately it will be ceased when malaria elimination is confirmed. However, malaria elimination programmes need to maintain rapid response teams and expertise with the capacity to deploy IRS any time a new focus with active local transmission is detected. Vulnerable areas such as those known to receive immigrants or workers from malaria-endemic countries need to be given priority in positioning such rapid response capacity.

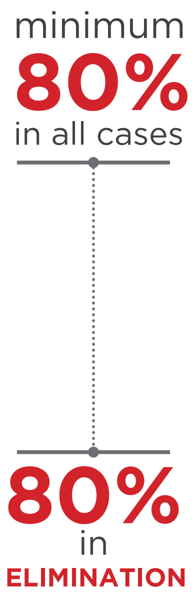
5.2

LONG-LASTING INSECTICIDAL NETS (LLINS)

LLINs can play an important role in malaria elimination if they are used regularly at the recommended high level of coverage. Studies have shown that LLINs are effective when their average use is 80 per cent or greater (WHO, 2008). In malaria control programmes such levels are achieved usually through mass distribution of LLINs in a wide area with at-risk populations. In malaria elimination, mass LLIN distribution for universal coverage can be scaled down to target populations in transmission foci. The challenge in using LLINs in malaria elimination is in dealing with the gap usually observed between LLIN ownership and actual use, particularly in areas where malaria transmission is low and mosquito nuisance is negligible. Consequently, in residual active and new active transmission foci, distributing LLINs in response to reports of local malaria cases may not be the best vector control option. However, distribution of LLINs is less labour intensive than IRS and once LLINs are distributed they are expected to be effective for much longer than IRS applications, which makes them useful in sustaining the low risk of transmission in areas where IRS is not recommended, such as new potential, residual non-active and vulnerable cleared up foci.

INDICATORS OF LLIN USE IN MALARIA ELIMINATION





The indicator for the effective level of LLIN use in malaria control, which is 80 per cent or greater, is **applicable also in malaria elimination**. Persistent awareness creation and public education are required to sustain that level in the targeted foci.

5.3

LARVAL SOURCE MANAGEMENT (LSM)

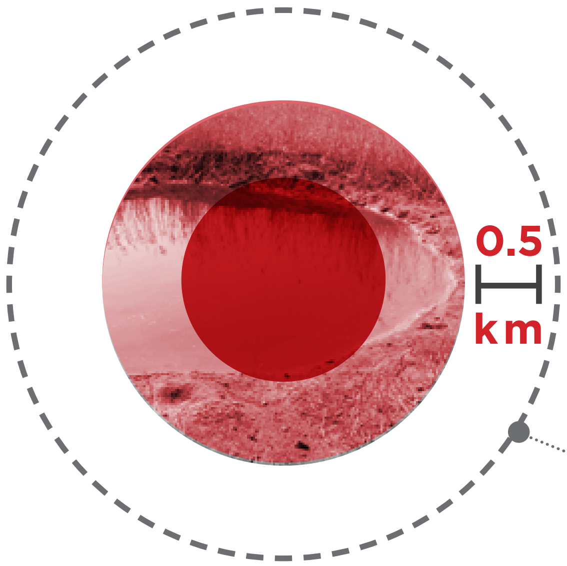
LSM methods include the application of chemical or biological larvicides and complete elimination or modification of potential breeding sites. LSM plays an important supportive or even leading role in malaria elimination where the target mosquito breeding sites are limited in number and are found around an identified focus. When malaria transmission is reduced to very low levels, complete interruption of transmission will become a challenge, as outdoor transmission will continue, particularly in areas where *An. arabiensis* is an important vector. This vector species tends to feed and rest outdoors as much as indoors, when and where blood meal sources and suitable resting sites are available. The outdoor resting segment of the population can continue transmitting the disease unless the breeding sites are eliminated or treated with effective LSM methods. With very high coverage, which might be attainable in malaria elimination owing to the limited size of the target area, LSM can contribute significantly to the reduction of the risk of malaria transmission. In Morocco, entomological investigations of the last foci of transmission showed that through lowering vector density, LSM reduced vectorial capacity to such low levels that resurgence of malaria was unlikely despite the presence of gametocyte carriers in the human host population (Faraj et al., 2009). However, in new active and residual active foci the main intervention should be IRS, but it can be supplemented with LSM to minimize the impact of outdoor-resting vector populations.

INDICATORS FOR LSM COVERAGE

The indicators for the impact of larval control in malaria transmission are:

The proportion of **breeding habitats** positive for larvae

Adult vector presence and density within the treated areas and their immediate surroundings



For LSM to be effective, **all potential breeding sites** in the targeted foci and immediate vicinity, which is a radius of about 0.5 km around the identified malaria case, **should be treated**.

6 GEOGRAPHICAL RECONNAISSANCE FOR VECTOR CONTROL IN MALARIA ELIMINATION

For planning and implementation of vector control interventions for optimal impact on foci transmission, geographical reconnaissance (GR) is critical in the elimination phase. GR is the activity that identifies target areas, including the spatial distribution and number of structures to be sprayed, the households to receive LLINs and the breeding sites for LSM. Furthermore, GR provides information on the distribution of breeding sites in relation to confirmed malaria cases and other relevant operational data. GR was used extensively in Mauritius throughout the malaria control and elimination programmes to identify foci of active or potential malaria transmission to guide interventions and for follow-up on progress (WHO, 2012b).

> “GR is the activity that **identifies target areas**, including the spatial distribution and number of structures to be sprayed, the households to receive LLINs and the breeding sites for LSM.”

GR conducted using handheld global positioning system (GPS) devices, geographic information systems (GIS) and computerized mapping has proved to be effective and efficient operational instruments for rapidly defining the spatial distribution of target populations in malaria elimination areas (Gerard et al., 2010). GR should be undertaken regularly to generate precise information for implementation of vector control interventions to accommodate the changing environment and, by implication, the changing transmission foci. Priority should be given to collecting and updating GR information from vulnerable areas.

7 SUSTAINING THE MALARIA-FREE STATUS

When complete interruption of local transmission of malaria has been achieved, vector control activities will be directed at preventing the reintroduction or re-establishment of malaria in the area covered by the elimination programme. In many countries in the African Region, environmental conditions and socioeconomic factors will continue to favour high vector breeding and human-vector contact, so countries from where malaria has been eliminated will remain receptive, and risk of epidemics is real if the human parasite carrier becomes available. Therefore, it is important for countries in the Region that have eliminated malaria transmission to continue vector surveillance and monitoring until all countries in the Region, particularly those with which they share borders, become free of the disease.

The challenge in sustaining the malaria-free status is in continuously minimizing outbreak risk factors, which are the potential for malaria transmission in elimination countries and the likelihood that an imported case will give rise to others that in turn could generate more cases, causing local outbreaks. The systematic and focused implementation of IRS, LLIN and LSM interventions and perhaps personal protection measures will greatly reduce the outbreak risk by the time elimination is achieved. Sustained effort, taking the appropriate vector control actions, particularly in highly vulnerable foci, is required to maintain the low risk. The choice of vector control interventions to be used, the consistency of application and the level of their coverage will be dictated by the level of the risk of malaria reintroduction. Up-to-date information on the existence and distribution of breeding sites and prevalence of vector larvae is extremely important, particularly in areas with a high risk of reintroduction and re-establishment of transmission. This requires a well-organized vector surveillance system. Moreover, maintaining the malaria-free status will require the awareness and contribution of all groups in the population, to ensure a deliberate checking of the risk factors for transmission.

The main risk for reintroduction of malaria is related to population movement between countries in the elimination phase and those where malaria is still endemic. Travellers by land in many cases stay in border areas, and imported infections are likely to concentrate in those localities. People travelling by boat may potentially bring malaria into ports and their surroundings. Other important entry points are airports and train stations, but most people using these are bound to end up in various parts of the country and these locations are not targetable. Left unchecked, imported malaria cases can develop into local epidemics and may bring the risk of re-establishment of transmission if the entry points are in receptive areas.

Appropriate vector control measures such as mandatory space spraying of buses, aeroplanes, trains and ferries, before they depart from endemic countries, are recommended to prevent the reintroduction of malaria in the country of destination through importation of infective vectors. WHO (2007b) describes the current aircraft disinsection procedures and similar methods that can be used to disinsect buses, trains and other forms of transportation that have the potential to transport malaria vectors.

Continuously updating GR data is vital so appropriate actions for sustaining the malaria-free status can be taken when required. Vector surveillance should be conducted particularly in potentially receptive areas, including monitoring of breeding sites for larvae and surveying both indoors and outdoors for the presence of adult mosquitoes. Follow-up actions and analysis of major changes in environmental parameters, especially meteorological features that may favour malaria transmission such as rainfall, temperature and environmental changes due to infrastructural modifications such as construction of dams, roads, irrigation schemes, new settlements, etc. should continue after malaria elimination. This will allow appropriate mitigation actions to be taken to reduce the risk of malaria reintroduction and re-establishment of local transmission from imported human cases or infective vectors. Maintaining entomological capacity at the appropriate administrative level as per the national malaria elimination programme (NMEP) policy, taking into consideration the country's specific situation, is critical. It is preferable to have a health management team or teams with entomological capacity at the district level in highly vulnerable areas to eliminate the costs of long distance travel from the central level and to ensure timely response to malaria threats when needed.

Adequate technical capacity and supplies and equipment such as those required for IRS also should be maintained and kept in good operating order to enable the system to respond to reported epidemics or obvious risks of epidemics. In addition to the NMEP vector control team, capacity can be created at the community level and in municipalities in urban areas to participate in vector monitoring, particularly in searching for mosquito larvae and adults.

Limited well-documented experiences and lessons in malaria elimination and maintenance of the malaria-free status in the Region is a problem that malaria control programmes that opt to move to the elimination phase are facing. The experience of Mauritius is one of the few cases that have been studied and documented recently (WHO, 2012b). Mauritius is a country with relatively high transmission potential but it has succeeded in maintaining the local malaria transmission level at zero (Box 2).

BOX 2

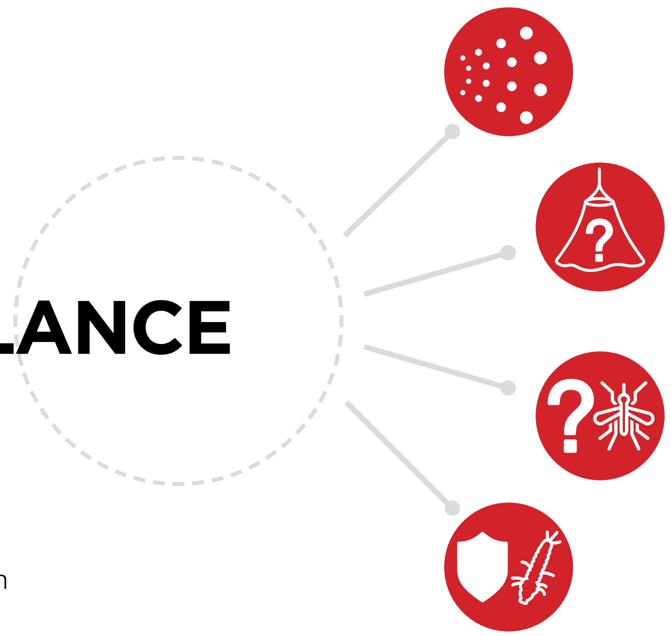
Experience of Mauritius in malaria elimination and maintenance of the malaria-free status

A case study report (WHO, 2012b) indicates that the first malaria elimination campaign in Mauritius was launched in 1948 with a mass deployment of IRS. Marked reductions in the density of mosquitoes were seen and *An. funestus*, one of the main malaria vector species, virtually disappeared. The decline in the vector population resulted in the reduction of the malaria burden, and by 1952 the previously stable and year-round malaria transmission had transformed into an unstable seasonal pattern. IRS was scaled down and continued in targeted foci, and larviciding was added to the vector control strategy, which was fully supported by continuous entomological surveillance. Between 1952 and 1967 Mauritius suffered only sporadic local cases. The last indigenous malaria case following this first campaign was reported in 1968 at which point the programme's strategy was shifted to prevention of reintroduction. Ongoing activities during the prevention of reintroduction phase included IRS limited to ports of entry, prophylaxis for travellers, surveillance of incoming passengers, education about malaria and provision of information for medical personnel on malaria case management.

No local transmission was detected until 1975 when an outbreak occurred in the port area where many migrant workers were living. The cases increased sharply from 8 in 1975 to 77 in 1980 after a large cyclone in 1979. The Ministry of Health responded to the resurgence by intensifying interventions and increasing the number of staff in the initial control efforts, with the required actions guided by GR. IRS using DDT was targeted to areas with positive cases in addition to other interventions. In 1982 Mauritius launched the second elimination campaign with the goal of reaching zero indigenous cases. The campaign emphasized case classification, management and elimination. The number of malaria elimination staff was also increased including for vector control and surveillance. By 1986 three types of vector control interventions, that is IRS, larviciding and vector surveillance, were implemented in the targeted foci either together or singly, depending on the level of the risk of transmission. IRS was undertaken in the active transmission foci. After the second elimination campaign, local malaria transmission was reduced and no locally-acquired case has been reported since 1997.

The experience of Mauritius demonstrates that it is possible to eliminate malaria and prevent its reintroduction even in a country with relatively high transmission potential. However, even Mauritius faces a serious risk of resurgence unless a stringent programme for prevention of reintroduction is put in place and sustained. Throughout the history of malaria in the country, the government maintained strong political and financial commitment to achieving and sustaining its elimination. The residents are legally obliged to participate in environmental management and vector control, which has resulted in high coverage of the populations at risk with effective interventions.

8 VECTOR SURVEILLANCE

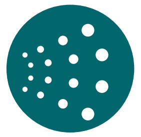


Vector surveillance is one of the critical activities in malaria elimination both to determine and target interventions to eliminate malaria transmission foci and to monitor the impact of interventions. Implementation of interventions for malaria elimination needs more precision than the control phase because the aim is to completely eliminate existing pockets of transmission or transmission risk. Vector surveillance is critical, therefore, to guide the targeted interventions in specific foci. Monitoring of vector bionomics, including abundance, feeding and resting behaviours, and insecticide resistance is pertinent. A number of WHO guidelines and protocols are available for reference on this (WHO, 1975, 2011; 2012c; WHO-AFRO, 2010).

Vector surveillance is not common in many national malaria control programmes. Strengthening the system, capacity and establishing functional vector surveillance systems are critical when programmes move to the elimination phase. The challenge is that vector abundance declines enormously as malaria control programmes progress to the elimination phase. This makes the measurement of important entomological indicators extremely difficult owing to the low levels of vector mosquitoes to be found in the environment. Thus, direct assessment of the quality of the interventions through bioassay tests and measuring of larval and adult vector densities will be essential.

8.1 MONITORING IMPLEMENTATION OF VECTOR CONTROL MEASURES

It is highly desirable to routinely assess through sustained vector surveillance the impact of the vector control interventions in achieving the objectives of eliminating local disease transmission and reducing the risk of its reintroduction. After an IRS campaign, bioassays should be conducted monthly during the expected effective residual life of the insecticide applied. The biological effectiveness and durability of LLINs should be monitored annually. There is emerging evidence that in areas with pyrethroid resistance, LLINs with poor physical integrity offer lower protection than intact nets. The efficacy of damaged LLINs may be compromised in areas with high levels of pyrethroid resistance (Ochomo et al., 2013). The effectiveness of LSM, particularly larviciding, should be monitored by checking for the existence of larvae, since LSM is applied in all identified breeding sites. Presence of adult mosquitoes in the surrounding environment also should be checked.



AFTER AN IRS CAMPAIGN:
MONTHLY bioassays should be conducted

AFTER LLIN DISTRIBUTION:
ANNUAL checks for biological effectiveness and durability should be done

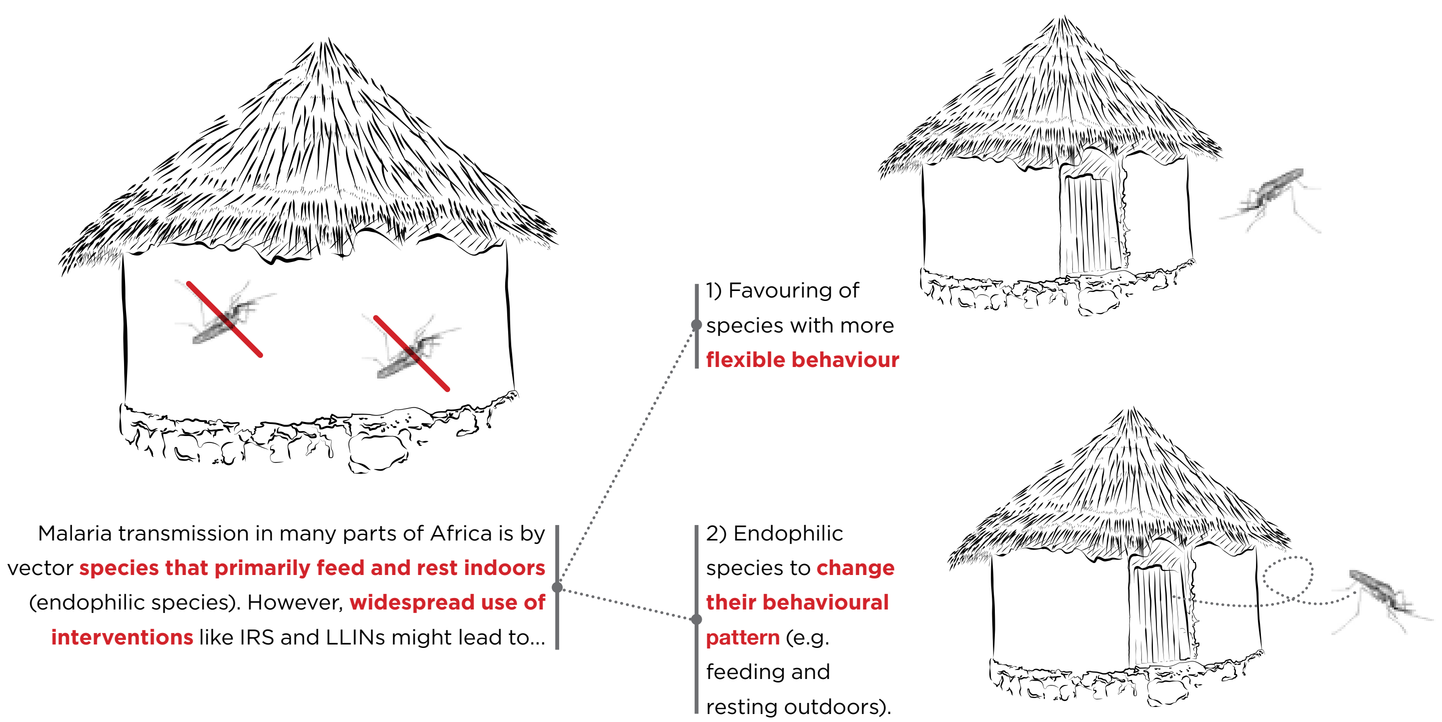
AFTER LSM:
Effectiveness should be checked by monitoring existence of larvae and adult mosquitoes.

8.2

MONITORING VECTOR BIONOMICS

One of the main distinctions between malaria control and elimination efforts is the importance of the geographical focus for key interventions. In malaria control programmes, interventions in general are applied uniformly across wide areas in an endemic country. As malaria cases decline, the interventions become increasingly localized. Therefore, for malaria elimination, vector control interventions must be increasingly targeted and intensified in the transmission foci. This cannot be achieved without a good vector surveillance system to monitor vector existence and abundance, vectorial capacity and changes in biting and resting site preferences. Generally, malaria transmission in many parts of Africa is by vector species that primarily feed and rest indoors, locations in which they can be efficiently targeted with IRS or LLINs. Nevertheless, there is growing evidence from across the continent that the widespread use of these interventions is modifying vector species composition, favouring species with the more flexible behaviour such as *An. arabiensis*. Furthermore, the application of insecticides indoors is likely to foster strong selection and even stimulate the highly endophilic species to change their behavioural pattern. The implication is that the outdoor-resting segment of the vector population, which is less amenable to the major interventions of IRS and LLINs, may continue to sustain low levels of transmission. This could undermine the long-term effectiveness of these interventions and prevent the achievement of elimination. An example of such a phenomenon, where the importance of partially exophilic species increases as that of a typical endophilic species diminishes and where also the endophilic species has adapted to a certain level of exophilic behaviour owing to effective vector control, is presented in Box 3. That situation re-emphasizes the importance of sustained monitoring of vector bionomics in elimination areas in order to adjust the vector control strategy to deal with outdoor transmission as well.

WHY DO WE NEED TO MONITOR VECTOR BIONOMICS?



Entomological data and vector control records must be maintained for monitoring changes in vector bionomics. A database should be maintained during the elimination phase and beyond, on information related to entomological monitoring and application of the chosen vector control interventions, including, but not limited to, breeding site mapping, foci entomological investigations, IRS, LLINs and larviciding (WHO, 2007a).

BOX 3

Changes in vector behavioural patterns due to IRS and use of LLINs

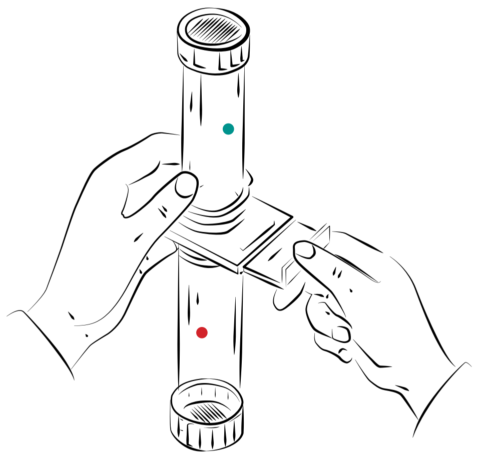
In the 1950s, following the widespread implementation of IRS in the South Pare region of Tanzania the highly endophilic vector *An. funestus* disappeared, leaving only an *An. gambiae* s.l. population that exhibited exophilic behaviour (Gillies and Smith, 1960). In the same period *An. funestus* was replaced by the highly zoophagic and exophilic species *An. rivulorum* and/or *An. parensis* on at least three distinct occasions, following IRS campaigns in South Africa, Kenya and Tanzania (Gillies and Smith, 1960; Gillies and Furlong, 1964). More recently, in Bioko Island, Equatorial Guinea, the main vector An. gambiae s.s., which was regarded as primarily feeding and resting indoors, was noted to change behaviour following IRS interventions.

In 2004, the Government of Equatorial Guinea, with the support of various partners, launched the Bioko Island Malaria Control Project (BIMCP). One of the interventions was IRS using deltamethrin (pyrethroid) applied once a year. In 2005 deltamethrin was replaced with bendiocarb (carbamate) upon the discovery of insecticide resistance among *An. gambiae* s.s. population in the area. Two rounds of IRS per year using bendiocarb continued. In 2007, mass distribution of LLINs was initiated, achieving a significant level of coverage in 2008. These vector control interventions, in conjunction with disease reduction strategies, substantially reduced childhood mortality on Bioko Island (Kleinschmidt et al., 2009). However, studies conducted in subsequent years indicated that the main vector *An. gambiae* s.s. was resting and biting outdoors at much higher levels than it had previously (Reddy et al., 2011). Reddy et al., (2011) concluded that it is likely that the long-term indoor application of insecticides stimulated adoption of outdoor host-seeking behaviour among residual *An. gambiae* s.s. populations, owing to the selection pressure imposed by the toxicity of bendiocarb used in IRS campaigns and the use of LLINs. They pointed out that such behaviour may be the result of effective IRS and/or LLINs interventions that kill mosquitoes that predominantly feed or rest indoors, resulting in a reproductive advantage for mosquitoes that opportunistically feed outdoors.

Whatever factor is responsible for this shift in the pattern of feeding and resting behaviour, the situation suggests that long-term application of IRS and LLIN use contributes to the increased tendency of outdoor feeding and resting among malaria vector populations. Therefore, surveillance on vector biology and ecology and monitoring of changes should be important components of elimination activities, owing to the significance of the impact such behavioural changes have on the effectiveness of the interventions to eliminate foci.

8.3 MONITORING AND MANAGEMENT OF INSECTICIDE RESISTANCE

Resistance to insecticides poses a big threat to malaria elimination. In the elimination phase the shift from universal to targeted deployment of vector control interventions might reduce the insecticide's effect on vectors, and to some extent reduce the risk of resistance, but not the pressure from agricultural and household pesticides. Therefore, annual monitoring of insecticide resistance following the WHO protocol and recommended test kit (WHO, 2013b) is essential for the required management action to be taken to safeguard the efficacy of the vector control interventions. Regular resistance monitoring may become problematic in the elimination phase, in which vector abundance is reduced markedly, so maximum effort should be made to obtain an adequate sample size for susceptibility tests.



ANNUAL monitoring of insecticide resistance is essential to safeguard the efficacy of the vector control interventions.

Insecticide resistance management is most effective when undertaken as a pre-emptive measure before resistance appears. The recommended strategies include rotation and mosaic application of different insecticides and a combination of interventions, particularly LLINs and IRS, using non-pyrethroid insecticides for IRS. LSM interventions during the elimination phase provide an additional opportunity for implementing a multifaceted resistance management strategy. When a larvicide is introduced, caution should be taken to avoid using an insecticide of the same class for IRS or LLINs.

The absence of an insecticide resistance monitoring and management system might rapidly jeopardize the gains in disease reduction, especially for IRS, which tends to lose efficacy as soon as the vectors become resistant to the insecticide used. If the effectiveness of interventions is affected by vector resistance to the insecticide, the potential to control transmission foci and eliminate malaria could be compromised. The negative impact of insecticide resistance on malaria control was documented in South Africa by NMCP (NMCP unpublished reports, Maharaj et al., 2005) (Box 4).

BOX 4

Impact of insecticide resistance on malaria control and elimination

South Africa is one of the pioneers in malaria control. The country has been implementing vector control interventions, particularly IRS, for more than half a century. DDT was the insecticide used from the 1940s to the 1990s. Through IRS, one of the main vectors, *An. funestus*, disappeared in the 1950s and the malaria burden diminished and its geographical distribution contracted and remained only in the north-eastern parts of the country. In 1999 NMCP replaced DDT with deltamethrin, which is a pyrethroid. By 2000 malaria cases had increased fourfold and in 2001 they reached epidemic levels.

The investigation conducted by NMCP with the support of the research institutes on the factors responsible for the steady increase of cases and epidemics indicated that *An. funestus* had re-emerged in the epidemic area owing to its resistance to the pyrethroid insecticide. The programme immediately reintroduced DDT, to which the vector population was found to be fully susceptible. That step resulted in a 91 per cent decline in malaria cases during the following year (Maharaj et al., 2005).

9 REGIONAL COOPERATION AND CROSS-BORDER VECTOR CONTROL

The success and sustainability of malaria elimination efforts in a country can be influenced by the malaria situation in neighbouring countries. This is particularly true in the African Region, where some countries planning for elimination have neighbours in the control phase. Cross-border collaboration between countries in the elimination phase and those in the control phase is more challenging than between countries in the same phase. This is because the strategies and priorities of the two phases of the programmes differ. Countries pursuing malaria elimination face the challenge of dealing with the potential reintroduction of the disease from malaria transmission in neighbouring countries. Therefore, the move towards malaria elimination should be supported by a formal system with the capacity and mechanism to foster collaboration in cross-border vector control. This will be in addition to the strict passive and active case detection and radical treatment of all imported cases in border areas to mitigate the malaria transmission risk.

It is unlikely that countries in the malaria elimination phase can achieve or sustain zero levels of local transmission unless they ensure a significant and sustained reduction in malaria transmission in the border areas of neighbouring countries in the control phase. Therefore, it is essential to have a well-coordinated multi-country approach with strong cross-border collaboration. Countries in the malaria elimination phase need to share information and harmonize vector control strategies with neighbouring countries, including the type and timing of interventions for border areas. Countries in the control phase need to collaborate with their neighbours in the elimination phase and to prioritize areas bordering those countries in vector control measures. In situations where such areas are not the priority for the country in the control phase, the country in the elimination phase could support implementation of vector control interventions across the border. Regional organizations such as the Southern African Development Community (SADC), the Intergovernmental Authority on Development (IGAD) and the Economic Community of West African State (ECOWAS) could play an important role in securing political commitments and facilitating such efforts (Box 5).

"The move towards malaria elimination should be supported by a formal system with the capacity and mechanism to foster collaboration in cross-border vector control."

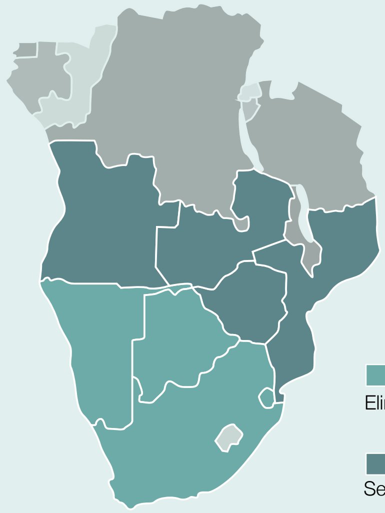
BOX 5

Cross-border collaboration in southern Africa

The Elimination Eight (E8) Regional Initiative
A very good cross-border collaboration example involves Botswana, Namibia, South Africa and Swaziland, commonly referred to as the Elimination 4 (E4) countries led by SADC that aims to eliminate malaria from their subregion. These four southern African countries find the task easier working together than individually.

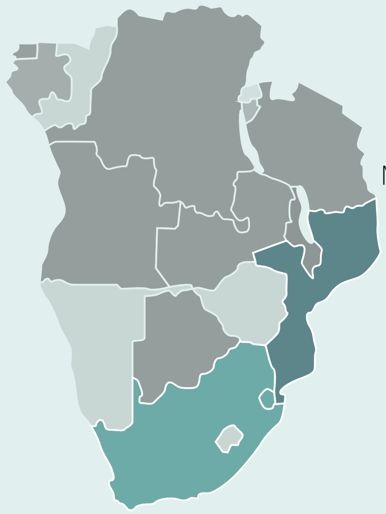
Regional coordination is critical for the success of transboundary collaboration with neighbouring countries in the malaria control phase. For instance, the current border line of malaria transmission in southern Africa extends across the northern and north-eastern areas of the E4 countries bordering the malaria endemic areas of their neighbours Angola, Mozambique, Zambia and Zimbabwe, who are referred to as the second line countries. In order for the E4 countries to achieve and sustain malaria elimination, cross-border collaboration with the second line countries is essential. Those countries need to reduce malaria incidence significantly in their southern border areas through scaling up malaria control efforts and working in collaboration with the E4 countries.

Recognizing the need for the countries to collaborate, SADC created the Elimination Eight (E8) Regional Initiative. This initiative pursues increased regional collaboration, coordinates cross-border activities and shares evidence and lessons learned among the E8 countries.



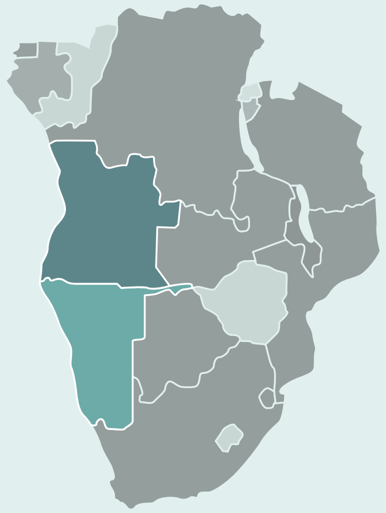
MAP OF THE ELIMINATION 4 AND SECOND LINE COUNTRIES

The Lubombo Spatial Development Initiative (LSDI)
This initiative was launched in 1999 before the strategic direction of the control programmes in the E4 countries was changed to elimination and the E8 Initiative was created. LSDI is a collaboration among eastern Swaziland, southern Mozambique and north-eastern KwaZulu Natal in South Africa. The malaria control programme of LSDI was set up to address the high malaria transmission levels in southern Mozambique. There was a clear understanding and agreement on the fact that even if malaria control measures were optimal in South Africa and Swaziland the disease burden could be reduced further only through a regional approach to deal with malaria transmission in the high burden areas of Mozambique, which borders and has impact on malaria transmission in adjacent areas of both South Africa and Swaziland. Significant reductions were made in malaria levels in the border regions of these two countries once malaria control interventions were implemented in the neighbouring areas in Mozambique. The introduction of LSDI resulted in the decline in malaria incidence rates in South Africa and Swaziland from around 25 per cent to less than 2 per cent, while in the control zones of southern Mozambique malaria prevalence in children between the ages of 2 and 15 years was reduced from levels above 60 per cent to 90 per cent during the baseline surveys to less than 15 per cent in all zones (Roll Back Malaria 2003).



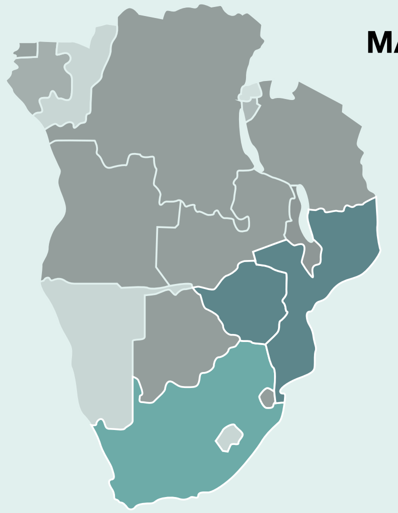
MAP OF LSDI COUNTRIES: SWAZILAND, MOZAMBIQUE AND SOUTH AFRICA

Trans-Kunene Malaria Initiative (TKMI)
TKMI was created in 2011 by Namibia and Angola to combat the spread of malaria in the two countries, which was necessary for Namibia to pursue its malaria elimination effort. The main objectives of the initiative were to foster malaria elimination in Namibia and provide Angola the support to push its malaria control efforts to the north. TKMI includes three malarious districts of the Kunene region of Namibia bordering the Cunene Province of Angola. The initiative promotes sharing of expertise, logistics and infrastructure between the two countries in order to implement effective malaria control programme in Angola, particularly IRS and LLIN use (Gueye et al., 2014).



MAP OF TKMI COUNTRIES: NAMIBIA AND ANGOLA

Mozambique-Zimbabwe-South Africa (MOZIZA)
This is a recent joint effort to reduce malaria transmission in the targeted border provinces of Mozambique, Zimbabwe and South Africa. For Zimbabwe, the initiative covers Matabeleland South Province, which is earmarked for malaria pre-elimination. That province shares its longest border line with the Limpopo Province of South Africa, one of the three provinces targeted for malaria elimination in that country. The general goals of the initiative are to reduce malaria transmission to less than 5 cases per 1000 at-risk population by 2015 in the targeted districts along the borders, particularly on the Zimbabwe side, and to ultimately eliminate malaria transmission. The initiative focuses on (1) developing and supporting a regional parasitological and entomological surveillance mechanism; (2) establishing a cross-border coordination and management system for policy harmonization in vector control, surveillance and epidemic preparedness and response, and synchronization of interventions to optimize resource use and impact; and (3) achieving and monitoring universal coverage of key malaria interventions in the targeted districts where they are deficient. There has also been technology transfer, particularly in vector control, between Zimbabwe and South Africa. The programmes collaborate in capacity building for IRS implementation and monitoring.



MAP OF MOZIZA COUNTRIES: MOZAMBIQUE, ZIMBABWE AND SOUTH AFRICA

Island countries in the Region, such as Cape Verde and Sao Tome Principe, do not need to deal with cross-border problems and collaboration. Apart from screening of persons arriving from high malaria endemic areas or countries, IRS or other suitable vector control measures such as LSM are recommended for such countries, predominantly targeting locations where most travellers are likely to stay and where potential vector breeding sites exist. Data from regular vector surveillance activities should provide guidance on where and when to target IRS or other vector control measures to reduce receptivity in those areas.

10 COMMUNITY AWARENESS AND ENGAGEMENT

Malaria elimination and sustainability of the malaria-free areas depend on the behaviours and day-to-day activities of the affected communities. Awareness and active community participation, especially in making sure no human-made breeding sites are created to reduce mosquito breeding and contribute directly to the lowering of the risk of malaria transmission. If awareness is raised in communities and the communities are equipped with the necessary information, they too can exert pressure on development projects to undertake the required mitigation actions for reducing malaria risks related to their project's activities. Raising the awareness of the communities and their leadership on the importance of being involved in malaria elimination and prevention of reintroduction, and their engagement and participation in these processes in their areas are critical. Communities that are knowledgeable about malaria and its serious impact on their well-being see its elimination as an important benefit and significantly contribute to malaria elimination efforts. Therefore, there is a need to have communities well informed of the transformation from malaria control to elimination and other actions, the roles and responsibilities of the different sectors and related legislation.

The community needs to be informed when there is a shift in the malaria strategy and should be able to contribute deliberately to the success of malaria elimination efforts and sustenance of the malaria-free status in the post-elimination period. They have to be well-informed and willing participants in the various interventions for malaria elimination. Individual families need to be cooperative for IRS to succeed and to accept and keep using LLINs. Informal reports from many communities indicate that acceptance of IRS has been maintained over long periods and it is welcomed for its general impact on household pests. But in some places fears concerning IRS safety have been responsible for the lack of cooperation from the community in its implementation. The significant decline in malaria cases also has been indicated as being responsible for the lack of interest in IRS in some communities. If provided with the required knowledge, guidance and tools, community and religious leaders can play key roles in creating the required understanding of the needs of their communities and the aims and activities of the programmes, which is important to engage them in efforts for malaria elimination and the prevention of its reintroduction. Community leaders and community-based organizations can play significant roles in ensuring high levels of compliance among their people, with the strategies in place.

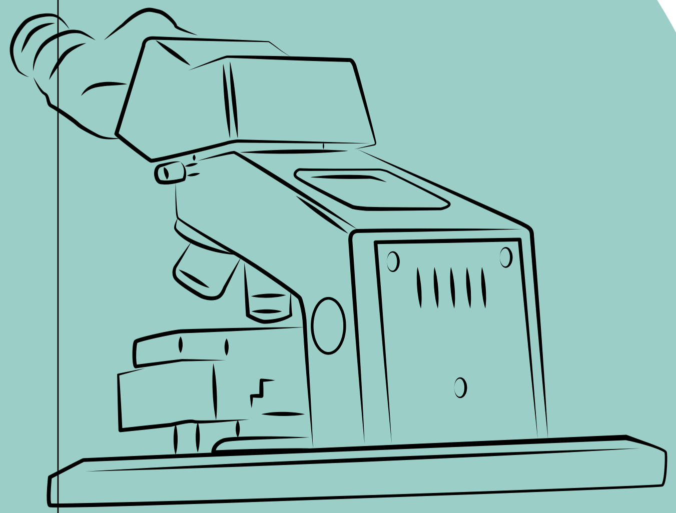
> "The community needs to be informed when there is a shift in the malaria strategy and should be able to contribute deliberately to the success of malaria elimination efforts and sustenance of the malaria-free status in the post-elimination period."

11 INTERSECTORAL COLLABORATION AND LEGISLATION

Malaria elimination cannot be achieved and sustained without the collaboration of the various sectors of society. All must be conscious of the need to avoid creating conducive environments for the transmission of the disease. The health system should assume its leadership role and exercise its mandate to coordinate efforts related to malaria elimination, including creating and strengthening the relevant technical capacity. Also, the health system is in charge of sharing information and raising awareness about the roles and responsibilities of the various stakeholders in malaria elimination and maintenance of the malaria-free status. Construction, agriculture, municipality and all other sectors should involve the ministry of health in the planning and designing of projects that have the potential to significantly change the environment and create favourable conditions for mosquito breeding as well as to ensure mitigation plans are included from the onset of the projects.

Municipalities should play a proactive role in reducing the risk of mosquito breeding in urban areas. Some Asian countries in the elimination phase have specifically targeted such risks and shifted responsibilities among sectors in order to ensure success. A similar approach should be introduced and used more regularly to sustain malaria elimination in the long term. Countries that opt for malaria elimination need to develop legislation to define and enforce different sectors' accountabilities for the interventions and to take appropriate action to mitigate risks related to environmental changes in line with the Libreville Declaration on Health and Environment in the African Region (WHO-AFRO, 2008).

12 RESOURCES AND CAPACITY FOR MALARIA ELIMINATION



Malaria elimination might cause a reluctance by authorities to commit personnel, time or expenditure to malaria efforts. But malaria elimination is a long-term investment and it can be achieved and sustained only through political commitment and allocation of adequate financial and human resources. A weakening in the commitment to malaria elimination or lack of availability of financial, material and human resources required to implement efficient vector control interventions that are supported by vector surveillance might lead to malaria resurgence and epidemics, and the investments and efforts made in the past will quickly be lost. Targeted and sustained advocacy and communication campaigns will be essential tools to maintain the investment momentum. If possible, documenting and disseminating data about the economic benefits of investing in the elimination of malaria such as savings for the health system in patient care and increasing revenues from agriculture and tourism can be useful in advocating for sustained commitments.

Continuous vector surveillance – and in some cases even vector control activities – is needed over many years. Therefore, the expertise and infrastructural and material capacity for entomological surveillance, including insecticide resistance, need to be strengthened and maintained in the elimination phase and beyond. To ensure this, the countries engaged in malaria elimination require an ongoing national malaria elimination or vector-borne disease [VBD] control programme. Closing down such programmes and allowing the expertise and staff to disperse has proved disastrous. One potential way to maintain the technical nucleus and competence in entomology and vector control is to broaden the mandate of NMEPs to control other vector-borne diseases such as dengue, yellow fever, leishmaniasis, Rift Valley fever and chikungunya. Such an integrated vector management approach targeting multiple vector-borne diseases with appropriate interventions would be beneficial in maintaining the capacity required to sustain the malaria-free status as well as to control other VBDs.

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