MALARIA SURVEILLANCE, MONITORING & EVALUATION: A REFERENCE MANUAL

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Abbreviations and acronyms

ACD	active case detection
ACT	artemisinin-based combination therapy
CHW	community health worker
DHIS	District Health Information System
G6PD	glucose-6-phosphate dehydrogenase
GIS	geographical information system
GPS	global positioning system
GTS	*Global technical strategy for malaria (2016–2030)*
HMIS	health management information system
IRS	indoor residual spraying
ITN	insecticide-treated mosquito net
LLIN	long-lasting insecticidal net
LSM	larval source management
MDA	mass drug administration
NMP	national malaria programme
PACD	proactive case detection
PCD	passive case detection
PCR	polymerase chain reaction
RACD	reactive case detection
RDT	rapid diagnostic test
SNP	single nucleotide polymorphism
SOP	standard operating procedure
TES	therapeutic efficacy study

1. Malaria surveillance as a core intervention

1.1 INTRODUCTION

Surveillance is "the continuous and systematic collection, analysis and interpretation of disease-specific data, and the use of that data in the planning, implementation and evaluation of public health practice" *(1).*

Pillar 3 of the *Global technical strategy for malaria 2016–2030* (GTS) *(2)* is transformation of malaria surveillance into a core intervention in all malaria-endemic countries and in those countries that have eliminated malaria but remain susceptible to re-establishment of transmission (**Fig. 1**).

Surveillance is therefore the basis of operational activities in settings of any level of transmission. Its objective is to support reduction of the burden of malaria, eliminate the disease and prevent its re-establishment. In settings in which transmission remains relatively high and the aim of national programmes is to reduce the burdens of morbidity and mortality, malaria surveillance is often integrated into broader routine health information systems to provide data for overall analysis of trends, stratification and planning of resource allocation. In settings in which malaria is being eliminated, the objectives of surveillance are to identify, investigate and eliminate foci of continuing transmission, prevent and cure infections and confirm elimination. After elimination has been achieved, its role becomes that of preventing re-establishment of malaria.

A malaria surveillance system comprises the people, procedures, tools and structures necessary to generate information on malaria cases and deaths. The information is used for planning, implementing, monitoring and evaluating malaria programmes. An effective malaria surveillance system enables programme managers to:

- identify and target areas and population groups most severely affected by malaria, to deliver the necessary interventions effectively and to advocate for resources;

FIG. 1.
Global technical strategy for malaria 2016–2030: framework, pillars and supporting elements
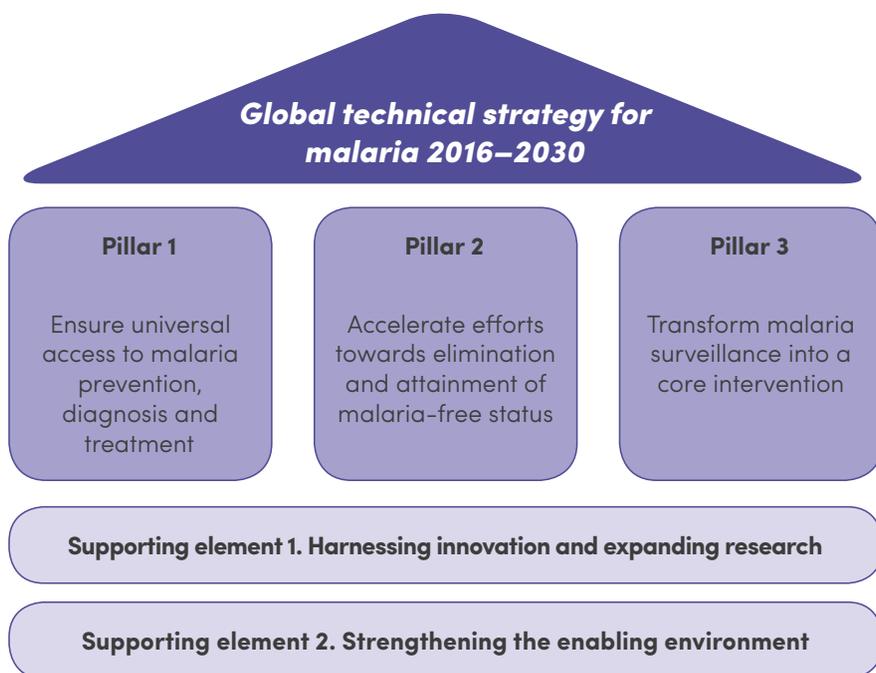
- regularly assess the impact of intervention measures and progress in reducing the disease burden and help countries to decide whether adjustments or combinations of interventions are required to further reduce transmission;

- detect and respond to epidemics in a timely way;

- provide relevant information for certification of elimination; and

- monitor whether the re-establishment of transmission has occurred and, if so, guide the response.

1.2 UPDATES OF PAST GUIDANCE

In 2012, WHO published two operational manuals for malaria surveillance, one for control _(3)_ and the other for elimination _(4)_. The following modifications and additions were made for this revised manual.

- The two manuals have been combined into a single document and their content has been updated.

- The revised manual is aligned with both the GTS *(2)* and the *Framework for malaria elimination (5)*, published in 2017, which define the concept of a "malaria elimination continuum" and new ways of classifying foci in elimination settings.

- Four new sections have been added: surveillance of antimalarial drug efficacy and drug resistance; routine and focus-linked entomological surveillance; forecasting, early warning and detection of epidemics; and monitoring and evaluation of national malaria programmes (NMPs).

- New sub-sections are included to cover surveillance in the private and community sectors and migrant and mobile populations and mapping of foci.

- Basic resources for surveillance data analysis are presented, and the case and focus investigation forms have been updated.

1.3 TARGET READERSHIP AND USE OF THIS MANUAL

The target readership of this manual is staff in ministries of health, NMPs and health information systems, partners involved in malaria surveillance and WHO technical officers who advise countries on malaria surveillance.

The manual covers subjects that are relevant to settings in which the burden of malaria is being reduced, as well as in elimination and prevention of re-establishment. A glossary of important terms is provided in **Annex 1**. In **section 1**, the general principles of malaria surveillance systems are presented, while subsequent sections provide general guidance for establishing a surveillance system **(section 2)**; the concepts and practice of malaria surveillance systems in all settings **(section 3)**; integration of drug efficacy assessments into routine surveillance during elimination **(section 4)**; entomological surveillance for routine monitoring and focus investigation **(section 5)**; forecasting, early warning, early detection and response to epidemics **(section 6)**; and recommended practices for monitoring and evaluating programmes on the basis of data from surveillance and other health information systems **(section 7)**.

The aim of this manual is to serve as a reference document for guidance on strengthening malaria surveillance systems. In particular, it provides information that can be used to develop national standard operating procedures (SOPs) in the following areas:

- malaria case surveillance in settings of malaria burden reduction and elimination **(sections 1–3)**;

- drug efficacy surveillance in elimination settings, especially in areas where each case is followed up in routine surveillance **(sections 3–4)**;

- entomological surveillance in settings of malaria burden reduction and elimination **(sections 3, 4 and 7)**;

- epidemic detection, preparedness and response, especially in low- to moderate-transmission settings of burden reduction **(sections 2, 3 and 6)**; and

- monitoring and evaluation of programmes and surveillance systems in all endemic settings (**section 7** and relevant parts in other sections).

1.4 MALARIA SURVEILLANCE ON THE CONTINUUM

The design and intensity of malaria surveillance systems, in terms of recorded details, promptness of reporting and investigations, frequency of analysis and response, depend on: the intended use of the surveillance data; the level and heterogeneity of malaria transmission and the resources available for surveillance. In previous editions of WHO manuals on surveillance *(3,4)*, a country was considered to be a single transmission setting, and advice on the design of its surveillance system was based on this premise. The natural heterogeneity of malaria, however, and the variable impacts of interventions and socioeconomic and environmental changes within a country result in progress often achieved at different speeds in different parts of a country and against different parasite species. Hence, a country may decide to conduct elimination activities in one part and to focus on reducing the number of deaths and disease in another. The GTS *(2)* therefore introduced the concept of a continuum (**Fig. 2**), whereby progress towards malaria elimination is considered to be a continuous process rather than a set of independent stages. By extension,

FIG. 2.
Malaria heterogeneity across the transmission continuum

As transmission decreases, malaria becomes focal, and the intensity and frequency of reporting increase. Surveillance systems evolve from reporting aggregate case data by month over large geographical areas (e.g. district) to reporting near-real-time individual case data in small areas (foci).
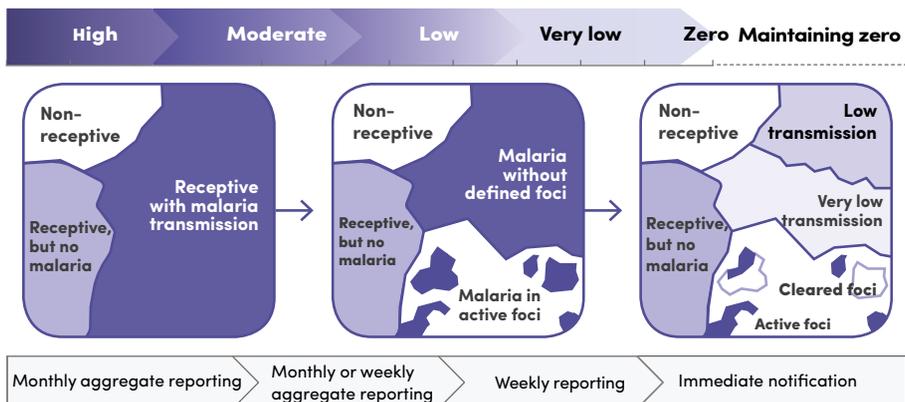
countries are now advised to establish surveillance systems that are appropriate to their heterogeneous epidemiology.

As transmission decreases, the epidemiology of malaria is likely to change.

- The number of uncomplicated malaria cases and related fevers will decrease.

- The numbers of severe cases and deaths will decrease, although the proportion of severe to uncomplicated disease may increase.

- Malaria transmission will become more focal.

- The age distribution of cases of disease will become more evenly distributed, reflecting decreasing exposure.

- In some settings, disease may become more prevalent among people in certain occupations, such as forest workers.

- Populations will become less immune, and the risk of epidemics and the associated case fatality ratio will increase if interventions are interrupted.

- Imported cases may represent an increasing fraction of the overall incidence.

- In countries with both *P. falciparum* and *P. vivax* malaria, the proportion of vivax will gradually increase, as the transmission of falciparum can be reduced faster with current interventions, while vivax infection includes a hypnozoite stage that will evade detection with current standard diagnostics.

The goals and possibilities of surveillance, monitoring and evaluation also evolve during this transition, as outlined throughout the manual.

- In areas of high transmission, programme monitoring and evaluation are based mainly on aggregate numbers, and actions are designed to ensure that the entire population has access to services and there are no adverse disease trends.

- In areas with low or moderate transmission, the distribution of malaria is more heterogeneous, and it is important to identify the population groups that are most severely affected by the disease and to target interventions appropriately. This will be facilitated by mapping areas of ongoing transmission and analysis of case distribution at community level.

- As transmission is reduced, the risk of epidemics increases; thus, cases at health facilities must be analysed more frequently to ensure early detection of a potential outbreak.

- As progress is made towards elimination, it is critical to ensure efficient detection of and response to new cases and foci. Individual cases of infection or clusters of cases should be investigated to identify risk factors, eliminate foci of transmission and maintain malaria-free status. Surveillance systems become more complex and resource intensive, and additional skills, training and activities are required. As the number of cases is reduced and a country nears elimination, the frequency of case investigations will decrease, thereby eventually reducing the costs of surveillance.

1.5 PRINCIPLES OF THE DESIGN AND ESTABLISHMENT OF MALARIA SURVEILLANCE

The core principles of the design and establishment of malaria surveillance systems are listed below.

- Accurate parasitological diagnosis of a malaria case is the foundation of a malaria surveillance system. Diagnoses should be made with either quality-assured malaria microscopy or WHO-recommended rapid diagnostic tests (RDTs) (see **Box 1**).

- All major components of a malaria surveillance system should be integrated into broader health management information systems (HMIS), including, where applicable, systems for reporting notifiable diseases. In some settings, a vertical system may be used initially, but it should allow communication with and eventually be integrated into the HMIS for sustainability. The HMIS system should, in turn, be responsive to the promptness and granularity of data required for effective malaria surveillance.

- National SOPs for surveillance should be based on a country's needs and on WHO recommendations. For elimination, regulations should be enacted through appropriate national mechanisms, so that, by law, malaria becomes a notifiable disease in all relevant sectors of the health system. In settings of burden reduction, all health sectors must also report data to the national HMIS.

- Regardless of the malaria burden, front-line staff involved in the detection, recording and reporting of cases should also be the first users of data. Thus, staff at all levels should be trained in examining and evaluating data from surveillance of both disease and operations, monitor programme progress, target interventions and detect problems that require action. Analytical capacity should therefore be available at all levels.

- Surveillance systems should address the heterogeneity of malaria within a country's boundaries. For example, monthly aggregate case

reporting may be sufficient in areas with a relatively high malaria burden, but, as the caseload diminishes, aggregated data should be reported weekly; then, individual cases should be reported weekly, and, once a decision has been taken for elimination, cases should be reported immediately. In elimination settings, cases should be linked to the village (or focus) and household of origin, where further case detection, treatment, classification, investigation, management and clearance of foci of transmission can be undertaken as appropriate.

- Necessary investments in surveillance and system transition, including in human resources, should be made to respond to the anticipated reduction in disease burden. For instance, surveillance systems that allow for immediate case notification, investigation and response should be in place before a country embarks on elimination.

- All surveillance data must be linked to a decision at some level of the health system, even if the decision results in no immediate change in interventions. Where appropriate, surveillance data should be combined with other data from the programme and the population to improve decision-making. In settings with a high or moderate burden of malaria, important markers of progress are trends in childhood deaths from all causes and malaria, the proportions of *P. vivax* and *P. falciparum* malaria where the latter was dominant before the intervention, and changes in the age distribution of the disease. In elimination settings, surveillance is linked to specific responses that should allow the detection of all cases of malaria infection by microscopy or WHO-recommended RDT (including symptomatic and asymptomatic infections) as early as possible; the prevention of onward transmission from each case through prompt, radical treatment and vector control; and the identification, investigation and management of all transmission foci, with appropriate measures for interrupting transmission as soon as possible.

- In all transmission settings, a concerted effort must be made to include cases detected in other sectors (e.g. in private and other nongovernmental health care facilities), as well as those detected in public health facilities. In elimination settings, it is critical that cases detected in all sectors are reported and investigated. Information is disseminated to stakeholders through mechanisms, such as open-access surveillance bulletins.

- After interruption of transmission, surveillance for malaria may become the broad responsibility of general health services. Nevertheless, the surveillance system should be supported by regular training and monitoring in a national programme to ensure identification of changes in the receptivity (i.e. suitability of the ecosystem for transmission of malaria) and vulnerability of the population (i.e. the frequency of influx of infected individuals or groups and/or infective

BOX 1.
Advantages of focusing on confirmed cases of malaria

A considerable proportion of cases of fever are not due to malaria, even in high-malaria transmission settings *(6)*. In the past, however, most countries endemic for malaria based diagnosis of the disease on fever only. With increasing access to RDTs for malaria, it is now easier to quickly test patients with fever for malaria and to treat them with effective drugs if they are positive. This not only ensures accurate management of fever patients and reduces wastage of antimalarial drugs but also increases the quality of surveillance data. The graph below is a simple illustration of the relation between suspected malaria and confirmed infection.

The graph suggests that in higher transmission settings a large number of febrile patients may be suspected of having malaria, the system may not have the capacity to diagnose all of them, and, among those who are tested, only a moderate proportion may have malaria. As transmission decreases, fewer patients are suspected of having malaria, but the systems are capable of confirming all cases, and very few have malaria. When cases are detected actively, however, everyone in an area may be tested for malaria, with or without a suspicion that they are infected. In such situations, caution is required in quantifying test positivity rates for suspected cases.
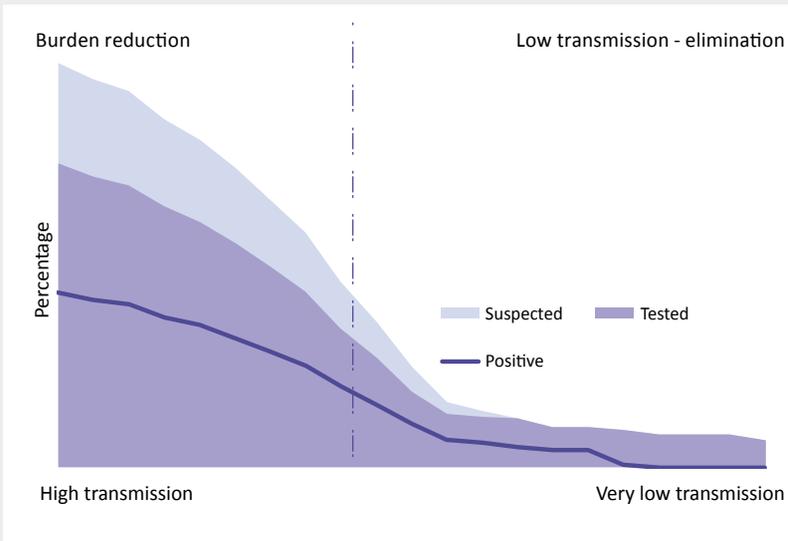
anopheline mosquitoes). Compulsory, immediate notification, diagnosis with quality-assured RDTs and microscopy must be maintained.

- Like most other health interventions, surveillance is likely to benefit from innovation and advances in technology. The choice of new technology should be based on proven additional benefits and the cost and sustainability, determined from empirical evidence by leading experts in the field, supported with the relevant WHO recommendations.

- Good understanding of the biology and behavioural ecology of vector species is essential for making programme decisions and monitoring and evaluating vector control interventions, including quality assurance. The efficacy of the antimalarial drugs used for treatment of parasite infection should also be monitored regularly. Data from entomological and drug efficacy surveillance should be interpreted in conjunction with epidemiological data as a basis for programme decisions (see **section 5**).

- Surveillance systems should be assessed routinely to ensure their accuracy, reliability, completeness, precision, timeliness and integrity. The assessment should also include the appropriateness of actions taken as a consequence of the results of surveillance.

2. Establishing malaria surveillance systems

Health information is one of the six building blocks of a health system *(7)*, and surveillance is the main component of a national HMIS. It comprises the people, procedures, tools and structures required to generate information for planning and targeting interventions and monitoring and evaluating malaria programmes.

- The people include decision-makers both inside and outside the health service who use data from surveillance systems, the health staff who gather and/or use the data and the patients and communities whose details are registered.

- The procedures include case definitions, reporting frequency, pathways of information flow, data quality checks, incentive schemes, data analysis, mechanisms for reviewing performance, methods for and frequency of disseminating results, using data for making decisions about appropriate responses, supervision and planning.

- The tools include report forms, tally sheets, registers, patient cards, dashboards, computer hardware and software, documentation and training materials.

- The structures include the ways in which staff are organized to manage, develop and use the system.

Deficiencies in any of these components may limit the capacity of a malaria control programme to undertake effective disease surveillance. Usually, a functioning, integrated, sustainable surveillance system addresses each of these areas. The information cycle shown in **Fig. 3** is relevant to all malaria transmission settings, but the frequency and intensity of activities along the cycle will increase on the pathway to elimination.

FIG. 3.

The health information cycle, centred on a competent, adequately resourced health workforce

Recording

Reporting

Analysis

Presentation

Interpretation and evaluation

Dissemination and use

People
(the patients and communities whose details are registered, the health facility staff who gather and/or use the data and decision-makers both inside and outside the health service who use the data)
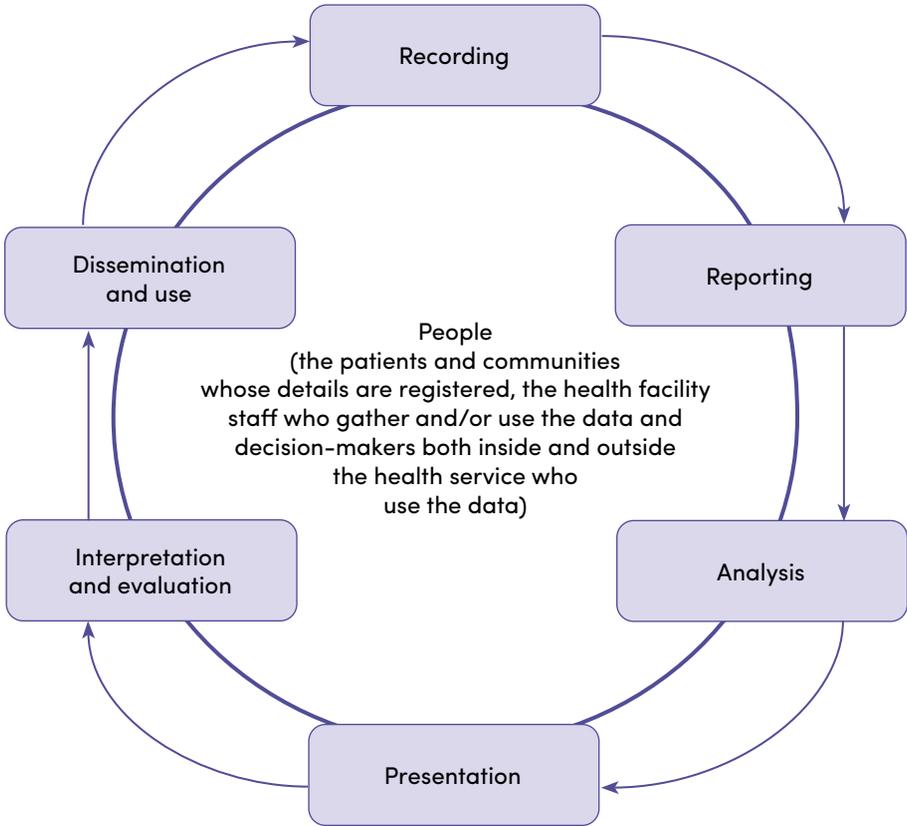
2.1 REQUIREMENTS AND PROCESSES

Progress against malaria may be more rapid in some parts of a country than in others; hence, the information (and its frequency) required to inform response and interventions will vary. In settings in which the main objective is to reduce the burden of malaria disease and deaths, the surveillance system is part of the routine HMIS. In elimination settings, a specific malaria surveillance system may be in place, although important components must be integrated into the HMIS.

Fig. 4 illustrates a broad framework for malaria surveillance in different transmission settings. It is aligned with the GTS *(2)* and the *Framework for malaria elimination (5)*.

FIG. 4.

Surveillance system processes and requirements along the continuum of malaria transmission settings

	High	Moderate	Low	Very low	Zero	Maintaining zero
	≥ 35% *Pf*PR or ~ 450 per 1000 API	10–35% *Pf*PR or 250–450 per 1000 API	1–10% *Pf*PR or 100–250 per 1000 API	> 0 but < 1% *Pf*PR or < 100 per 1000 API		No transmission

Pillar 3 of the GTS 2016–2030 Transform malaria surveillance into a core intervention						
Case detection	Passive case detection			Passive and active case detection		
Recording	Outpatient and inpatient registers			Individual patient forms		
Reporting frequency	Monthly		Weekly	Immediate case notification		
Resolution of reported data	Aggregate cases by sex and age category			Case report, age, sex, residence, travel history and case classification		
Data use: health facilities	Data analysed monthly		Weekly	Data analysed in near real time		
Data use: intermediate levels	Data analysed monthly		Weekly	Data analysed weekly		
Data use: national	Data analysed monthly or quarterly		Weekly	Data analysed weekly		
Response time	Monthly or quarterly		Weekly	Case investigation within 24–48 h, focus investigation within 1 week		
Feedback frequency to upper and lower levels	Annually or quarterly		Monthly	Every 2 weeks		
Surveillance system monitoring	Every two years		Annually	Annually or more frequently		

GTS, *Global technical strategy for malaria 2016–2030*; PR, parasite rate; API, annual parasite incidence
Active case detection includes both reactive case detection (RACD) triggered by an index case and proactive case detection (PACD) (see **section 3.2**).

In areas in which transmission remains moderate to high and the main goal of national programmes is to reduce the burden of disease, there are often so many malaria cases that each confirmed case cannot be examined individually. Instead, the analysis is based on aggregated numbers obtained from routine health information systems, and action, such as determining suitable interventions and increasing coverage, is taken at population level. The initial focus will be on ensuring good-quality data, which is based on the following.

- All people with suspected malaria are examined with a diagnostic test.

- Cases are correctly classified according to the test result and treated with nationally recommended antimalarial agents.

- The quality of both microscopy and RDTs is controlled.

- Registration and reporting from health facilities are complete and consistent.

- A system is in place for assessing the surveillance system, including auditing of data quality.

- There is a process of analysing and using the surveillance data for response and for monitoring and evaluating programmes.

These conditions must be in place before countries transition to complex elimination surveillance systems. The parasite rate and annual parasite incidence thresholds presented in the framework in **Fig. 4** should be used as broad measures of the transition of a surveillance system and are not prescriptive. The aim is to highlight the notion of a continuum of transmission within a country and the need for a surveillance system that reflects the heterogeneous epidemiology. The ability to implement surveillance depends not only on the level of transmission but also on factors such as the strength of the health system and available resources. Most countries conducting elimination activities may consider that an annual parasite incidence of 100 per 1000 population is a relatively high threshold for starting case and focus investigations and may find a lower caseload to be more practical.

As transmission is progressively reduced, it becomes increasingly possible, and necessary, to track and respond to individual cases. The thresholds of transmission are not fixed; therefore, some surveillance strategies, especially in lower-transmission settings, could be initiated earlier if the resources are available. The frequency of reporting initially increases from monthly to weekly and then to near-real time, and the resolution of data increases from aggregated cases to a line listing of patients. In elimination

settings, however, it is critical that the surveillance system allow immediate notification of individual cases, followed, where appropriate, by prompt case and focus investigation and response.

In all settings, the quality of surveillance systems must be monitored continuously by:

- maintaining an up-to-date list of operational health facilities and other notification sources;
- making sure that all core and support functions of the systems are in place;
- keeping track of which facilities have submitted the required reports and their timeliness;
- tracking proportion of cases and foci investigated where applicable;
- following up missing, incomplete and delayed reports;
- reviewing the data submitted and following up on incomplete or erroneous data;
- providing positive feedback to health facilities that submit timely, complete, accurate data; and
- ensuring a system for up-to-date training of surveillance staff.

Data from surveillance must be interpreted carefully to identify any weaknesses in systems. During analysis and interpretation of surveillance data, information from other sources, such as surveys, civil and vital registration systems and censuses, should be included, as appropriate.

2.2 PEOPLE-CENTRED SURVEILLANCE

The basis of a surveillance system is the community that is being served and the health workers who attend to their health needs. The frontline health workers and volunteers who are usually responsible for patient care and data recording and transmission must feel recognized and rewarded for their efforts through regular feedback, training and overall good staff management. At all levels of the information cycle, adequate investment must be made in infrastructure and human resource capacity to run and maintain surveillance systems and enable effective use of information for decision-making.

As countries reduce their malaria burden, the intensity, resolution and frequency of surveillance will increase. Surveillance will change from aggregated to case reporting and analysis. Case and focus investigation will require specialized field teams and greater analytical capacity.

Sufficient person-time is required at district, provincial and national levels for data acquisition from health information departments; importing, merging, cleaning and analysing data; mapping; and producing surveillance bulletins and reports. Regular feedback will be required, not only to other levels of the health sector but also to communities. Ministries of health, NMPs and partners should ensure that the necessary human capacity is in place and that national SOPs support all surveillance activities.

Disease surveillance requires epidemiological, statistical and computer skills and, at district and higher levels, experience in monitoring and evaluation. It is usually advantageous to link training in malaria surveillance with other training activities in order to save costs and to make more effective use of health workers' time. When possible, training in malaria surveillance should be given at the same time as training in HMIS or malaria case management, particularly in the use of diagnostic testing. The pre-service curricula of medical, nursing and pharmacy schools should be updated to reflect the latest requirements for disease surveillance. Countries should ensure that not only the public sector but also nongovernmental organizations and the private sector participate in surveillance systems, by reporting data, feedback and joint training.

2.3 RECORDING

The annexes to this manual provide suggested registers and forms that can be adapted for use by countries. Registers should provide space for recording essential data elements, such as test results, and no unnecessary elements, as the more data there are in registers and forms, the less likely it is that the forms will be completed accurately, if at all. When possible, forms should reflect current guidance, such as that provided in standard treatment guidelines, surveillance SOPs and monitoring and evaluation manuals, with a clear justification of how the variables collected will be used.

In countries where the burden of malaria is substantial and the caseload is such that individual case investigation may not be possible, malaria surveillance systems are often part of broader communicable disease surveillance or the health information system, which should be adapted to include the basic data elements suggested in this manual.

In low-transmission settings in which malaria is relatively rare and confined to particular locations, there may be a separate malaria reporting system, which allows timely response to individual cases and can be adapted according to the recommendations in this manual. The system should communicate as much as possible with the HMIS, and the main components should preferably remain integrated into the HMIS to ensure long-term sustainability.

It is important to involve all stakeholders in discussions about revising a system, especially those involved in data collection in health care facilities, who can provide valuable information about the constraints they face and practical suggestions for improvement. An inclusive process creates a sense of ownership and encourages the adoption and use of forms. New and revised forms should be tested on a small scale (e.g. in one administrative unit for 6 months) before they are used widely. After the final adjustments have been made, the documentation on use of the forms should be updated and data collectors trained in their use. When the new forms are supplied to health facilities, the old ones should be removed or destroyed to ensure that health workers do not use previous systems because of a disruption in the stationery supply or lack of familiarity with the new forms. A regular supply of forms should be ensured to alleviate this problem. When possible, an electronic system with the required back-up should be used to minimize the cost of data recording and improve the efficiency of the system. The data required by level of malaria transmission are listed in **Table 1**. Refer to **Fig. 4** for the transmission thresholds for the three broad classifications used here.

See **Annex 5** for focus mapping, **Annex 6** for an example of a register for health facilities, **Annex 7** for forms for recording outpatient attendance, **Annex 8** for daily and weekly records of outpatient attendance at health centres and hospitals, **Annex 9** for a discharge register for inpatient departments of health centres and hospitals, **Annex 10** for reports from health posts and community health workers (CHWs) to health facilities, **Annex 11** for reports from health facilities to district level, **Annex 12** for line lists of malaria cases and deaths among inpatients to be reported at district level in low-transmission settings, **Annex 13** for line lists of all confirmed malaria cases to be reported at district level in low-transmission settings and **Annex 14** for a supervisory checklist for countries with high or moderate transmission.

TABLE 1.
Data recorded by level of the surveillance system and aim of the programme

LEVEL	BURDEN REDUCTION (HIGH, MODERATE, LOW)	BURDEN REDUCTION (VERY LOW) AND ELIMINATION	PREVENTION OF RE-ESTABLISHMENT
Field (household and focus)	When transmission is relatively high and the goal is to reduce the burden, case and focus investigation may be applicable only rarely and among high-risk groups, such as internally displaced populations and migrants or during outbreaks. The information recorded in case and focus investigations will be similar to that in elimination settings. Additionally, threshold graphs and intermediate-level (e.g. district) situation reports and post-epidemic assessment reports are required in epidemic detection and response. Regular community household surveys are useful to track changes in parasite prevalence and intervention access and coverage.	In case investigations, the following should be recorded for the index case and other cases seen in the community during active case detection (ACD): • case and household identification number • when possible, contact information, such as a telephone number; • longitude and latitude of household; • date of testing, address, age and sex; • fever history (if used for screening), including date of onset of symptoms; • type of diagnostic (RDT or microscopy); • test results by parasite species;treatment given and follow-up;occupation; • travel history; • other potential risk factors (e.g. sleeping habits); • ownership and use of LLIN; • household receipt of IRS; • date of intervention (LLIN distribution or IRS); • and case classification (local or imported; in elimination settings, cases should be further classified into indigenous, introduced, induced, recrudescent or relapsing) In focus investigations, the following should be recorded: • focus location; • date of investigation;number of cases seen. • during ACD by case classification; • information on factors associated with transmission; • focus classification; • focus response; • and date and type of response	Same data elements as during elimination; focus investigations should be done only if the case is local (i.e. indigenous or introduced) or an imported case has been reported in a highly receptive focus (see **section 3.6**).
Health posts and community health workers	For outpatients, registers should record: • date of attendance; • patient's name, age and sex; • patient's village of residence; • whether a new attendance or a repeat visit for the same episode;	For outpatients, registers should record: • date of attendance; • patient's name, age and sex; • patient's village of residence; • when possible, contact information, such as a telephone number; • whether a new attendance or a repeat visit for the same episode;	Same data elements as during elimination.

LEVEL	BURDEN REDUCTION (HIGH, MODERATE, LOW)	BURDEN REDUCTION (VERY LOW) AND ELIMINATION	PREVENTION OF RE-ESTABLISHMENT
	• presence of malaria symptoms (e.g. fever); • type of diagnostic (RDT or microscopy); • malaria test result by parasite species; and • treatment given	• presence of malaria symptoms (e.g. fever); • type of diagnostic (RDT or microscopy) • malaria test result by parasite species; • treatment given; • travel history; • location of work; and • preliminary case classification (local or imported).	
Health centres and hospitals	For outpatients, registers should record: date of attendance; • patient's name, age and sex; • patient's village of residence; • whether a new attendance or repeat visit for the same episode; • presence of malaria symptoms (e.g. fever); • type of diagnostic (RDT or microscopy)malaria test result by parasite species; and • treatment given. • Inpatient discharge or ward registers should contain:date of admission; • patient's name, age and sex • patient's village of residence;type of diagnostic (RDT or microscopy) • malaria test result by parasite species; • treatment given; • length of stay; and • reason for leaving (discharged, referred, died, transferred or absconded).	For outpatients, registers should record: • date of attendance; • patient's name, age and sex; • patient's village of residence; • when possible, contact information, such as a telephone number • whether a new attendance or a repeat visit for the same episode; • presence of malaria symptoms (e.g. fever); • date of onset of symptoms; • type of diagnostic (RDT or microscopy) • malaria test result by parasite species; • treatment given; • travel history; • location of work; and • preliminary case classification (local or imported). Inpatient discharge or ward registers should contain: • date of admission; • patient's name, age and sex; • patient's village of residence; • type of diagnostic (RDT or microscopy) • malaria test result by parasite species; • treatment given; • length of stay; • reason for leaving (discharged, referred, died, transferred or absconded); • travel history; • location of work; and • preliminary case classification (local or imported)	Same data elements as during elimination.

LEVEL	BURDEN REDUCTION (HIGH, MODERATE, LOW)	BURDEN REDUCTION (VERY LOW) AND ELIMINATION	PREVENTION OF RE-ESTABLISHMENT
Intermediate level (e.g. district)	Monthly or weekly reports of the numbers of: • suspected malaria cases; • malaria tests performed; • confirmed cases, by species; • outpatient attendances; • inpatient discharges and deaths; • and inpatient malaria discharges and deaths, by species. Data disaggregated by health facility, subdistrict or village when possible. Annual records of: • malaria programme interventions, structures by type and staff by cadre; • maps showing the distribution of confirmed cases, inpatients and deaths by health facility catchment area, village or administrative boundary, to be updated annually; • an entomological database of *Anopheles* species; and • all reports and analyses produced by staff at intermediate level (e.g. district) during the previous 5 years and submitted to higher levels.	From all sectors (public, private and community), weekly reports of the numbers by PCD and ACD of: • suspected malaria cases, • malaria tests performed and • confirmed cases, by species and classification; • number of cases notified on time; • number of cases investigated on time; • number of foci investigated on time; and • types of response by type of focus. Data disaggregated by health facility and focus Monthly records of: • malaria programme interventions, structures by type and staff by cadre; • malaria case notifications; • malaria case investigation forms, including the results of ACD (**Annex 2**); • focus investigation forms (**Annex 3**); • a list of foci with changes in class over time • (**Annex 4**); and • an entomological surveillance database	Same data elements as during elimination.

Create a vector-control and intervention database containing information on IRS coverage, number of LLINs, ACTs, RDTs distributed, larval control (biological and chemical larviciding, environmental management activities and "behaviour change communication" activities.

File and keep all periodic and annual reports and district analyses produced by staff during the past 5 years and submitted to higher levels.

Collate feedback and other information from higher levels. The team should analyse aggregated and case-based data. Clear illustrative mapping, electronically or on paper, should be routine. Customized electronic dashboards should be the norm for display of data analysis outputs.

LEVEL	BURDEN REDUCTION (HIGH, MODERATE, LOW)	BURDEN REDUCTION (VERY LOW) AND ELIMINATION	PREVENTION OF RE-ESTABLISHMENT
National	Same as intermediate levels but recorded for all intermediate levels. National reports and data aggregation for global monitoring.	Same as intermediate levels but recorded for all intermediate levels. Data recorded will include • national malaria case register – a consolidated list of all malaria cases supported by case investigation forms; • malaria focus investigation data: all data from the malaria focus investigation form (**Annex 3**); • list of foci with changes in class (**Annex 4**) – the status (category) of each focus is re-evaluated after each new confirmed case and at least at the end of each transmission season; • NMP health structures and staffing; • national malaria laboratory quality assurance data; • reports of activities of specially assigned mobile teams; • entomological surveillance data; • vector control activities and interventions; • malaria surveillance reports and analyses sent by intermediate levels (e.g. districts); and • national annual malaria surveillance reports and analyses	Same data elements as during elimination

ACD, active case detection; ACT, artemisinin-based combination therapy; IRS, indoor residual spraying; LLIN, long-lasting insecticidal net; NMP, national malaria programme; PCD, passive case detection; RDT, rapid diagnostic test. In areas of elimination and prevention of re-establishment patients should be followed up to ensure compliance with treatment and complete cure (see **section 4**)

2.4 REPORTING

Particular attention should be paid to ensuring that all private and public health facilities and CHWs report accurately and on time. Programmes should have an up-to-date inventory of all the public and other health facilities that are expected to report and should follow up any delays. The coordinates of all health facilities should be known so that their location can be shown on a map.

Depending on the transmission context, aggregated data (from areas where the focus is on reducing the burden) or line-listings of patients (in very low transmission and elimination settings) are expected to be submitted routinely throughout the surveillance system. The case data should be supported by information on the number of health facilities and CHWs who are expected to report and the actual number who do so; this information can be written on the health facility reporting form. The data from health facilities and CHWs should be kept separate and not added to health centre attendance, to avoid affecting trends over time by fluctuations in reporting from lower-level facilities (e.g. a sudden outbreak of cases may be assumed if several late reports are received from health posts). If CHWs have been in place for a long time and the data they provide are unlikely to change trends, there is no harm in aggregating them with health facility data.

As the caseload decreases, data should be aggregated and reported weekly. Case reporting is easier when electronic data systems are used and are linked to a central database. The system can be further simplified by using electronic patient registers and a mechanism to automate data aggregation.

During elimination, cases must be notified immediately to the field team, and data may be transmitted as a patient line list almost daily. This is increasingly possible with open-source software such as the District Health Information System version 2 (DHIS2) (https://www.dhis2.org/) and increasingly cheap portable phones, tablets and computing appliances. Surveillance officers should immediately notify the district (or equivalent) team and the NMP of all confirmed cases of malaria by telephone, SMS or email. The notification should include the patient's name, village or neighbourhood and district (or equivalent) of residence, date of malaria testing, type of test and *Plasmodium* species. The NMP should immediately alert the local field investigation team, which should plan to investigate the case and, if necessary, focus. If a case was obviously imported and occurred in an area that is not receptive and where imported cases are quite common, it may be acceptable to relax further case or focus investigations.

The expected frequency of reporting and the detail of the data to be reported are shown in **Fig. 4** according to the epidemiology of the area of interest.

2.5 DATA ANALYSIS AND INTERPRETATION

Data from malaria surveillance systems are important for tracking geographical and temporal trends in disease incidence, detecting epidemics, assessing progress towards programme targets and evaluating the impact of interventions and the quality of the surveillance system. Routine use of surveillance data is expected to improve both programme decision-making and the surveillance system as gaps in data completeness and quality are identified and addressed. Most national surveillance systems now use electronic systems, and programmes should use digital dashboards for analysing key indicators and trends. Details of the analysis, interpretation and use of data on malaria outbreaks and epidemics are given in **section 6** and for programme monitoring and evaluation in **section 7.**

Two examples are provided to highlight some of the considerations to be made in analysing surveillance data. **Box 2** describes the transformation of malaria case counts to incidence.

BOX 2.
Adjusting for population size: calculating incidence rates

Absolute numbers of malaria cases, inpatients and deaths can be used to estimate trends over time and to identify places in which the problem of malaria is greatest. Absolute numbers are less useful for assessing which populations are at highest risk for acquiring malaria, because most geographical units have different population sizes. For example, it is not immediately clear whether 500 cases in a population of 17 000 represents a higher risk for malaria than 300 cases in a population of 8500. To facilitate comparison of populations, the number of cases is usually expressed for a standard population of 1000 or 10 000, by dividing the number of cases by the population size and multiplying by the standard size of population desired:

- Population A: 500 cases/17 000 population x 1000 = 29.4 cases per 1000 population

- Population B: 300 cases/8500 population x 1000 = 35.3 cases per 1000 population

Adjustment to a standard population can also take into account the growth of populations over time, which may be significant if trends in cases are examined over an extended period such as 10 years.

The denominator is generally the population at risk for malaria. This is defined as the population in areas in which there is ongoing transmission. People travelling to such areas may acquire malaria, but they are not usually included in the population at risk. For international comparisons and other situations in which information on the overall risk to populations is desired (including the risk of those not exposed to malaria), the total population of a country may be used as the denominator. If cases are broken down by age, sex or occupational group, the sizes of these groups should be used as the denominators. In elimination settings, use of the populations at risk in foci of transmission to quantify national incidence may result in incorrect classification of a country as having a high malaria incidence. In such situations, it may be better to use case counts, but care should be taken in using these data in trend analyses, as the counts may change with increasing case detection as countries undertake active surveillance.

Programme managers may be interested in knowing the size of other populations, such as those living in areas where vectors are circulating or target populations for interventions, but these figures are generally not used in calculating incidence rates.

Estimates of population size published by a relevant government department should be used; such departments include a statistical office, planning bureau or census office. The estimates are usually based on projections from censuses undertaken at intervals of about 10 years; population growth rates between censuses are used to project population sizes after the latest census. Thus, as the time of the next census approaches, the population projections may differ considerably from the actual population sizes, particularly at local level. When new census results are released, the projected populations calculated for previous years must be updated to take into account the latest – and more accurate – counts.

In the last stages of elimination, the use of the annual parasite incidence is of little value and the programme should use actual case counts.

Box 3 shows the influence of health facility attendance, diagnostic testing and reporting rates on the computation of malaria incidence rates. These issues are common, especially in areas where the goal is burden reduction, the surveillance system may not capture all malaria cases, and complete malaria confirmation with RDTs or microscopy has not yet been achieved.

BOX 3.
Influence of health facility attendance, diagnostic testing and reporting rates on reported malaria incidence rates

Crude incidence rates derived by surveillance of malaria cases take into account the size of the population but may not reflect the true incidence of malaria in a population because, as shown in the surveillance cascade:

- most reports are from the public health sector;

- the proportion of patients with suspected malaria who attend public health facilities (from which most data are derived) may differ by area and over time;

- the proportion of people attending public health facilities who have a diagnostic test may differ by area and over time; and

- health facility reporting rates may differ by area.
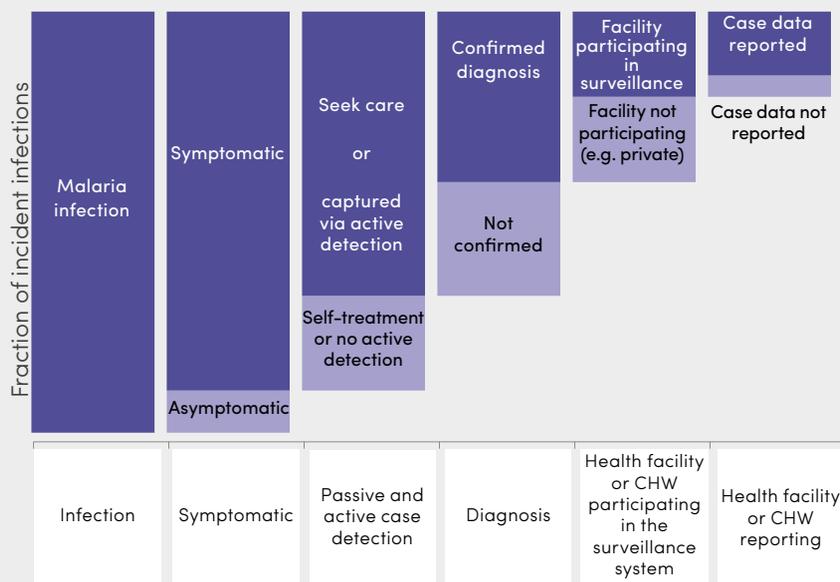
The example below shows the results for two districts, one urban and one rural, with different rates of malaria. The crude incidence rate in the urban district is half that in the rural district, but in the urban district a larger proportion of patients seek care in public health facilities, a larger proportion receive a diagnostic test, and a larger proportion of health facilities submit monthly reports. Because of these factors, the reported incidence of malaria is higher in the urban district (14 per 1000) than in the rural one (12 per 1000).

		Urban district	Rural district
A	True number of cases per 1000 population	50	100
B	Cases attending public health facilities (%)	60	40
	Cases potentially detected per 1000 (A × B)	30	40
C	Attendees receiving a diagnostic test (%)	60	50
	Cases potentially detected per 1000 (A × B × C)	18	20
D	Health facilities that report (%)	80	60
	Cases potentially detected per 1000 (A x B x C × D)	14	12
Percentage of all cases detected		29	12

Thus, when areas with better access to health facilities and better health facilities report a higher incidence of malaria than areas with limited access, it is advisable to examine other indicators (overall health facility use rate, percentage of people who receive a diagnostic test and completeness of health facility reporting) in interpreting the data. It may also be useful to examine other indicators, such as rates of diagnostic test positivity.

If the rates of facility use and reporting are known, incidence rates based on the numbers of malaria cases seen in health facilities can be adjusted for these factors to provide a more representative estimate of incidence *(8)*. When computing incidence, it is important that cases be linked to their places of origin and of diagnosis, especially when the burden is very low and many cases may come from outside the location of the nearest health facility.

2.6 USING DATA FOR MAKING DECISIONS IN MALARIA CONTROL PROGRAMMES

Decisions about programme policies, strategies, approaches, structures and priorities must be based on the best available data to ensure that maximum impact is achieved with the available resources, to improve the results that programmes can achieve and to enhance accountability. To produce data for decision-making, a NMP must constantly monitor critical components of programme performance, including process indicators (e.g. the number of commodities distributed and where), input indicators (e.g. the fraction of targeted households that received indoor residual spraying (IRS) and the number of insecticide-treated nets (ITNs) or LLINs purchased), intermediate indicators (e.g. impact of an intervention on vectors) and outcome indicators (e.g. malaria incidence). Processes should be set up for regular validation and analysis of the collected data and the programmes adjusted in response.

Data should be collected and analysed regularly at all levels of the malaria programme and used at each level to inform actions or decisions. For example, central programme managers need information on overall performance in order to track progress and report to their government and donors. They also need measures to ensure timely distribution of pharmaceutical products and avoid stock-outs. At provincial, state or district level, malaria managers require analysis of intervention coverage in order to identify gaps, adjust strategies to cover underserved areas, identify the true focus of transmission and evaluate the effectiveness of interventions. Feedback to individual health facilities should, for example, indicate their testing and reporting rates and how these rates compare with those elsewhere. Digital dashboards and regular surveillance bulletins are effective ways of monitoring these metrics. Health facilities should clearly define the extent of their catchment areas in order to link disease counts to the population accurately.

All staff should be trained in recognizing the importance of data and how they are used in decision-making. The results of analyses should be shared with those who collected the data so that they become aware of the value of the data. **Box 4** outlines approaches for disseminating and using data and information for planning. The use of data for decision-making is further discussed in **section 7.**

BOX 4.
Approaches to disseminating data

Formal meetings. If the data generated by a surveillance system are to be used to improve the operation of an NMP, managers must ensure regular opportunities for review. A schedule of meetings should be established to review malaria trends, which might include:

- community with health facility staff – monthly or quarterly;

- health facility staff with malaria control programme staff at intermediate level (e.g. district) – monthly; and

- intermediate level staff with NMP staff – quarterly performance review (meetings might have to be held less frequently or regionally in order to create opportunities for national staff to meet all intermediate staff during a year).

Supervision. Supervision by national and intermediate level is required to build an information system and to ensure the completeness of reporting, analysis and discussion of data and follow-up of recommended actions. During visits to health facilities (and CHWs) and intermediate-level team offices, supervisors should check that registers are up to date, with all fields completed, that the data on report forms correspond to the information in registers and tally sheets, that core analysis graphs and tables are up to date and that discussions are held on interpreting trends and potential action (see **Annex 14** for an example of a malaria surveillance supervisory checklist). Health facility (and CHW) staff should be encouraged to investigate all inpatient malaria cases and deaths.

Feedback. Intermediate-level managers should prepare feedback for health facilities (and CHWs) monthly or quarterly and should include private health facilities that provide data. The feedback should reflect not only the data submitted by the health facility but also comparisons with other facilities in the same administrative unit and summary statistics for the unit as a whole, including responses. A regular bulletin could be produced in a standard format for presenting district results (based on control charts) and comparisons of health facilities. Feedback can also be part of the supervision process. An example of a monthly bulletin for high- and moderate-transmission countries is shown in **Annex 15**.

A national feedback bulletin should be produced each quarter, showing indicators by relevant administrative unit (**Annex 15**). As transmission is reduced, mapping could be extended to subunits, to

present more detailed epidemiological information on remaining affected locations and population groups, and eventually to foci. The bulletin should be widely circulated, not only as feedback to health staff but also as information for the public, other government departments, institutions, implementing partners and neighbouring areas or countries. Elected leaders should also be sent the bulletin on malaria, possibly with the malaria situation shown according to political boundaries, to instil understanding and support for malaria control at the highest level.

2.7 STRUCTURE OF SURVEILLANCE SYSTEMS

2.7.1 Systems, functions and coordination

Structures for disease surveillance differ by country and by programme goals. In some countries, data functions are undertaken by an integrated HMIS unit rather than by separate programmes. This arrangement can ensure good coordination in system design and reduce duplication in requests for data. Malaria programme managers must liaise closely with health information staff to ensure prompt access to relevant data. In other countries, most data management is undertaken by programme staff. In these cases, coordination with information units is necessary to ensure use of common datasets, such as population projections, health facility lists and coding systems. Opportunities should be created for consolidating analysis of information with other programmes, so that progress in malaria control can be put into perspective.

In order to coordinate system developments across programmes, a "health information system development committee" might be established, with representatives from a variety of health programmes and senior management. The committee could ensure that the information system prepared by the ministry of health is coherent, rather than one that is incompatible, unnecessary or unsustainable. **Table 2** lists the various components of HMIS and general issues related to each component.

TABLE 2.

Components of HMIS relevant to malaria surveillance

COMPONENT	ELEMENTS	DESCRIPTION
Resources for health information systems	Legislative, regulatory and planning framework, personnel, financing, logistics, information technology and communication systems.	Resources comprise everything the system requires, from office supplies to computer systems, staff and their capacity and policies that allow the system to operate. The system of each country should be designed to make the best use of available resources and meet the country's needs.
Recording	Essential indicators, definitions and data elements, paper and/or electronic registers, data storage, data verification, training and mentoring.	See **section 7** and annexes for indicators to be monitored and evaluated. Some of the indicators are derived from population surveys and censuses and can be used in identifying country indicators.
Data reporting	Data storage repositories, transmission and completeness, quality of data verification and adjustment, data verification.	In settings where the goal is burden reduction, aggregated monthly or weekly data should be sufficient to estimate trends and make relevant decisions. The frequency of data reporting is determined by the programme objectives and resources (see **Fig. 4**). In elimination settings, immediate reporting of individual cases is required.
Data analysis and presentation	The transformation of data into information requires capacity for basic statistical analysis, preparation of analytical and standard graphs and of surveillance bulletins, including stratification, and of reports and presentations.	User dashboards, reports, queries and alerts give access to the information resulting from data analysis.
Interpretation and evaluation	Data may be used to assess disease trends, detect epidemics and determine the response, quantify and forecast resource requirements, assess programme performance and adjust interventions.	National information can be used in day-to-day management of a malaria control programme. Greater value should be placed on information collection, management, feedback and use (see **section 7**).

Adapted from reference *9*
HMIS, health management information system

Fig. 5 illustrates the typical data and information flow in an HMIS and linkages with national programme databases used for decision-making.

The steps in strengthening HMIS, in most situations building on existing systems *(10)*, are as follows.

- Review the existing system.
- Define the data needs of relevant units in the health system, such as the community, health system, intermediate and central levels.
- Determine the most appropriate, effective data flow.
- Design the data collection and reporting tools.
- Develop the procedures and mechanisms for data processing.
- Develop and implement a training programme for data providers and data users.
- Pilot test and, if necessary, redesign the system for optimal data collection, data flow, data processing and data use.
- Monitor and evaluate the system.
- Prepare effective data dissemination and feedback mechanisms.
- Continuously strengthen the HMIS.

FIG. 5.
Data flow and analysis, from national HMIS to NMP decision-making
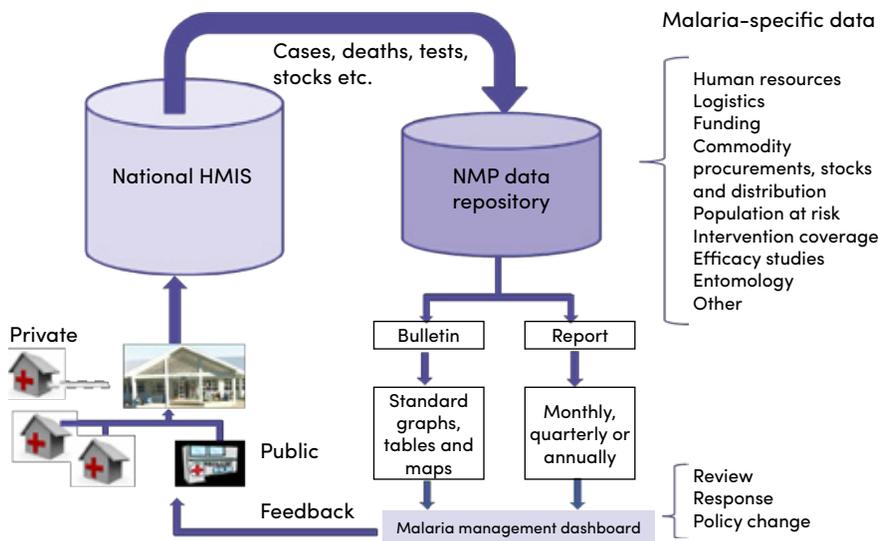
HMIS, health management information systems; NMP, national malaria programme

Establishing a surveillance system for elimination takes more time, as it often requires updating legislation and policies, establishing new system components (for case and focus investigations, active case detection (ACD) and laboratory quality control), training and recruiting staff and educating the public. Lessons learnt from the establishment of surveillance systems in various epidemiological settings should be used to prepare gradually for active elimination nationwide. The preparatory activities should be supported by changes to legislation to ensure that malaria is a mandatory notifiable disease and all health sectors, including the private sector, are required to use similar case definitions and participate in all aspects of surveillance.

Because of more intense activities, surveillance systems for elimination require additional staffing, sometimes with new or revised responsibilities.

- Staff at national level are responsible for policy-making and decision-making, coordination, supervision, monitoring and evaluation of programme management and progress. The staff should preferably include clinicians, epidemiologists, parasitologists, entomologists, laboratory experts, communication experts and information technology specialists (including data managers and geographic information systems technicians). The national reference laboratory will provide support to the ministry of health in establishing quality assurance systems for diagnostic testing.

- At intermediate levels (provinces, regions and districts), depending on the public health structure and the size of the country, epidemiologists, parasitologists, entomologists and data managers may be required, particularly in areas with active foci and repeated imported cases. These staff members are responsible for all aspects of malaria surveillance, including data collection and analysis, monitoring and early recognition of outbreaks or changes in disease trends. They may also lead a well-trained case and focus investigation team.

- At health facilities, case investigations may require trained staff who can rapidly and effectively investigate new cases of malaria to classify them appropriately. Transport and stocks of vector control commodities must be available.

- National programme should try to provide all laboratory diagnostic services free of charge to patients at public facilities and, if possible, at private facilities. All laboratories that conduct testing for malaria should be part of a quality management network, and data should be reported to the national surveillance system.

Surveillance should include the private sector, CHWs and mobile and migrant populations. **Fig. 6** illustrates the process of surveillance for malaria elimination and the activities at each stage.

FIG. 6.
Processes and activities for establishing malaria surveillance for elimination

Develop strategy, guidance and capacity	Surveillance system ready for elimination	Passive case detection, investigation, classification and notification	Further case investigation, detection and classification	Entomological and environmental investigations	Focus response	Focus classification
Develop surveillance SOP		Notify within 24 h	Start when caseload is very low (e.g. ≤3 cases/week/investigation team)	If sentinel site data not available and depending on the class of the case and focus, trigger entomological and/or environmental investigation in the focus.	Decide on response based on case and focus investigations of factors contributing to transmission and information on recent interventions in focus register.	Update focus classification in the focus register at the end of a calendar year, if necessary.
Reach consensus on data elements and indicators		Report line list of cases. Case investigation form completed for each patient	Decide on investigation schedule and size of detection radius.	Decide on timing and intensity of investigations according to case and focus classification and availability of recent data from focus or sentinel sites.	Record response activities for case and focus.	
Establish case-based reporting system		Define location of focus initially from routine case data. Maintain a focus register.	Decide on ACD (RACD, PACD or both)			
Establish case and focus investigation system			Investigate and classify cases.			
Train health staff in SOP and system use						
Establish infrastructure (tablets, PCs, transport etc.)						
Establish response and monitoring & evaluation systems						

Activities in the focus

Surveillance systems must be prepared for case investigation, ACD and focus investigation before such activities begin.

ACD, active case detection; M&E, monitoring and evaluation; PACD, proactive case detection; PC, personal computer; SOP, standard operating procedure

2.7.2 Surveillance in the private sector

Health services in the private sector may be delivered for profit or not for profit. The not-for-profit sector is often run by faith-based or public–private initiatives, which in many countries may also be registered as public health facilities. Surveillance for malaria by the private sector should, in principle, be identical to that in the public sector, with similar forms and reporting of the same core data elements at the same frequency (**Table 1**). In many malaria-endemic countries, however, the private sector is less well regulated than the public sector and has limited capacity for accurate diagnosis and reporting; some may not recognize the value of reporting data *(11)*. Thus, surveillance in the private sector is often inconsistent, with limited reporting to the national health information system. Nevertheless, in sub-Saharan African countries, nearly 40% of patients seek treatment in the private sector, and in some countries outside Africa this figure is over 50% *(12)*; the proportion is often higher in urban areas, and remote rural areas are often served by an informal private sector.

National dialogue, coordination, incentives, regulation and accreditation should be used to encourage the private sector to report to the surveillance system. Improved public health sector service delivery and better access are also likely to reduce reliance on the private sector, thereby increasing the proportion of cases identified in the public sector.

In settings in which the goal is to reduce the burden of malaria, data from passive case detection (PCD) in the private sector may be aggregated, whereas in elimination settings they should be case-based. Nevertheless, case-based reporting should be encouraged in areas for burden reduction if the electronic system is advanced enough to include case details without adding to the health worker workload.

The private sector has no mandate for case investigation but should be required by law not only to treat patients according to national guidelines and notify each case but also to refer all cases (before or after treatment) to the public sector for further investigation and classification. The increasing availability and flexibility of mobile and Internet technology will improve surveillance in the private sector *(13)*.

The following general guidelines should help countries to improve malaria surveillance in the private sector.

- Map private health sector providers by type (formal or informal), location (urban or rural), regulation (registered or unregistered), level

of reporting and connectivity to a mobile and/or Internet network and other relevant characteristics.

- Set up a database (preferably geocoded) of private health care providers who manage malaria cases.

- Explore approaches to strengthening regulation. In high-burden settings, legal provisions should require that entities involved in malaria diagnosis and treatment are registered with the relevant authorities and that their licences are renewed regularly. In eliminations settings, health legislation should ensure that all health care providers report confirmed mal aria cases as part of notifiable disease surveillance.

- Conduct studies to determine the appropriate approaches and incentives to improving malaria case management and surveillance in the private sector in the national context.

- Foster close, routine interaction among the ministry of health, NMPs and the private health sector by disseminating information, regular visits, supportive supervision and training.

- Provide the private sector with simple, inexpensive reporting materials and systems, including mobile and Internet applications. In some contexts, minimal financial incentives or free/subsidized antimalarials and diagnostics may help with improved private sector surveillance.

- Ensure consistent feedback to facilities in the private sector that report data to the national system.

- Help the private sector to obtain subsidized or free diagnostics and case management commodities.

2.7.3 Surveillance by community health workers

CHWs extend public health services to hard-to-reach areas or underserved populations to expand diagnosis and treatment. Often, these workers are designated to a health facility, the staff of which oversee their activities and provide health commodities and to which the CHWs report cases and use of commodities. In areas with relatively high caseloads, CHWs may report aggregated data monthly. In elimination settings, they should be capable of immediate diagnosis, treatment and case notification and, when possible, participate in ACD, case and focus investigations.

The minimum data collected during community surveillance are the same as those collected at health posts (**Annex 6**). The records of such services should be reported and analysed separately from national data; otherwise, national trends will be skewed by additional cases detected by CHWs. Cases detected passively through the routine system should be reported

separately from those detected actively in the community (see **section 3.2**). In settings in which CHWs are well established and the data they report are unlikely to change trends, there is no harm in aggregating the data into health facility reports. Mobile health applications have made it possible to establish efficient surveillance systems involving CHWs and volunteers (*14*).

2.7.4 Surveillance of high-risk groups, including migrant and mobile populations

Populations who are at higher risk for malaria than the general population may be present in all settings. Migrant and mobile populations, including those in specific occupations (e.g. forest workers, road constructors), livelihoods (e.g. nomadic pastoralists), illegal and/or undocumented immigrants, refugees and internally displaced persons and tourists *(15)*, may be at higher risk for malaria infection and disease *(16)* and may serve as residual reservoirs of infection, contributing to sustaining or the re-emergence of transmission. The characteristics of these populations that expose them to higher risks include their mobility, occupations that result in frequent contact with the vector, poor access to health prevention and treatment, poverty, displacement and cultural factors that result in marginalization. Mobile populations near international borders could import malaria infection from endemic to non-endemic but receptive areas. Conversely, populations moving or migrating from malaria-free areas to endemic areas could be at high risk of disease because of lack of immunity.

These high-risk populations tend to organize themselves, and identification of such organizing systems will indicate the best way to improve access and surveillance. As some migrant and mobile populations may wish to remain undetected for legal reasons, a trustworthy, safe environment should be created to ensure access to interventions and surveillance.

The surveillance strategies used in such situations should maximize case detection and response, and the main goal should be improved access to health services. **Fig. 7** illustrates a stepwise approach to documenting high-risk populations, conducting surveillance and responding. Mapping of migration routes is important for designing appropriate surveillance of mobile populations and updating information on those at highest risk, as the risk factors and populations may change over time.

FIG. 7.

An approach to surveillance and response for high-risk populations

Identify and/or classify high-risk groups and risk factors.	Assess malaria burden and access to health care	Establish systems for surveillance, monitoring and evaluation.	Respond with suitable interventions.
• Assemble information on the size, type and location of high-risk groups. • Assemble information on organizations working with these groups. • Assess the type and degree of mobility and the system of any social organization. • Assess security, connectivity and other operational factors. • Assess any risks for malaria to which they may be exposed, e.g. area of known high risk, non-immune populations.	• Conduct a formal assessment in a rapid survey of the size of the population at risk, the extent of malaria infection, the type of parasite species, the potential vector, access to health care and coverage of interventions. • Map the location of the populations. • Document occupational, social and environmental risk factors. • Prepare an immediate response and a plan for routine access to care and surveillance.	• Establish appropriate surveillance systems (PCD and/or ACD). • Establish efficient recording and reporting systems. • Conduct surveys at appropriate intervals to collect additional data. • Regularly assess disease trends, risk factors and intervention coverage. • Determine the extent of importation of malaria attributable to particular population groups and the risk they pose to elimination.	• Revise the response strategy on the basis of new data. • Design approaches within and between countries to mitigate the risk of importation to elimination. • Ensure extensive coverage of the population with appropriate interventions. • Prepare effective social and behavioural change communication strategies to ensure that high-risk groups use the recommended approaches to prevention and treatment.

2.8 SURVEILLANCE DURING PREVENTION OF RE-ESTABLISHMENT

Countries and subnational areas that have eliminated malaria must prevent re-establishment of transmission and must therefore maintain a surveillance system in order to rapidly identify all cases of malaria that might indicate the emergence of transmission, although some activities may be scaled down. Surveillance systems may at this stage be integrated with broader disease surveillance systems. Nationwide early detection and prompt treatment of imported malaria cases that could result in re-establishment of transmission and monitoring of changes in receptivity and vulnerability should be a priority. The probability that malaria will become re-established differs by area, as follows.

• When the receptivity or vulnerability of an area is 0, there is no risk for re-establishment of transmission.

- In areas with low receptivity and vulnerability, early case detection by a vigilant general health service, complemented by epidemiological investigation of every suspected local case and focus of origin and rapid, appropriate curative and preventive measures, may be sufficient to prevent re-establishment of transmission. Within and between country cross-border surveillance becomes important to reduce risks of importation.

- In areas with higher receptivity and vulnerability, it may be necessary to supplement these activities with ACD, which could be combined with other regular activities involving house visits.

- In localities that are highly receptive and highly vulnerable, it may be necessary to reduce receptivity during the transmission season by using timely, targeted vector control measures, including IRS and, where applicable, larviciding. These should be implemented on the basis of continually updated information on the local situation. In the longer term, it is preferable to use interventions that durably reduce the risk for transmission in these areas, without repeated application of chemicals.

2.9 CERTIFICATION OF ELIMINATION

Countries in which there has been no indigenous malaria case for at least the past 3 consecutive years and that have the surveillance systems necessary to prove that this is the case and the capacity to prevent re-establishment of transmission can apply to WHO for certification of malaria elimination. Gaining such certification involves a review of national documentation and field visits to recent transmission foci to verify that there have been no indigenous malaria cases. A field evaluation is mandatory, in order to confirm that the national surveillance system could detect local transmission should it occur and that a funded programme for prevention of re-establishment is in place. The complete list of documents required is available in the WHO manual *Framework for malaria elimination (5)*. The documents related to surveillance are:

- complete information on cases and active malaria foci in the 5 years before the last identified indigenous case (by species), with supporting maps;

- the national malaria case register with case investigation forms for all cases for at least the previous 5 years;

- annual malaria surveillance reports for the past 10 years;

- reports of quality assurance of diagnostic methods; and

- detailed reports on entomological and vector control activities.

Subnational verification of malaria elimination is an option for large countries that have achieved interruption of local transmission in certain parts of their territory, such as major cities or geographically isolated territories (e.g. islands). Subnational verification enables large countries to "shrink the map" of malaria endemicity by epidemiological stratum. The documentation required for subnational verification is similar to that for national certification and will thus form part of the evidence for elimination certification. Although subnational verification means that parts of a country can be declared malaria-free by the government, certification applies only nationally. WHO does not certify subnational elimination.

Once a country has been certified by the WHO as malaria-free, information on malaria cases detected, by species, classification and origin, and brief histories of all reported introduced and indigenous cases, if any, should be submitted to WHO annually to prove that transmission has not been re-established.

3. Concepts and practice of malaria surveillance

This section provides information on malaria case definitions and classifications; the different approaches to case detection and their appropriateness on the pathway to elimination; and case and focus investigation, classification and response.

3.1 CASE DEFINITIONS

A suspected case of malaria is one in which an individual has an illness suspected by a health worker of being due to malaria, generally on the basis of the presence of fever with or without other symptoms. This suspicion triggers the process of parasitological confirmation by microscopy or RDT and a subsequent decision about whether to treat the individual for malaria. *All suspected malaria cases should be confirmed parasitologically (5)*. When malaria diagnosis is not available and confirmation is not possible but a case of malaria is suspected and is treated as such, the case should be reported as a *presumed* malaria case. Criteria must be established in national treatment guidelines for defining which patients who attend health facilities (public or private) or CHWs should be given a parasitological test. *All suspected, presumed, tested and positive cases must be reported through the surveillance system.*

Common criteria for suspecting malaria include:

• for residents of endemic areas (high to low transmission) and active foci in elimination areas: patients with fever or a recent history of fever; and,

• for residents of non-endemic areas with very low transmission or maintaining 0 transmission: patients with unexplained fever and a history of travel to an area at risk of malaria, either within the country or abroad.

More specific categories in areas of active elimination are:

- all febrile patients in an active foci, especially during the transmission season;

- people with a history of malaria in the past 3 years and fever or recent history of fever;

- people who had fever within 1 year of visiting a malaria-endemic area (domestic or foreign), sometimes extended to 3 years for areas of risk for *P. vivax*;

- patients with fever, malaise and chills;

- people with anaemia of unknown cause;

- patients with fever of unknown etiology;

- patients with hepatomegaly or splenomegaly (or both); and

- recipients of blood donations who have fever during the 3 months after transfusion.

The established criteria should be disseminated to all health providers and the public, and the programme should provide periodic reminders.

A case of uncomplicated malaria is that in a patient with symptomatic malaria parasitaemia without signs of severity or evidence of vital organ dysfunction *(17)*.

- In areas where the main aim is to reduce the burden of disease and deaths, a malaria case is often considered to be that in a person with malaria infection, confirmed by microscopy or RDT, accompanied by clinical symptoms such as fever.

- Febrile illness may be due to other causes. The majority of fevers are not due to malaria in populations that have acquired immunity to malaria but also in areas where there is little transmission. A case of fever and parasitological confirmation by microscopy or RDT should, however, still be classified as malaria. If a concurrent disease is suspected, it should be further investigated and treated.

- Data on confirmed cases recorded in outpatient registers are used as a proxy for uncomplicated malaria for surveillance purposes. In addition, in elimination settings, individuals with malaria infection detected during ACD but who not have severe symptoms are considered to have uncomplicated malaria.

- In areas of elimination, all malaria infections are important because they may lead to onward transmission. Therefore, all patients with parasitaemia are considered "malaria cases", regardless of whether clinical symptoms are present.

- Some patients who test negative by microscopy or RDT may have very low levels of parasitaemia that are detectable only by more sensitive techniques, such as polymerase chain reaction (PCR), a highly sensitive test for detecting very small amounts of genetic material from parasites. Such levels of parasitaemia are generally considered not to be clinically significant in most settings; however, their contribution to sustaining transmission remains inconclusive, and diagnostic testing with microscopy or a standard RDT should allow adequate tracking of malaria trends. Tests might have to be repeated if no other cause of fever is identified and the symptoms continue.

A case of severe malaria is that in a person with the clinical and laboratory features listed in section 7 of the WHO *Guidelines for the treatment of malaria (17)*.

- For surveillance purposes, inpatient malaria cases are considered a proxy for severe malaria *(17)*. (Some countries with low transmission and in the elimination phase might, however, admit uncomplicated malaria cases to hospital to ensure full adherence to treatment or radical cure.)

- A death of which the primary cause is complications of severe malaria is considered a death due to malaria.

- The numbers of inpatient malaria cases and deaths should be taken from the register of discharges in which malaria is the confirmed primary diagnosis or from ward books if discharge registers are not available.

- In settings in which the aim is to reduce the burden, some malaria cases and deaths may be missed if overall use of the health sector is low. In such cases, the numbers of inpatients and deaths at all hospitals and health centres should be reported.

- In all transmission settings, malaria deaths should be notified to higher levels of the health system for investigation and response. In areas of elimination, all cases and deaths must be notified and investigated immediately.

Appropriate quality-assured diagnostic and laboratory support must be available for accurate management and classification of malaria. Further details are provided in the WHO *Parasitological confirmation of malaria diagnosis (18) Malaria microscopy quality assurance manual (19)* and the *Methods manual for product testing of malaria rapid diagnostic tests (20)*.

3.2 CASE DETECTION

Cases can be detected across the transmission continuum by PCD, when patients seek care for their illness from health workers, and/or by ACD, which includes testing for malaria or screening for symptoms followed by testing in high-risk groups or locations in the community. On the basis of the criteria listed in **section 3.1**, all suspected malaria cases should be confirmed with a high-quality diagnostic test, recorded and reported following confirmation with microscopy or RDT.

Passive case detection (PCD) is detection of malaria cases among people who go to a health facility or a CHW on their own initiative to get treatment, usually for fever.

Active case detection (ACD) is detection by health workers of malaria cases in the community and in households, sometimes among population groups who are considered to be at high risk. ACD can be conducted as fever screening followed by parasitological examination of all febrile patients or as direct parasitological examination of the target population.

3.2.1 Passive case detection

If the population has good access to health services (public, private, nongovernmental organization or community services), the majority of cases will be identified early by PCD and treated to reduce the risks of severe disease and death and may also contribute to reducing transmission. In elimination settings, PCD should cover the whole population, including those living or working in remote areas or who are hard to reach, to ensure coverage with rapid testing, treatment and reporting.

High-quality coverage with PCD is therefore a critical prerequisite for reducing the burden of and eliminating malaria. Programmes should map or otherwise determine whether there are communities located in receptive areas (i.e. with competent vectors, a suitable climate and a susceptible population) that are far from public health facilities and add additional health posts, CHWs or volunteers to those locations, to extend the reach of the PCD network. Optimizing PCD should be a priority of national programmes in terms of access to care and surveillance.

3.2.2 Active case detection

ACD is important in elimination programmes for detecting symptomatic cases that are not detected by PCD and asymptomatic cases in the community. ACD surveillance systems, with case detection, notification and investigation, should be established in all elimination areas when the caseload is very low but should not be considered a substitute for optimizing PCD. As in PCD, all cases identified by ACD should undergo full quality-assured testing and treatment, be followed up to confirm clearance of the infection if part of the RACD process and be reported to the health information system.

ACD is conducted intermittently outside health facilities (including village health posts) by health workers who visit patients at their houses, workplaces, schools or other locations, such as markets. Thus, periodic (e.g. monthly) visits to mining camps by a health team would be considered ACD, as there is no fixed facility and no regular service between health worker visits. Cases detected by CHWs are considered to be detected passively if the patients visit a CHW's home for consultation but detected actively if they are identified by a CHW at regular visits to patients' houses. ACD may also involve parasitological examination of everyone in a targeted population (mass testing), whereas in PCD only symptomatic cases are usually tested. In some countries, pregnant women may be routinely tested for malaria at antenatal care clinics, even when they have no obvious symptoms; any case identified should therefore be considered as passively detected.

ACD is further classified into proactive case detection (PACD) and reactive case detection (RACD). PACD is undertaken in populations that have limited access to facilities or inadequate health-seeking behaviour and in high-risk groups (e.g. remote and/or migrant populations, refugees, armed forces, forest workers, long-distance drivers). PACD is not prompted by an index case and is performed regularly at specific times (mainly during the transmission season) to confirm active local transmission in target populations and to detect cases early. RACD may be undertaken in response to an index case, the epidemiological characteristics of which trigger additional ACD, in which a household or a population potentially linked to the case is tested or screened for symptoms and tested before treatment. Index cases are usually seen at a health facility. ACD for *P. vivax* and *P. ovale* malaria may still miss a substantial proportion of cases because hypnozoites cannot be detected with current testing methods. As the majority of relapses occur within the first 3 months of infection with *P. vivax* or *P. ovale*, it is advisable to combine RACD with PACD conducted at appropriate intervals, especially during peak transmission seasons.

Typically during both PACD and RACD, all members of the households within a circumscribed area (around the index case in the case of RACD) would receive a parasitological test with or without screening on the basis of a history of fever, other malaria-related symptoms and travel history. If the index case is imported, RACD should also be done among fellow travellers. **Box 5** gives guidance on conducting malaria ACD during house-to-house visits in transmission foci.

BOX 5.
Organizing ACD by house-to-house visits

- In RACD, a visit is triggered by the report of a single or a cluster of index cases in a focus. For PACD, visits are made intermittently to determine the presence and extent of transmission among identified high-risk groups in areas with ongoing transmission or populations living in highly receptive foci where transmission has recently been interrupted. PACD may also be used as a complement to RACD in areas where *P. vivax* is the dominant parasite or in rare cases where you have *P. ovale*, to ensure that as many as possible of relapsing cases are identified in good time.

- RACD is done when there are few cases (e.g. no more than three cases per week per investigation team) and few remaining foci of transmission.

- Local health care providers or mobile teams list the targeted population by household (and map them with a GPS when possible), with the assistance of local authorities. The target population should be completely covered. People working in organizations associated with the target population should be included in the lists, such as transport workers, development project workers and the military. People living in outlying hamlets, who may not be recorded on household lists, should also be covered. All efforts should be made to include people living clandestinely in the target area, such as illegal immigrants. For RACD, the target population may be determined as that within a radius around the index case.

- A plan of visits is prepared, and the targeted population is informed of the dates and times they will be visited. It is important to obtain community participation and support for this activity through visits, contact with local leaders and the mass media. PACD may be done once a month during the high-transmission season and may or may not be complemented by RACD, depending on the caseload. ACD should be done only when there are very few cases and foci of transmission.

- ACD is conducted when family members are most likely to be at home (i.e. before or after work, in the early evening) or at school. Markets, religious places and other community structures might be used in order to cover the whole targeted population.

- ACD is usually conducted by mass testing of household members. When this is not operationally feasible (e.g. when diagnostic and human resources or drugs are limited), or needed (as in near-elimination settings when the vast majority of cases are symptomatic), household members may be asked about recent fever, and those with a history of fever or who are febrile on the day of the visit are tested. There is no fixed rule for the recall period; 14 days (currently used in standardized surveys for malaria control) is probably suitable in most settings. Body temperature can be recorded, but this is not essential.

- Testing is done with an RDT or microscopy. Blood slides should be examined on the same or the following day at a local laboratory, if possible (otherwise, the slide should be sent to the nearest laboratory). If the interval between blood sampling and examination is more than 1 day, care must be taken to avoid fixation of erythrocytes in the thick films (as may occur in hot weather); for example, slides should be haemolysed as soon as the film is completely dry, or dried slides should be stored in a cool box. Thick blood films must be protected from flies.

- Any person in a clinically severe state should be assisted in obtaining medical care, whether or not he or she has malaria.

- People found to have malaria are treated immediately, and cases and foci are investigated epidemiologically. Treated cases are followed up to ensure complete cure.

- A register of all people whose blood was taken during ACD is completed. The register includes the identification number of the household and, for the head of the household, address, name, age and information on risk factors (e.g. occupation, ownership and use of an ITN and IRS in the past year), date blood taken, type of testing and results (species, and where possible stage, density and presence of gametocytes).

3.3 CASE CLASSIFICATION

Case classification becomes important during the last stages of elimination and is a primary reason for case investigations. Once a case has been investigated (see **section 3.6.1**), it is classified into one of the categories shown in **Fig. 8**, described in the *Framework for malaria elimination (5)* and the *WHO malaria terminology handbook (21)*, as locally acquired, imported or induced. **Box 6** provides further information for classsification.

FIG. 8.
Classification of malaria cases
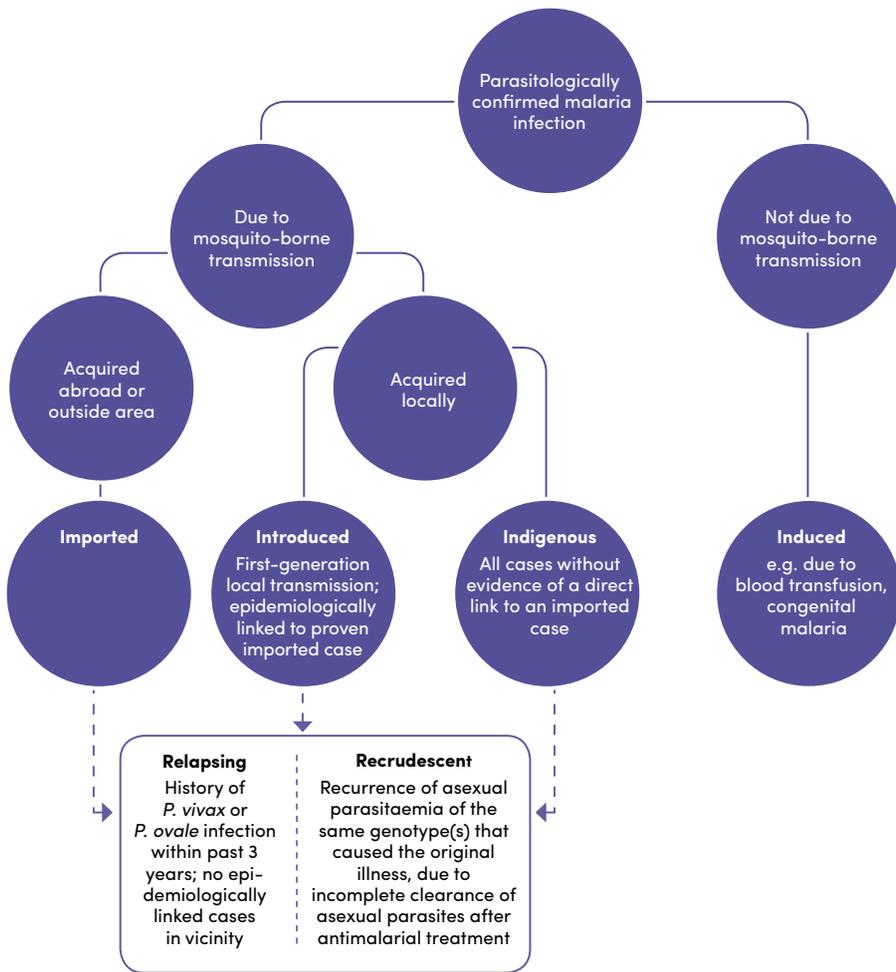
From reference *5*

3.3.1 Locally acquired cases

A locally acquired case is one that is due to mosquito-borne transmission and is acquired within the area of investigation (e.g. country, district or focus). Such cases are also known as "autochthonous". The two types of locally acquired malaria cases are:

- indigenous: any case contracted locally, with no strong evidence of a direct link to an imported case; and

- introduced: any case contracted locally, with strong epidemiological evidence linking it directly to a known imported case (first generation from an imported case; i.e. the mosquito was infected by a patient classified as an imported case). There is limited practical value in classifying cases as introduced in areas of known transmission.

It is difficult to differentiate between introduced and indigenous cases. Both indicate local transmission, showing that malaria control was not strong enough to interrupt transmission. Indigenous transmission is more serious, because it indicates that neither prevention nor treatment contained the spread of malaria beyond the first-generation (introduced) case. Prompt treatment may not prevent first-generation transmission in all circumstances but should prevent second-generation transmission by destroying gametocytes.

The following criteria are used to classify a case as "introduced".

- The case can be linked to a single imported case. Generally, the imported case will have been identified during PCD or case investigations in the focus.

- Possible transmission pathways and incubation period for all confirmed cases by type of parasite is determined by investigators during case investigations.

- If the patient is considered to have a recent infection but has no travel history that suggests importation and resides in the same household as an imported case or within a 1-km radius (or equivalent anopheline mosquito flight range) of an imported case, the case can be classified as introduced.

- If in doubt, cases should be classified as "indigenous". In active foci with a relatively large number of cases, there is limited value in determining whether a case is introduced, and all cases should be considered indigenous.

Some locally acquired cases may be recrudescent or relapsing and thus not indicate ongoing local transmission. Some countries may not be able to genotype the parasites in all infected individuals in order to define recrudescence. For operational purposes, it may be sufficient to consider a case as recrudescent if the episode of malaria is due to the same species as the first episode and occurred within 30 days (for *P. falciparum*) or 60 days (for *P. vivax*) of documented noncompliance with treatment with the first-line medicine.

3.3.2 Imported cases

An imported case is one that is due to mosquito-borne transmission and is acquired outside the area in which it was detected, in a known malarious area to or from which the patient has travelled outside the elimination area. In areas with ongoing local transmission, elimination programmes should reserve the category "imported" for "exotic" parasite species and recent arrivals from endemic countries. For all other cases occurring during the transmission season, it is prudent to assume a local origin of the infection, unless there is strong evidence to suggest otherwise.

Uncertainty may arise in classifying cases as "imported" rather than "introduced" or "indigenous" when the patient has a dubious travel history or suffers a relapse of a *P. vivax* or *P. ovale* infection that was acquired earlier and was not radically cured. If the evidence is unclear, the classification that reflects more local transmission should be assigned; for example, cases should be classified as "introduced" or "indigenous" rather than "imported". This conservative classification ensures that malaria elimination programmes are more responsive to possible renewed transmission on their national territory. Often, the investigative skills of the lead epidemiologist are put to the test in determining where and when in the country an infection was acquired. Guidance provided in **Box 6** may help the investigation team in case classification. In this scheme, "imported" includes locally imported cases, that is, cases in which infection occurred in areas outside the focus but in the same country. For global reporting, such as to WHO, cases should be classified as imported only if the infection was acquired in another country.

A common mistake is to assume that a case is imported because the patient visited a country or area known to be endemic for the parasite species in question. Most malaria-endemic countries, however, contain large areas in which there is no risk of transmission and seasons during which no transmission takes place. It is essential to determine exactly where the patient stayed and when before concluding whether he or she could have been exposed to malaria abroad. If such detailed information on the country visited is not in the public domain (e.g. in the country list at http://www.who.int/ith), the NMP can request the assistance of WHO in

obtaining the information or can contact the equivalent organization in the country in question directly.

BOX 6.
Operational aspects of classification of cases

Correct epidemiological classification of malaria cases is crucial in malaria elimination when there are very few cases, because it is the basis for classifying foci and for selecting surveillance and other control measures.

Distinguishing between "imported" and local cases

The probability that a case was imported is associated with several factors, which should be weighed in making the final assessment, as outlined below.

- The timing of travel to and from endemic areas to determine how long they stayed:

    o The usual delay between an infectious mosquito bite and a primary clinical attack is 7–30 days. The minimal incubation period (i.e. from inoculation to onset of symptoms) of malaria in humans is about 7 days for *P. falciparum* and 10 days for *P. vivax* infection. Thus, detection of malaria parasites within 0–7 days for *P. falciparum* or 0–10 days for *P. vivax* of arrival in country would indicate that the person was infected before arriving.

    o People who have lived in malaria-free areas for 2 or more years and have low immunity to malaria are highly likely to have clinical symptoms shortly after the usual incubation period.

    o When the time between returning from travel to an endemic area and detection of malaria infection increases beyond 6 months, the probability that the case is truly due to an imported infection starts to decrease and the probability that the case is due to local transmission increases.

- The parasite species:

    o *P. falciparum* infections can last for 18–24 months, but several febrile episodes would be expected during that period, because parasite density increases intermittently

to cause fever or symptomatic illness. Predominantly asymptomatic long-term infections are unlikely to occur in people with low antimalarial immunity, but they are possible.

o   *P. vivax* infections due to activation of hypnozoites can cause infection up to 5 years after the previous infection or clinical episode but are most likely within 3 years. Experience in many countries shows that nearly 50% of imported cases occur within 1 month of arrival back in the country of residence and up to 75% by 3 months *(22).*

- The probability of local transmission in the areas of residence and occupation of the patient:

o   If a person lives and works in a place in which there has been no local malaria transmission for many years, with adequate surveillance, and the person travelled to an area of known transmission within 6 months of documented infection, classification of the case as "imported" is straightforward.

o   If the area has had no malaria for more than 3 years and has reasonable surveillance or has no known appropriate vectors, local transmission is unlikely.

o   If the malaria patient lived in a focus with recent local transmission (classified as "residual non-active" focus), the probability that the case is truly "imported" is lower.

o   Cases in areas with local transmission (classified as "active" foci) should rarely (or never) be classified as "imported". In cross-border areas with frequent population movement, especially for routine treatment-seeking, it may be programmatically useful to ensure careful classification of importation, even in active foci, so as to alert authorities across the border.

- The extent of surveillance in the area in which the case was detected and the extent and quality of the field investigation around the home and work area of the case:

o   Consistently negative test results from strong previous surveillance and extensive blood sampling during the field investigation decrease the probability of local transmission.

3.3.3 Induced cases

An induced case is one that is not due to mosquito-borne transmission but to a blood transfusion or other form of parenteral inoculation of the parasite. Such cases are easy to classify if the person lives and works in an area in which there has been no known transmission for many years and has a history of blood transfusion or other exposure to blood that could have transmitted malaria. The incubation period (i.e. the delay before onset of clinical symptoms) after contamination with infected blood from a needle-stick injury ranges from 4 to 17 days, with a median of 12 days. Induced cases never give rise to clinical relapses, because there are no liver-stage parasites.

3.4 FOCUS CLASSIFICATION

The heterogeneity of malaria across the continuum of transmission results, in most settings, in spatial clusters of relatively higher transmission, which can be referred to practically as foci of transmission. For the purpose of malaria surveillance, however, the term "focus" is used mainly to refer to the few definable areas in which transmission persists during the final stages of elimination.

> A "**focus**" is a defined, circumscribed area situated in a currently or formerly malarious area that contains the epidemiological and ecological factors necessary for malaria transmission.

A focus can be classified into one of three types (**Table 3**); the relations among different types of focus are shown in **Fig. 9**. Focus classifications should be updated periodically. In countries with seasonal transmission, focus classifications are often reviewed at the end of each malaria transmission season or annually. The status of a focus should also be reviewed as new cases appear and field investigations are undertaken. The results of focus investigations are maintained at subnational and national levels (comprising a focus "register"), and a summary of the status of foci is updated at least annually (**Annex 4**). Where an indigenous case is reported in cleared or non residual active foci the focus should immediately be reclassified as active to trigger immediate response (see **Fig. 9**).

TABLE 3.

Focus classification recommended in the *Framework for malaria elimination*

CLASSIFICATION	DEFINITION	OPERATIONAL CRITERIA
Active	A focus with ongoing transmission.	Indigenous case(s) have been detected within the current calendar year.
Residual non-active	Transmission interrupted recently (1–3 years previously).	The last indigenous case(s) was detected in the previous calendar year or up to 3 years earlier.
Cleared	A focus with no local transmission for more than 3 years and which is no longer considered residual non-active.	A focus with no indigenous case(s) for more than 3 years, where only imported or/and relapsing or recrudescent cases or/and induced cases may occur in the current calendar year.

From reference 5

FIG. 9.

Classification of malaria foci
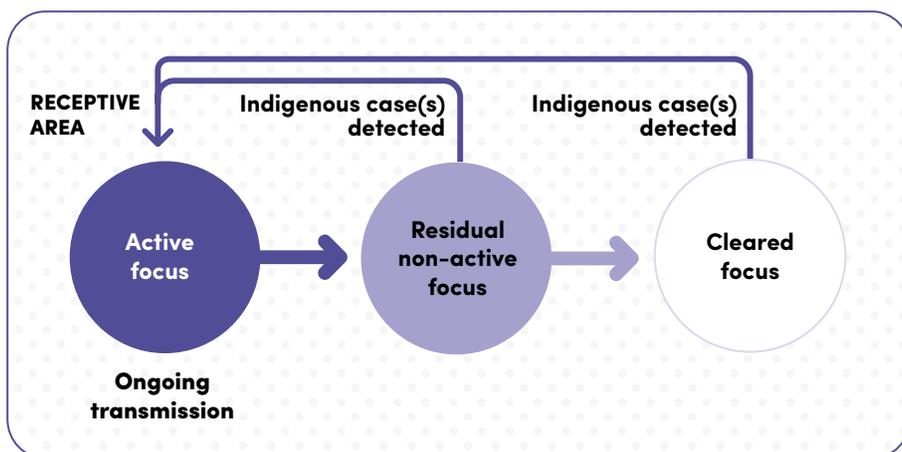
From reference 5

3.5 ROUTINE ACTIVITIES IN MALARIA ELIMINATION SURVEILLANCE AND RESPONSE

A variety of activities underpin the elimination of malaria in a focus (**Fig. 10**).

FIG. 10.
Routine activities in focus-based surveillance and response

	Prevention	Passive case detection	Active case detection	Community mobilization	Drug efficacy surveillance	Entomological surveillance	Monitoring and evaluation
Active	Universal coverage of IRS and/or LLIN Larviciding and other environmental management activities[a] Mass drug administration[b]	High coverage of routine case management services. High-quality diagnosis and treatment. Community health workers or volunteers in settings where access is low. Individual case reporting and notification in place. Case investigation form completed at health facility, preliminary case classification implemented.	Monthly PACD during high transmission season (especially for vivax and ovale where relapse is a problem). Case investigation and RACD when there are few cases (e.g. fewer than three per week per investigation team). Investigate all cases during RACD. RACD radius limited to households of index case(s) or immediate neighbours. Final case classification completed. All cases followed up to ensure compliance with treatment and complete cure.	Routine community engagement and knowledge transfer on malaria prevention, treatment and environmental management. Use ACD process for supplementary community engagement. Work with institutions that train the health workforce to ensure maintenance of good clinical and laboratory practice as malaria becomes rare. Work with all sectors to support communication activities.	Efficacy surveillance linked to case follow up of index cases and others detected in the community during RACD. (See **section 4** for more information.)	Maintain active entomological surveillance in sentinel sites. Conduct spot checks in focus as necessary. (See **section 5** for more information.)	Register all foci. Ensure all households are mapped. Update population data by age category. Update interventions implemented in foci. Update focus case reports by PCD, ACD, parasite species, age range and class. Reclassify foci annually, if necessary. Evaluate intervention coverage using routine investigations. Analyse disease trends. Evaluate quality of interventions, including case management, routinely. Evaluate quality of passive and active surveillance systems routinely. (See **section 7** for more information.)
Residual non-active	Universal coverage of IRS and/or LLIN Larviciding and other environmental management activities[a]		PACD only for high-risk groups. Case investigation and RACD for all cases. RACD in the whole focus if case is locally acquired. RACD only for household of index case or immediate neighbours and fellow travellers if imported. All cases followed up to ensure compliance with treatment and complete cure. Final case classification completed. No need for RACD if cleared focus is not receptive.				
Cleared	Universal coverage of IRS and/or LLIN if still highly receptive. Larviciding and other environmental management activities.[a]	High coverage of routine case management services. High-quality diagnosis and treatment. Infected patients may be admitted for directly observed treatment. Individual case reporting and notification in place. Case investigation form completed at health facility, preliminary case classification implemented.					

ACD, active case detection; PACD, proactive case detection; RACD, reactive case detection; IRS, indoor residual spraying; LLIN, long-lasting insecticidal net; MDA, mass drug administration; LSM, larval source management; SOP, standard operating procedure

[a] Larval source management should be used where vector breeding sites are few, fixed and findable. Routine sentinel entomological surveillance should be maintained in all transmission settings. For entomological surveillance during focus investigation, see **section 5.**

[b] See WHO recommendations and mass drug administration field manual (23) for further guidance.

These routine foci activities include:

- scale up of appropriate preventive interventions;

- optimization of access to routine malaria case management at health facilities, and where appropriate, through CHWs;

- implementation of initial case investigation and prompt case notification through the PCD system whether or not case investigation and RACD happen in the community;

- implementation of PACD among high risk groups or during high risk periods (high transmission season) when cases are still too many to implement RACD;

- implementation of RACD when cases are few (for example no more than 3 cases per week per investigation team) (see **section 3.6**);

- focus investigation and response micro-planning as necessary (see **sections 3.6** and **3.7**);

- continuous community mobilization to participate in elimination activities and communication to raise awareness;

- follow up of cases once a case investigation and/or a RACD approach is in place to ensure compliance with treatment and complete cure (see **sections 3.6** and **4**);

- regular entomological surveillance through representative sentinel sites, supplemented with spot checks during focus investigation as necessary (see **section 5.5**);

- annual monitoring and evaluation activities to track trends in malaria, ensure optimization of interventions, including surveillance systems, and to reclassify foci as necessary.

3.6 REACTIVE SURVEILLANCE ACTIVITIES IN THE FOCUS

Case investigation, detection and focus investigation are elimination surveillance activities that are interconnected and are important for reliable determination of source of infection and classification of cases (**section 3.3**) and foci (**section 3.4**) to inform appropriate response (**section 3.7**).

For planning purposes national SOPs should define a suitable schedule for case investigation, case detection and focus investigation. **Fig. 11** illustrates elimination surveillance with the examples of case notification within 1 day, case investigation within 3 days and focus investigation within 7 days, a "1–3–7" approach adopted from the guidance in China *(24)*.

FIG. 11.

Case notification and case and focus investigation systems according to the "1–3–7 days" approach
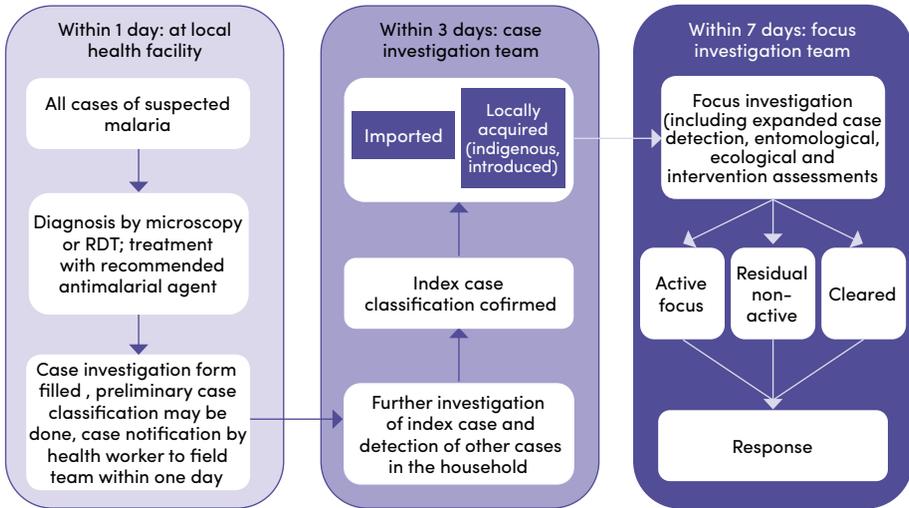
RDT, rapid diagnostic test. Indigenous and introduced cases may further be classified as relapsed (*P. vivax* or *P. ovale*) or recrudescent. It is practically harder to classify imported cases as relapsed or recrudescent. Induced cases are rare. See **section 3.3** for case classification.

Fig. 12 provides a detailed description of process and activities from the moment an index case is identified until a decision on focus response is made. For illustrative purposes a separation is made between community case investigation, active case detection and focus investigation. However, in practice investigation and detection of cases in the focus are part of the broader focus investigation, while the latter may also include additional investigations to determine causes of transmission.

A case and focus investigating team may comprise:

- a health worker at a health facility or the intermediate-level (e.g. district) malaria focal point, who is usually the head of the team, understands the epidemiology of malaria and has experience in field investigations of malaria cases;

- a skilled laboratory technician, if microscopy is the main diagnostic tool, or any health worker with good training in RDTs when these tests are used for surveillance;

- an epidemiologist, who is often a focal point.

- entomological staff from intermediate or central levels when entomological surveillance is required during focus investigation; and

- local health facility personnel and village health volunteers who know the area.

FIG. 12.
Reactive surveillance and response activities

Activities in the focus

Health facility or community health worker

New case identified and treated.

Initial case investigation conducted to determine probable time and place of infection.

If imported, information on relevant fellow travellers is obtained.

Case notified to the investigation team.

Investigation of index case(s) in household

Case investigation form for index case finalized.

Likely time and place of infection determined.

Case classified as imported or local (indigenous, introduced).

Cases may further be classified as relapsing or recrudescent.

Active

Local

Case detection in index household or radius.
If unusual parasite, case detection in whole focus.
Cases treated, investigation forms completed for all and classified.

Raise awareness about possible causes of transmission and advise on prevention and Provide additional vector control if needed.
If no recent entomological data, do spot checks (see **section 5**).
Pay close attention to new developments that pose risks of transmission.

Complete focus investigation form (if no focus investigation in last 4 weeks).
Update focus register and maps.

Imported

Case detection in index household.
Cases treated, investigation forms completed for all and classified.
Co-travellers tracked, tested, treated and investigation forms completed.

Residual non-active

Local

Case detection in whole focus.
Cases treated, investigation forms completed for all and classified.
Any introduced case must be clearly linked with imported case.

Raise awareness about possible causes of transmission and advise on prevention and treatment.
Provide additional vector control if needed.
For local cases, assess reasons for secondary or primary transmission.
If no recent or relevant entomological data, do spot checks (see **section 5**).
Pay close attention to new developments that pose risks of transmission (receptivity and vulnerability).

Complete focus investigation form.
Update focus register and maps.
Reclassify focus immediately as active if local case is indigenous.
Develop appropriate response plan to interrupt transmission.

Imported

Case detection in index household or radius.
Cases treated, investigation forms completed for all and classified.
Co-travellers tracked, tested, treated and investigation forms completed.

Cleared

Local

Case detection in whole focus.
Cases treated, investigation forms completed for all and classified.
Any introduced case must be clearly linked with imported case.

Provide additional vector control if needed; raise awareness.
Undertake entomological surveillance to establish reasons for local transmission (see **section 5**).
Pay close attention to new developments that pose risks for transmission (receptivity and vulnerability).

Complete focus investigation form.
Update focus register and maps.
Reclassify focus immediately as active if local case is indigenous.
Develop appropriate response plan to interrupt transmission.

Imported

Case detection in index household or radius.
Cases treated, investigation forms completed for all and classified.
Co-travellers tracked, tested, treated and investigation forms completed.

Raise awareness about possible causes of transmission and advise on prevention and treatment.
Provide additional vector control if needed.

Follow up all cases to ensure compliance with treatment and complete cure

- In cases of relapse and recrudescence, no further case detection or focus investigation is required.
- In residual non-active and cleared foci, locally acquired cases should be further classified into introduced and indigenous. Although this will not affect the investigation or response, it is required for focus reclassification.

- RACD and related activities in cleared foci is similar to that in settings of prevention of re-establishment of transmission.
- There are situations where it is not possible to make a definitive case classification after investigation of the index case at the household. This may require additional investigation in the focus.
- If there is no recent investigation triggered by an index case, routine focus investigation should still be done at least once a year during the peak transmission season and during scale-up of interventions such as IRS.

3.6.1 Case investigation

The aim of case investigation is to determine whether an infection was acquired locally and the likely location of infection, and therefore whether there is indigenous malaria transmission or factors that may lead to onward transmission. The collection of a detailed history of an index case at a fixed point of care (health facility or CHW) is the basis of initial case investigation (**Fig. 12**). Recording of detailed patient history is an integral part of surveillance for elimination and should be implemented at the fixed points of care even when a case will not be followed up in the community. Follow-up of a case to ensure compliance with treatment and complete cure is also part of case investigation.

In practice, case investigations in the focus should be done as part of RACD when the total case burden in a country is very low (for example, no more than three cases per investigation team per week), there are few foci of transmission and adequate resources are available; in particular, skilled personnel are required at peripheral level, with adequate transport and malaria commodities.

The timing of case investigations depends on the dominant parasite species; patients with *P. vivax* infection may develop gametocytes and be infectious to the mosquito before symptoms appear, requiring rapid intervention. The investigator should be aware that some patients may have hypnozoites and the case may be due to relapse. Countries should decide on the best timing of investigations, recognizing that delays in case notification and in case and focus investigations and response could result in severe disease and death, increased transmission or reintroduction of transmission, depending on the focus class and type of parasite. The investigation team should ideally initiate an investigation within 1–3 days of notification of a malaria case at the home or workplace of the index case.

Once the case investigation is complete at the household of the index case, a determination is made of the likely source and time of infection and the case is classified (**Fig. 12**).

3.6.2 Reactive case detection (RACD)

RACD is triggered by the identification and notification of an index case. After the investigation and classification of the index case, RACD may be implemented within the household of the index case, or over a radius around the household or within the whole focus (**Fig. 12**). RACD may be undertaken for the following reasons:

- to investigate an outbreak (an above-normal number of index cases) in any type of focus;

- in active foci, to ensure high coverage of case management;

- in all types of focus when a local case is due to a unusual parasite, which was either previously eliminated or is new to the focus;

- to identify locally acquired or imported cases in residual non-active or cleared but receptive foci; and

- to reclassify cases (and eventually foci) from active to residual non-active to cleared and to verify that elimination has been achieved sub-nationally or nationally.

The process of RACD involves the following steps:

- obtain epidemiological data on previous cases in the same focus, including age, sex, occupation, timing and species involved, and maps of the locations of cases (by house and village). These data should be available from existing records and should be prepared before the start of the investigation. Information of the index case(s) should also be available.

- register all residents of households in which RACD is to be conducted to ensure complete detection and coverage of other interventions.

- identify the household (or other likely origin and or location of infection) of the index case on the basis of information from villagers, village health volunteers and the map of the focus.

- sensitize the household (or co-workers) about malaria, its symptoms, cause, prevention and where to go for care.

- complete a case investigation form for each confirmed malaria case (see example in **Annex 2**). The form contains demographic information, including workplace(s); the history of the current illness, including diagnostic test results and treatment; use of preventive interventions; travel history and details of fellow travellers; where, how and from whom the infection might have been acquired. It concludes with a section for classification of the case (to be filled in once the case investigation has been completed). The form must record the dates of all aspects of the travel and clinical history. An assessment of the likely location and source of infection is made and the case is classified.

- obtain information on potential malaria vectors in the vicinity of the case, available sentinel site data are not sufficient (see **section 5.5**).

- undertake ACD in populations considered likely to harbour parasites, usually those within a defined radius of the index case. When resources

permit, the whole focus should be covered, as there may be cases of malaria outside the immediate vicinity of the index case. Fever could be used to screen populations for testing, or mass testing could be conducted. The extent of ACD will depend on the factors listed in **Box 7**. PACD may be repeated each month after RACD during the peak transmission season to ensure all new infections are detected and treated.

- where evidence shows no receptivity to malaria, there is no need to investigate imported cases at community level; however, fellow travellers of the imported index case might be tracked to provide treatment. If co-travellers are from a focus outside of the operational area of an investigation team, the appropriate authority should be informed to investigate these cases.

BOX 7.
Factors that determine the extent of RACD in a field investigation

Epidemiological situation. Index cases considered to be due to local transmission may trigger geographically more extensive RACD. An apparently imported, relapsing or recrudescent case, especially in an area with low receptivity, might trigger more limited case detection; however, it is always better to err on the side of caution – if local transmission is at all possible, it is advisable to undertake RACD, at least in the surrounding cluster of households.

Receptivity (presence of abundant anopheline vectors and other ecological and climatic factors that favour malaria transmission). Highly receptive areas should always be covered by RACD.

Type and degree of vulnerability (proximity to a malarious area or frequent influx of infected individuals or groups or infective anophelines). Vulnerability guides both the type and the extent of RACD in each area or subpopulation.

Type and extent of clustering. Local or national knowledge about the pattern of clustering of infection and local experience with the vectors' ecology and breeding sites will determine whether to plan geographically wider or narrower RACD.

Breeding sites. Knowledge of likely breeding sites in the area or locality may result in wider or more focused RACD.

History of infection. History of infection in the area and the type of focus (active, residual non-active and cleared; see **section 3.4**) will influence the type and extent of RACD. When the index case is the first in a new active focus, less will be known about the focus and its

population, and widescale RACD of febrile and non-febrile infected residents may be required to characterize the situation thoroughly and to establish a baseline. If the index case is one of many cases in the same locality in the current transmission season in a well-known focus, RACD may be more targeted, because the at-risk populations will already be known.

Location of the infection. The hypothesized source of infection (work site or residence) will influence the type and targeting of RACD.

Resources. The amount of resources available will guide the type of RACD; for example, screening people with a recent symptomatic illness versus mass testing. The aim is to optimize the use of available resources and complete the investigation within a short time, such as 7 days.

Parasite species: There is currently no method for detecting liver-stage malaria infections. Radical cure of individuals with such parasites is required to clear the liver stage.

Awareness: Regularly repeated RACD will increase case detection and will teach the population to use the free services at the local clinic for parasitological examination in all cases of fever, for compliance with drug doses prescribed and use of preventive interventions.

From reference *21*.

3.6.3 Focus investigation

A focus investigation is conducted to identify the main features of a location, including the populations at greatest risk, the rates of infection or disease, the distribution of vectors responsible for malaria transmission and the underlying conditions that support it. Such an investigation therefore involves demographic, epidemiological, entomological and environmental surveillance (see **section 5.5**) and monitoring of intervention coverage and quality (**section 7**).

The delineation of transmission areas into foci is of practical value only if it results in few foci of relatively small size, so that their investigation is operationally feasible. Delineation that results in hundreds of foci in an area probably indicates that malaria transmission is still widely established, and the area may not be

suitable for focus investigation or response. For operational purposes during elimination, a focus is of the same size as a small village, where households are separated by short distances. This allows completion of a focus investigation in a day or two. Urban foci may be smaller, given the high density of population per area.

The process of case investigation at the household and RACD or PACD in the community are part of the epidemiological components of a focus investigation. However, focus investigations may not involve community case investigations or detection and could be implemented on their own to understand entomological, environmental, intervention determinants of transmission. In general, the following conditions necessitate further focus investigations:

- investigation to determine causes of unusual increase in cases;

- investigation linked to RACD when cases are very few (see **section 3.6.2**) to determine if additional response is required. If an investigation was undertaken in an active focus recently (e.g. within the past 4 weeks), it may not be necessary to conduct full focus investigation in response to an index case, although case investigations and RACD may still be done.

- investigation following the identification of a rare parasite in the focus to determine extent and cause of transmission;

- investigation following the identification of a local case in a residual non-active or cleared focus to determine extent and cause of transmission;

- routine investigations to monitor coverage and quality of interventions.

The timing of a focus investigation depends on the parasite species. ACD linked to an index case should preferably be completed within, for example, 7 days of case notification. During a focus investigation, the relevant form should be completed (**Annex 3**). The district- or intermediate-level malaria focal point is responsible for ensuring that all foci are investigated and that reports for all foci (sometimes called "focus passports") are available and kept up to date. In some settings, the focus investigation team may be in a health facility. If a focus encompasses the boundaries of two or more districts, provinces or even countries, collaboration will be required to eliminate transmission. "Straddling foci" are often the most puzzling for epidemiologists, because administrative boundaries may make the sources of infection difficult to determine.

A map should be drawn or digitally produced, with standard and recognizable keys, to show:

- geographical features relevant for malaria transmission (e.g. rivers, rice fields, dams, ponds, forests, roads, altitude);

- the locations of all households, highlighting those in which cases have been detected in the previous 3 years (with the parasite species responsible for each case);

- vector breeding places and possible sites of transmission, especially when larval source management (LSM) is used;

- the location of test and treatment sites, including areas and households where ACD has been undertaken; and

- distribution and coverage of vector control interventions.

Both paper and electronic maps can be used, but the latter are more flexible and easier to update, given the increased availability of mapping technology (including on mobile devices) and the extension of routine information systems to be "map enabled". Additional features relevant to malaria transmission and control, such as the location of health facilities, should be added.

Geolocation is used to gather the coordinates (often longitude and latitude) of a specific location. Addition of mapping or geolocation capability to a surveillance system makes case and focus investigations more efficient and the products of data analysis more visually powerful, so that they can reveal potentially important geographical variation in both risks and risk factors. Methods used to geolocate and map malaria cases to household level include:

- integrating a malaria surveillance system with an automated mapping system to geolocate detected cases in known locations;

- collecting the coordinates of individual malaria cases with a global positioning system (GPS)–enabled device after they have been detected and geolocating the residence, regardless of the location of infection, as the patient may have infected vectors before receiving radical treatment; and

- if case coordinates cannot be acquired, obtaining information from the patient about relevant location(s), such as residence, work or other places in which he or she may have been infected, which can then be plotted on a map and the coordinates read; geolocation with this method is less certain than the other two approaches.

Once malaria cases have been geolocated, they should be displayed on a map to identify possible transmission areas and to classify cases and foci to guide further targeted investigations. The boundaries of a focus should

include the area in which transmission is occurring if the focus is active and in which there is a risk for onward transmission from the detected case(s), whether locally acquired or imported. Geographical reconnaissance involves gathering detailed data for planning and implementing responses and ensuring optimal coverage of all activities, especially vector control within the focus. **Annex 5** lists the stages, purpose and activities at each stage of geographical reconnaissance and focus mapping with geographical information systems (GIS).

An example of a map of a focus showing the GPS locations of households and the malaria cases detected is shown in **Fig. 13**.

Once the case and focus investigations have been completed, the following actions are necessary.

- The malaria focal point and the entomologist determine whether local transmission is occurring and decide on a final classification of the case and focus.

- The malaria focal point, in consultation with district and national experts, prepares a response plan based on the results of the field and focus investigations, including the entomological evaluation when relevant.

- Copies of the completed case forms and the results of the investigation (including from ACD) and foci register are distributed to the NMP, the national malaria laboratory, the reporting district team and the reporting health facility.

FIG. 13.
A focus map showing the distribution of households geolocated by GPS, roads and river
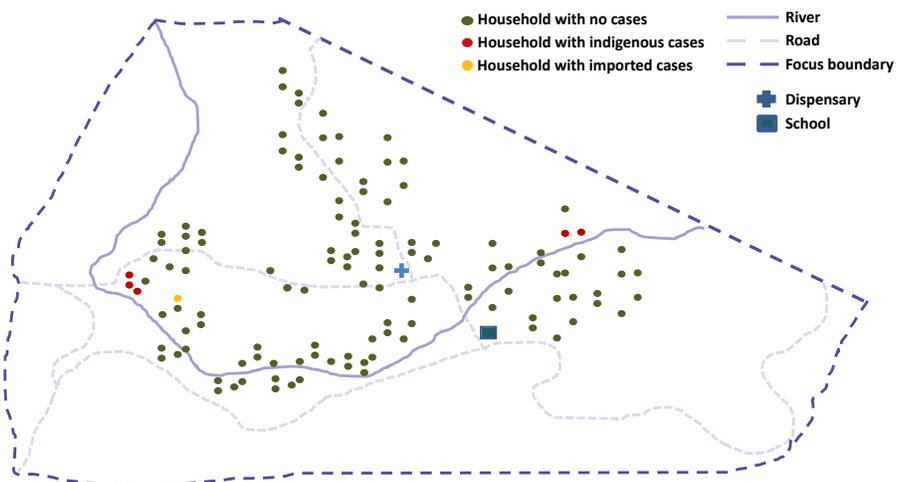
The maps and household checklists produced during focus mapping should be used to target responses in the transmission focus (e.g. treatment or vector control). All the information should be in the form of both a visual guide for field officers to reach the locations where work is required and a checklist for field officers to ensure that all populations, structures and other features (e.g. potential breeding locations) are reached or covered.

Data on field activities should be recorded on household checklists and map data. The data can then be updated and analysed in applications such as GIS software to assess and evaluate the coverage of interventions and activities conducted (as illustrated in **Fig. 5**). Data should include the locations of additional malaria cases detected by RACD, the coverage of vector control activities or the location of breeding sites. Programmes should maintain and regularly update inventories of transmission foci. Customized applications (e.g. integrated malaria surveillance systems) could be designed to permit malaria programmes to analyse intervention data rapidly and automatically, to ensure that all activities within the transmission focus are conducted with optimal coverage and on time.

3.7 FOCUS RESPONSE

Most interventions in a focus are implemented routinely (**Fig. 11**) and the response to an index case or PACD during the high transmission season are mechanism to optimize these interventions or respond to unusual situations. Providing treatment to infected individuals, supplementary vector control and increasing community awareness are part of the focus response during house-to-house visits during RACD. The responses in active, residual non-active and cleared foci are similar but have important differences.

- Vector control measures are assessed for their appropriateness, coverage and use in accordance with the local context of malaria, with particular attention to the receptivity of the area.

- PCD services are accessible to all members of the population throughout the year and are supported by supervision at defined intervals.

- In active foci, there are several options. High coverage of appropriate vector control should be ensured. Population-wide treatment (MDA) or possibly PACD (with screening and testing or with testing alone) could be considered at appropriate intervals, especially just before or during the transmission season. If a testing approach is chosen but no cases are found after several rounds of PACD, the frequency may be reduced or the strategy changed to RACD, as necessary.

- In residual non-active foci, PACD may be used at key times (e.g. mid- and late transmission season) to screen the people most likely

to have malaria (e.g. those with fever, migrant labourers and those who do not use prevention) in order to identify local cases indicative of ongoing transmission. RACD is then conducted to follow index cases. If indigenous cases are identified, the focus is reclassified as active (see **Fig. 12**).

- In cleared foci, the programme should rely on the surveillance system to rapidly identify any malaria cases and to determine whether local transmission has resumed. Depending on the receptivity of the cleared focus, RACD can be conducted after identification of an index case. If new indigenous cases are identified, the focus is reclassified as active (see **Fig. 12**).

4. Surveillance of antimalarial drug efficacy and drug resistance

4.1 INTRODUCTION

Information on the efficacy of recommended malaria treatment is critical for ensuring progress towards elimination and ensuring that patients receive efficacious treatment. WHO has prepared a standard protocol for therapeutic efficacy studies (TES) and tools for data analysis and monitoring *(26)*. TES are considered the gold standard for assessing antimalarial drug efficacy, and the resulting data are used to inform national malaria treatment policy in malaria endemic countries. TES are designed for monitoring the efficacy against both *P. falciparum* and *P. vivax* of any of the recommended first- and second-line medicines as well as any medicine that is to be assessed before possible introduction into the treatment policy.

In areas in which there are very few malaria cases, it will be difficult to recruit enough patients to obtain interpretable information on drug efficacy. If these areas are pursuing malaria elimination, their surveillance systems will likely have been strengthened to improve case detection, increase case reporting from all sectors (private and public), ensure that all patients receive the full, supervised, recommended treatment (including radical cure) and confirm complete cure by following up patients at regular intervals *(5)*. In these areas, monitoring of drug efficacy can be integrated into the routine surveillance system (see **section 4.4**).

4.2 THERAPEUTIC EFFICACY STUDIES

TES are prospective evaluations of patients' clinical and parasitological responses to treatment for uncomplicated malaria. Studies conducted according to the WHO protocol *(27)*, repeatedly at the same sites and at regular intervals, allow early detection of changes in treatment efficacy and comparison of results within and across regions over time.

Resistance to antimalarial drugs (except for partial resistance to artemisinins) is defined by WHO as the ability of a parasite strain to survive or multiply (or both) despite administration and absorption of a drug given in doses equal to or higher than those usually recommended, but within the tolerance of the patient. Treatment failure is defined as the inability to clear malarial parasitaemia or prevent recrudescence after administration of a therapeutic regime of a recommended antimalarial medicine, regardless of whether clinical symptoms are resolved. Drug resistance is only one of several factors that may cause treatment failure. Although a TES can help to predict the likelihood of resistance to an antimalarial drug, confirmation and characterization of parasite resistance require additional tools (e.g. in-vitro or ex-vivo tests, analysis of molecular markers and measurement of drug concentrations in the blood), for which WHO standard protocols are available (27).

4.2.1 Protocols in different transmission settings

The standard TES protocol and the inclusion criteria can be adapted to the transmission level to ensure a minimum sample size for a sentinel site (**Table 4**).

TABLE 4.
Inclusion criteria for *P. falciparum* therapeutic efficacy studies in different transmission settings

TRANSMISSION LEVEL	STANDARD INCLUSION CRITERIA
High	Patients with fever, aged 6–59 months and 2000–200 000 asexual parasites/µL.
Moderate	Patients with fever or a history of fever, children ≤ 12 years and 1000–100 000 asexual parasites/µL.
Low	Patients with fever or a history of fever, all age groups and ≥ 250 or 500 asexual parasites/µL
Very low	Patients with fever or a history of fever, all age groups and any parasitaemia

4.2.2 Sentinel sites

TES are conducted at sentinel sites, which are carefully selected based on the required number of malaria cases, adequacy of facilities and qualifications of staff. The minimal requirements for establishing a sentinel site are: trained, motivated clinical personnel and microscopists; a laboratory equipped for blood film examination; and knowledge of

the level of transmission intensity, as these influence the inclusion criteria. The sentinel site may be in a community or a health facility at district or provincial level.

Patients attending hospitals may have more complex clinical presentations, be more likely to have had previous drug failure and be more difficult to follow up. Thus, whenever possible, monitoring should be done in or close to the community.

Sentinel sites should represent all the epidemiological strata in the country. Preferably, a site should have access to the required sample size. If this is not possible, the required sample size can be obtained by combining data from single-arm studies conducted in several sites in a geographical unit. Thus, what constitutes a sentinel site depends on the transmission setting. It may be:

- a single health facility (health centre, hospital) or temporarily established facility in a community (typically in high-transmission settings);
- a group of health facilities (health centres, hospitals) in the same town or city (typically in high- or moderate-transmission settings);
- a group of health facilities (health centres, hospitals) in the same district (typically in low-to-moderate-transmission settings);
- a group of health facilities (health centres, hospitals) in several districts in the same province (typically in low-transmission settings); or
- cross-border health facilities (health centres, hospitals) in two neighbouring countries (rare).

Repeated TES at a few sites are adequate for collecting consistent longitudinal data, documenting trends and informing the national treatment policy. WHO recommends that a TES be performed at each sentinel site at least once every 2 years.

4.2.3 Classification of responses to treatment

In areas with high, moderate or low transmission, genotyping by PCR is required to distinguish between recrudescence (of the same parasite strain) and reinfection (with a different parasite strain). For any patient with parasitaemia on or after day 7, the genotypic profiles of the parasites (on day 0 and the day of parasite recurrence) must be compared and the patient classified according to the PCR findings.

In TES, treatment responses are classified as shown in **Table 5**.

TABLE 5.
Classification of responses to treatment

EARLY TREATMENT FAILURE
• danger signs or severe malaria on day 1, 2 or 3 in the presence of parasitaemia;
• higher parasitaemia on day 2 than on day 0, irrespective of axillary temperature;
• parasitaemia on day 3 with axillary temperature ≥ 37.5 °C; and
• parasitaemia on day 3 ≥ 25% of count on day 0
LATE CLINICAL FAILURE
• danger signs or severe malaria in the presence of parasitaemia on any day between 4 and 28 (or day 42) in patients who did not previously meet any of the criteria of early treatment failure; and
• presence of parasitaemia on any day between 4 and 28 (or day 42) with axillary temperature ≥ 37.5 °C in patients who did not previously meet any of the criteria of early treatment failure.
LATE PARASITOLOGICAL FAILURE
• presence of parasitaemia on any day between 7 and 28 (or day 42) with axillary temperature < 37.5 °C in patients who did not previously meet any of the criteria of early treatment failure or late clinical failure.
ADEQUATE CLINICAL AND PARASITOLOGICAL RESPONSE
• absence of parasitaemia on day 28 (or day 42), irrespective of axillary temperature, in patients who did not previously meet any of the criteria of early treatment failure, late clinical failure or late parasitological failure.

4.2.4 Use of TES results for changing treatment policy

The results of TES are the main basis for determination of the national treatment policy by the NMP. The key outcome indicators of TES are the proportion of patients who are parasitaemic on day 3 (currently used as an early warning signal for identifying suspected partial artemisinin resistance in *P. falciparum*) and the proportion of patients with treatment failure by day 28 or day 42. To ensure the efficacy of the malaria treatment selected for national policy, WHO recommends a change in the national

malaria treatment policy if the total treatment failure rate is ≥ 10% (as assessed by TES) and that the NMP adopts antimalarial medicines with a parasitological cure rate of > 95%.

4.3 MOLECULAR MARKERS OF RESISTANCE TO ANTIMALARIAL DRUGS

Drug resistance is one of the causes of treatment failure, and characterization of the molecular markers of drug resistance is an important means of understanding resistance to antimalarial treatment. Once the genetic changes associated with resistance are identified, drug resistance can be confirmed and monitored with molecular techniques. A limited number of genes involved or potentially involved in the resistance of *P. falciparum* to antimalarial drugs have been identified: *Pfcrt (P. falciparum* chloroquine resistance transporter) conferring resistance to chloroquine, *Pfdhfr (P. falciparum* dihydrofolate reductase) conferring resistance to pyrimethamine and *Pfdhps (P. falciparum* dihydropteroate synthase) conferring resistance to sulfadoxine. Increased copy numbers of *Pfmdr1 (P. falciparum* multidrug resistance 1 protein) and *Pfpm2–3 (P. falciparum* plasmepsin 2–3) have been associated with *P. falciparum* resistance to mefloquine and piperaquine resistance, respectively. Resistance of *P. falciparum* to artemisinins is strongly associated with point mutations in the propeller region of the *PfKelch13* gene (**Table 6**).

4.4 MONITORING THE EFFICACY OF ANTIMALARIAL DRUGS IN SETTINGS WITH VERY LOW TRANSMISSION

In areas of very low transmission, it may be impossible to accrue the number of patients required for a TES. If the country has strengthened its surveillance systems for eliminating malaria, surveillance of drug efficacy can be integrated into the routine surveillance system. In some countries with very low transmission, however, the surveillance systems are not yet sufficiently strong for this to be feasible.

4.4.1 Settings without strong surveillance systems

If countries have too few cases for a TES even after the inclusion criteria have been adjusted and data combined from sites all over the country (country aggregated data), information on molecular markers of drug resistance can be used to monitor trends. To do this, countries should systematically collect dried blood spots on filter papers for analysis of the

known and validated molecular markers every year (see **Table 6**). The aim should be to collect data from a sample large enough to obtain significant results.

TABLE 6.
Validated molecular markers for resistance to antimalarial drugs

CHEMICAL FAMILY	DRUG	MOLECULAR MARKER
4-Aminoquinolines	Chloroquine	*Pfcrt* SNP
	Amodiaquine	Molecular marker yet to be validated.
		Studies show that amodiaquine selects for *Pfmdr1* (86Y).
	Piperaquine	*Pfpm2-3* copy number
Antifolates	Pyrimethamine	*Pfdhfr* SNP
	Sulfadoxine	*Pfdhps* SNP
Amino-alcohols	Mefloquine	*Pfmdr1* copy number
	Lumefantrine	Molecular marker yet to be validated. Studies show that lumefantrine selects for *Pfmdr1* (N86). Recent data do not confirm *Pfmdr1* copy number as a marker of lumefantrine resistance.
Sesquiterpene lactones	Artemisinin and artemisinin derivates	*PfK13* SNP
Naphthoquinone	Atovaquone	*Pfcytb* SNP

SNP, single nucleotide polymorphism

While molecular markers can be used to monitor trends, clinical data will nevertheless be needed to inform treatment policies. If the molecular analysis shows significant increases in markers of drug resistance for the recommended treatment, all efforts must be made to collect high-quality information on patient treatment outcomes rapidly for a possible change in policy.

4.4.2 Integrated drug efficacy monitoring into areas with strong surveillance systems

Areas pursuing malaria elimination are expected to have a strong surveillance system (**section 3**). In these areas, monitoring of drug efficacy can be integrated into the routine surveillance system by ensuring that the

data collected on all malaria cases in the routine surveillance system can and are also being used to generate information about drug efficacy. For this purpose, the surveillance system is expected to have the capacity for:

- good case detection;

- reporting on all cases of malaria, whether detected in the public or the private system;

- ensuring that all patients receive the full recommended treatment (including for radical cure) under supervision; and

- following up patients to confirm complete cure.

In TES, data are collected only on symptomatic cases (with fever or a history of fever). In integrated drug efficacy surveillance (iDES), data are collected on all cases, including asymptomatic cases and all species detected by PCD or ACD and subsequently reported to the surveillance system.

The role of the private sector and community services such as village health workers in detecting cases, providing treatment and following-up patients differs by country. In all countries, however, the NMP should be responsible for compiling and analysing data. A good diagnostic quality assurance system, covering all sectors involved in diagnosis, must be in place to generate reliable data. To ensure prompt, appropriate treatment of patients, and thereby elimination, the treatment policy must be up to date and both first- and second-line treatments must be available in all facilities providing diagnosis and treatment.

The activities and information required for integrated surveillance of drug efficacy are described below. They comprise:

- patient classification and diagnosis,

- molecular analysis,

- treatment,

- patient follow-up,

- information on efficacy of first- and second-line treatments,

- classification of responses to treatment,

- data interpretation and policy considerations and

- budgeting for monitoring antimalarial efficacy.

The procedures and the amount of data collated depend on the system in place and the resources available. The absolute minimum data that must be collected for analysing drug efficacy are data on all patients collected at least at twice: on the first day of treatment (day 0) and on the specified last day of follow-up. The data to be collected include characterization of the case, such as parasite species, the treatment provided, whether the patient was symptomatic, whether the case was detected by PCD or ACD, whether treatment was supervised and the treatment outcome. The case should also be classified as imported, introduced, indigenous, induced, relapsing or recrudescent. Further details on case characterization are given in reference *5* (see also **section 3** and **Table 7**).

The text below and **Table 7** describe the mandatory and additional information recommended for collection in routine surveillance systems for analysis of drug efficacy. It is expected that the mandatory information will already have been collected in elimination settings with strong routine surveillance systems. When possible, the countries should collect all the information recommended below, as more data result in better information to guide policies.

Patient classification and diagnosis

As part of routine surveillance in elimination settings, a detailed case investigation and recording of probable origin are required in order to classify cases as imported, indigenous, induced, introduced, relapse or recrudescent. All suspected malaria cases are diagnosed (with species identification) by an RDT and/or microscopy on day 0; microscopy is mandatory for detecting recurrent parasitaemia during follow-up and on the last day of follow-up. If resources allow, parasite detection on day 0 should include identification of species and stage (asexual and sexual) by microscopy.

Molecular analysis

Genotyping to distinguish between reinfection and recrudescence is not mandatory because the risk that treated individuals will experience recurrent parasitaemia due to a new infection is very low because of the small number of malaria cases in elimination settings. For this reason, all cases of recurrent parasitaemia will be considered by default true recrudescence (true treatment failure) if treatment is supervised. However, an additional blood sample can be collected on filter paper on day 0 and on the day of parasite recurrence. Blood samples can also be used to confirm species, assess known molecular markers of antimalarial drug resistance and facilitate identification of the geographical origin of parasites.

Treatment

All efforts must be made to supervise all treatment, including primaquine for patients with *P. vivax* infection. It must be recorded whether all doses of the treatment given were supervised. *P. vivax*-infected patients should be tested for glucose-6-phosphate dehydrogenase (G6PD) status. Patients with treatment failure (recurrence of parasitaemia with the same species during the follow-up period; for classification of failure (see **Table 5**) should be given supervised second-line treatment and followed up again until cure is achieved. Hospitalization of patients during treatment is recommended if feasible.

Patient follow-up

All treated malaria patients should be followed up to the last day of the follow-up period appropriate for the species and the treatment administered. Specifically, the follow-up period for patients infected with *P. falciparum* is 28 days for drugs with a short half-life (artesunate + sulfadoxine–pyrimethamine, artemether–lumefantrine, artesunate–amodiaquine) and 42 days for drugs with a long half-life (artesunate–mefloquine, dihydroartemisinin–piperaquine and artesunate–pyronaridine). The follow-up period for individuals infected with *P. vivax* is 28 days for asexual stages and 3 months for relapses. If human and financial resources allow, the follow-up period for cases of falciparum infection can be extended to 42 days after administration of a treatment with a short half-life or 56 days after treatment with a drug with a long half-life. In some settings, *P. vivax* patients should be followed up for 1 year.

At a minimum, all infected individuals should receive a clinical consultation and parasitological evaluation on day 0 and on the last day of follow-up (i.e. day 28, day 42 or the day of treatment failure). If fever or symptoms develop at any time during the follow-up period, the patients should undergo parasitological and clinical evaluation. Any consultations, including those that are unscheduled, should be documented. If an infected individual does not attend the mandatory consultation on the final day, intensive efforts must be made to locate him or her. If feasible, additional follow-up on day 3 and then weekly on days 7, 14, 21, 28, 35 and 42 for patients with *P. falciparum* infection is recommended. Similarly, weekly follow-up on days 7, 14, 21 and 28 and then monthly is recommended for patients with *P. vivax* (and *P. ovale* infection).

TABLE 7.
Mandatory and recommended activities for integrated surveillance of drug efficacy

ACTIVITY	MANDATORY	RECOMMENDED
Patient classification and diagnosis.		
Patient classification	Classification of case as imported, indigenous, induced, introduced, relapsing or recrudescent. Detailed case investigation and recording of likely origin of malaria.	.
Diagnosis on day 0	Identification of symptoms (uncomplicated, severe). Species identification by RDT and/or microscopy.	Parasitaemia by microscopy. Gametocytaemia by microscopy. PCR.
Diagnosis on any additional day of follow-up		Microscopy.
Diagnosis on final day of follow-up	Microscopy.	PCR.
G6PD	G6PD testing for vivax patients.	
Molecular analysis		
Markers of reinfection or recrudescence		Blood collected on day 0 and day of failure for analysis of markers of reinfection or recrudescence.
Markers of drug resistance		Blood collected on day 0 for analysis of markers of drug resistance.
Identification of origin		Blood collected on day 0 for genetic analysis to facilitate identification of geographical origin of parasites.
Treatment		
Supervision of treatment	Ensure that all treatments are given under direct supervision, including treatment with primaquine for patients with *P. vivax* malaria.	Hospitalization of patients during treatment.
Treatment failure	All cases of treatment failure must receive second-line treatment (supervised) and be followed up for an additional full follow-up period.	Hospitalization of patients during treatment.

ACTIVITY	MANDATORY	RECOMMENDED
Patient follow-up		
Follow-up period: *P. falciparum*	End date 28 days after start of treatment with a drug with a short half–life or 42 days after start of treatment with a drug with a long half–life.	42 days after start of treatment with a drug with a short half–life; 56 days after start of treatment with a drug with a long half–life.
Follow-up period: other species	End date 28 days and 3 months (for relapses) for *P. vivax* and *P. ovale*. Due to limited evidence, follow-up recommended until day 28 for *P. malariae* and 42 days for *P. knowlesi*.	Up to 1 year for *P. vivax*.
Days of patient follow-up	End date defined as: • final day of follow-up (see above) if cured, or • any day on which the patient presents with recurrent parasitaemia with or without symptoms after treatment (additional full follow-up period required after second–line treatment).	Additional follow-up on day 3 and then weekly on days 7, 14, 21, 28, 35 and 42 (49, 56) for *P. falciparum* and days 7, 14, 21 and 28 and monthly for *P. vivax* and *P. ovale*.
Information collected on days of follow-up	Clinical symptoms, temperature, presence of parasitaemia at day 0, end day or any day of recurrent parasitaemia.	Clinical symptoms, temperature, asexual and sexual parasitaemia (by microscopy) at follow–up visits. Alternatively, clinical symptoms only may be collected by telephone and additional follow-up visits made if deemed necessary.

PCR, polymerase chain reaction; G6PD, glucose–6–phosphate dehydrogenase

Information on efficacy of first– and second–line treatments

The objective of TES is to monitor the efficacy of first– and second–line treatments and, if required, that of any newly registered treatment for which information is necessary for a possible policy change. The main objective of integrated surveillance of drug efficacy, including supervision of treatment and patient follow-up, is to ensure patient cure and progress towards elimination. Information on drug efficacy is collected primarily for the first-line treatment given to patient as per the national treatment guidelines; a secondary objective is to inform treatment policy. Data on

the efficacy of second-line treatment are collected only for patients with recrudescent infections after first-line treatment.

Classification of responses to treatment

As mentioned above, genotyping to distinguish between reinfection and recrudescence is not mandatory. When genotyping is not available, recurrent parasitaemia in all patients who received the mandatory supervised treatment is considered to be true recrudescence (true treatment failure). If information is available on genotype, the data should be PCR-corrected. If the treatment was not supervised, recurrent parasitaemia cannot be considered a true treatment failure, but it is important that all efforts are made to supervise subsequent treatment and register the outcome. When all the recommended data have been collected, each patient can be classified as per **Table 5** with the following limitations: The classification shown in **Table 5** can be used for infections with *P. falciparum* and for the first 28 days' follow-up for *P. vivax* only. Any recurrent vivax parasitaemia in the follow-up period after day 28 must be classified as a relapse. Early treatment failure can often not be classified in integrated surveillance, as the data will not be available. Furthermore, the category of early treatment failure cannot be used for patients with severe malaria diagnosed on day 0.

Data interpretation and policy considerations

Data must be analysed continually, especially for patients with treatment failure and for programmatic issues, including the number of patients lost to follow-up and whether second-line treatment was given to patients with treatment failure as per the national treatment policy. In addition to continual analysis, a fixed time should be set to review and discuss all data (e.g. an annual evaluation meeting), at which time data can be shared and discussed with WHO. The WHO malaria treatment guidelines *(17)* recommend that first-line treatment be changed if the total failure rate exceeds 10%; however, efficacy and failure rates should be considered in the context of their confidence intervals. Policy decisions can be informed by additional information, including on molecular markers, especially in very low transmission settings where there may be too few patients to obtain the desired level of precision (5%) and a confidence interval of 95%. In elimination settings, any treatment failure must be investigated, as this represents a potential source of onward spread of malaria.

4.4.3 Budgeting for monitoring antimalarial efficacy

To ensure that a country conducting TES has sufficient resources, the following should be budgeted for: human resources, travel and transport,

equipment and supplies, patient costs, technical assistance, supervision, a quality-assurance system, data management and laboratory support for genotyping. In addition, provision should be made for the necessary training, monitoring to improve the quality of clinical procedures and data collection, management, validation and reporting, which is usually provided by a consultant over 2–3 weeks. There must be strict adherence to the study protocol to ensure data quality.

When drug efficacy monitoring is fully integrated into surveillance activities, the funding, including for recommended activities such as analysis of molecular markers, should be part of the overall surveillance budget. Sufficient funding and human resources must be allocated to both the collection and analysis of data and supervision of the overall system.

5. Entomological surveillance and vector control monitoring and evaluation

5.1 RATIONALE, DEFINITION AND OBJECTIVES

Globally, vector control has contributed significantly to reducing malaria morbidity and mortality *(28)* and accounts for the majority of the projected cost of implementing the *Global technical strategy for malaria 2016–2030 (29)*.

Insecticide-based interventions, namely LLINs and IRS, are currently the core vector control interventions for malaria prevention. These interventions affect adult mosquito populations to reduce malaria transmission in various ways. Insecticides on nets or the interior surfaces of dwellings knock down, kill or repel vectors. As coverage of insecticidal interventions increases, mass killing of vector populations can result in protection even of those people in a community who are not directly covered by LLINs, in what is known as "community protection" *(30,31)*. LLINs also provide personal protection against mosquito bites because of the physical barrier of the netting. These effects lead to a reduction in vector survival (longevity) and vector density, ultimately reducing the capacity of mosquitoes to transmit malaria parasites. Both LLINs and IRS are most effective where local vectors prefer to bite and rest indoors (i.e. are endophagic and endophilic); however, these interventions still provide an important level of control when local vectors primarily feed (exophagic) *(32)* and rest (exophilic) outdoors.

Targeting the aquatic immature stages of mosquitoes (eggs, larvae and pupae), referred to as larval source management (LSM), may also reduce malaria transmission by affecting the density of adult vectors. This is considered supplementary to the core interventions outlined above. LSM consists of the permanent removal or temporary disruption of standing water to eliminate or reduce mosquito egg-laying and immature stages or of regular application of biological or chemical insecticides to water bodies

to kill or disrupt the development of immature stages. These methods may be effective (singly or in combination) in settings where there are few, fixed and findable aquatic habitats of malaria vectors.

Indicators of programme progress in vector control coverage, access and use are of critical importance (see **section 5.6** and **Table 14**). The quality of vector control products must be monitored to ensure that they adhere to specifications and perform effectively and safely throughout their life. Monitoring the performance of vector control interventions includes assessing the durability of LLIN products in the field and the residual efficacy of IRS formulations after application to walls and ceilings.

Core and supplementary interventions may exert selection pressure that affects the frequency, intensity or mechanisms of insecticide resistance. Variations in the impact of interventions on individual mosquito species as a result of differences in susceptibility to insecticides or propensity to contact interventions can result in more efficient killing of certain species and alter species composition. Thus, the overall effectiveness of interventions against the remaining vectors may change over time, necessitating alternative or supplementary interventions. Systematic tracking of vector species and their characteristics and monitoring of interventions to identify any modifications that might be required in vector control strategies are therefore essential.

Entomological surveillance can be defined as the regular, systematic collection, analysis and interpretation of entomological data for risk assessment, planning, implementation, monitoring and evaluation of vector control interventions. All surveillance activities must be clearly linked to programme decisions to ensure optimal vector control. In malaria intervention programmes, the main objectives of entomological surveillance are to:

- *Characterize receptivity to guide stratification and selection of interventions.* Potential malaria transmission within a country often differs significantly, as indicated by the heterogeneity in receptivity (see **section 5.5**). The entomological parameters considered in risk characterization include the vector species present and the characteristics that influence transmission.[1] Important traits such as biting (time, place and host preference), dispersion and resting behaviour should be known for all the principal vectors, as these traits determine receptivity and thus guide the selection of interventions. Characterization of receptivity can be used to target vector control in order to ensure appropriate coverage of at-risk populations *(33)*.

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[1] Importation of vectors from other areas (including those that fly or are passively transported by aircraft, ships or other means) may be another component of vulnerability, but this is a minor consideration in most settings as it is relatively rare.

Better targeting of interventions contributes to optimized use of resources and may ultimately increase impact.

- *Track the relative density of malaria vector species (and their bionomics[2]) to determine the seasonality of transmission and the optimal timing of interventions.* The composition of vector species should be tracked over time; up-to-date information is important, as the relative density of species can change with seasonal and other environmental changes and with effective interventions.

- *Track insecticide resistance as a basis for choosing insecticides.* Vectors have developed physiological resistance to the insecticides used in interventions (mainly LLINs and IRS), which must be monitored closely. The frequency, intensity and mechanisms of resistance should be assessed in the principal malaria vectors and, when possible, in secondary vectors. Information on insecticide resistance should be used in choosing insecticides, in line with insecticide resistance management plans. This is of increasing importance as new vector control tools, including new insecticides, become available.

- *Identify other threats to the effectiveness of vector control.* The composition and behaviour of vector populations may change and thus undermine the effectiveness of interventions. For instance, the relative proportion of outdoor transmission may increase as a result of effective control of endophagic and/or endophilic vectors. Vectors should therefore be tracked to detect any significant change in the location in which transmission takes place, in order to decide whether supplementary interventions are required, such as new tools to control outdoor transmission.

- *Monitor vector control intervention coverage and quality to identify gaps and opportunities.* The intervention(s) used should also be monitored to ensure optimal implementation and to indicate any corrections required. Monitoring of interventions includes assessing coverage, access, use and their acceptability and quality, such as the physical or fabric integrity and insecticidal activity of LLINs and the residual efficacy of IRS.

Entomological surveillance activities required to achieve these objectives may include:

- identifying the malaria vector species;

- measuring species-specific vector densities and ascertaining vector composition;

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[2] Vector bionomics is the study of the mode of life of organisms in their natural habitat and their adaptation to their surroundings. Basic studies are those on the development of immature stages and the influence of environmental conditions on the life of adults.

- determining vector blood-feeding habits (zoophilic, anthropophilic);

- assessing other vector behaviour (exophily, endophily, exophagy, endophagy);

- monitoring vector susceptibility to insecticides (frequency, intensity and mechanisms of resistance);

- measuring the rates of infection of the vector with the malaria parasite (sporozoite rate, oocyst rate); and

- identifying the aquatic habitats of immature stages of vectors and habitat characteristics.

The monitoring and evaluation activities required to achieve the above objectives may involve:

- measuring the coverage, access, use and acceptance of interventions (see **section 7**);

- measuring the durability of LLINs in the field;

- measuring the residual efficacy of insecticides; and

- observing application of larviciding.

These indicators should be measured over time in order to identify any appreciable and informative trends.

5.2 SURVEILLANCE SYSTEMS FOR ENTOMOLOGY AND VECTOR CONTROL

Entomological surveillance should be conducted to inform vector control planning and implementation to ensure that appropriate interventions are being used where they are needed; it should be directed by the NMP. The surveillance approach used in a country will depend on its past and present malaria epidemiology. The surveillance strategy should therefore be appraised periodically and revised if necessary to ensure cost–effective use of resources for vector control, particularly when significant changes in caseloads are being observed through reporting or surveys. Collaborations with other vector control programmes, research institutions, central or regional reference laboratories and other partners should be drawn upon for technical and programme support, as appropriate.

Surveillance can be categorized as preliminary or baseline surveys, routine sentinel surveys for observation of trends, spot checks for supplementary data collection and focus investigations during elimination or in response to outbreaks (**Box 8**).

BOX 8.
Types of surveys for vector control

Preliminary or baseline surveys: These initial, time-limited surveys are used to gather baseline data for planning vector control measures. They provide information on the vector species present, their resting and feeding habits, changes in species composition by season and over time, types of water bodies used as larval habitats and vector susceptibility to insecticides. Information on local vector species and their ecology, biology and behaviour will often have been assembled and used to inform current control or elimination strategies. Data from these types of surveys can also be used to identify appropriate sentinel surveillance sites.

Routine sentinel surveys: Long-term observations are made regularly, such as monthly, quarterly or annually, in fixed locations. Their purpose is to identify any change in vector species density and composition, behaviour, susceptibility to insecticides and even infection rates, which may explain any observed epidemiological trends in malaria transmission, and ultimately to indicate the appropriate response. All malaria-endemic countries should have established entomological surveillance sites that have been carefully selected on the basis of multiple criteria (see next page). As transmission decreases and malaria becomes more focal, the location of sentinel sites should be adjusted to ensure collection of data that are applicable to the remaining transmission foci.

Spot checks: Ad-hoc assessments are carried out in selected locations as a supplement to routine observations and when more information is required to inform programme adjustment or response. Spot checks may include investigations in areas where there are suspected problems in the quality of implementation of an intervention; an expected increase in receptivity and/or vulnerability, perhaps due to reintroduction or proliferation of a vector species as a result of environmental changes; the presence of vulnerable populations due, e.g. to resettlement, migration or mining; and heightened risks for importation due to increased human movement in border areas or transport routes linked to endemic countries.

Focus investigations: These investigations are undertaken in areas of new, persistent or resurgent malaria transmission to determine why the interventions being used are no longer reducing transmission. They are short-term, reactive epidemiological investigations in settings of elimination or prevention of re-establishment. The trigger for a focus investigation could be an increase in the prevalence of parasite infections or clinical malaria cases.

Routine entomological surveillance is distinct from the more detailed evaluations of entomology and vector control in operational research, which is usually conducted by partner institutes, including national research or academic institutions, to answer specific research questions, rather than as routine monitoring. Operational research is not discussed in this manual.

General criteria for selecting surveillance sites

Sites for conducting routine entomological sentinel surveys should ideally represent the range of eco-epidemiological settings in a country, including ecological zones with different malaria vector species and epidemiological regions or zones with different levels of malaria transmission (see **section 7.4**) (*33,34*). It is essential that data generated at entomological sentinel sites can be linked to information on local malaria epidemiology (see **section 3.5–3.7**), such as at a health facility that serves as a sentinel site. Sentinel surveillance should be conducted iteratively, and the location of sites might have to be changed on the basis of epidemiological and entomological data. In areas where transmission has ceased because of effective control, sentinel surveillance should be used to re-assess the receptivity of the area. Depending on the outcome, surveillance sites should be maintained in areas in which transmission has been interrupted but where significant risk remains or should be (re-)moved from areas with no or low malariogenic potential.

The other main characteristics to be considered in selecting entomological sentinel sites are the:

* vector control interventions being used or planned, to ensure selection of sites that are representative, such as use of LLINs only, IRS only, LLINs and IRS, LLINs and larviciding;

* past or current use of insecticides in agriculture, which can affect the susceptibility of vectors to the insecticides used in malaria vector control;

* previous transmission levels, including hot spots with a history of epidemics;

* locations or areas at high risk of importation of cases, infected vectors or invasive vector species, such as ports, border posts or resting stops along major transport routes;

* ongoing or planned development that might change receptivity or vulnerability, such as increases in human or vector populations (e.g. at dam sites);

- location and availability of human resources and infrastructure, including trained personnel (entomologists, vector control technicians and mosquito collectors), facilities (insectaries, laboratories) and equipment (microscopes, test kits);

- location and availability of health facilities or partner institutes to house equipment and provide human resources for surveys; and

- anticipated accessibility of sites during the planned times of surveys, such as periods of high rainfall.

The number of sentinel sites required strongly depends on the size and ecological and epidemiological diversity of a country. It is proposed, as an approximate guide for monitoring resistance to insecticides, that there should be at least one sentinel site for every 500 000 nets distributed or 200 000 houses sprayed (*35–37*). This is equivalent to about one site per 1 million people protected, although the exact number will depend on the country's epidemiology and population density. The distribution and number of sites should be reviewed periodically and adapted according to epidemiological data, identified patterns of resistance and available human and financial resources.

5.3 MAIN MALARIA ENTOMOLOGICAL INDICATORS

Along the continuum of transmission, national programmes should build a strong evidence base on the ecology, biology and bionomics of vectors, as identified by relevant entomological indicators. The priority and relevance of each indicator depends on the transmission setting and the current and planned interventions. Various methods and techniques are available for measurement (**Table 8**; **Annex 16**). Knowledge of these parameters is essential to characterize malaria transmission dynamics within a country in order to guide stratification and action (*38–40*). New or refined indicators and methods to measure them may be required as new vector control tools, technologies and approaches become available for use. (A research agenda for entomological surveillance may be required to guide the development of indicators as programme priorities change.)

TABLE 8.
Entomological surveillance indicators

NO.	INDICATOR	OUTCOME(S)	CALCULATION OR EXPLANATION
Adult vector composition			
1.1	Occurrence	Adult female vectors present or absent.	Presence of *Anopheles* species known to support the development of *Plasmodium* sporozoites. Requires correct identification of species.
1.2	Density	Number of adult female vectors collected, usually per sampling method and unit time.	Collection numbers are reported by individual sampling method or summed for all sampling methods.[a] Vector seasonality refers to changes in species abundance by season. Vector composition is the relative abundance of each species as a proportion of the total number of vectors collected.
Adult vector behaviour			
2.1	Human biting rate	Number of adult female vectors that attempt to feed or are freshly blood–fed, per person per unit time.	Number of female *Anopheles* vectors collected that were freshly blood–fed or attempted to feed per total number of units of collection. The units of collection depend on the sampling method; yields from human landing catches are reported per human per collection hour, and yields from CDC light traps, pyrethrum spray catches and window exit traps are reported per trap per night per number of human occupants in houses used for collection.
2.2	Human blood index (host preference)	Proportion of blood–fed adult female vectors that feed on humans.	Number of female *Anopheles* vectors that feed on human blood / total number of *Anopheles* vectors from which the blood meal was identified.
2.3	Biting time	Number of adult female vectors that attempt to feed or are freshly blood–fed, per person per unit time, usually expressed per 2–h increment.	As for "human biting rate" but reported for individual time increments. Numbers are compared by period to identify peak biting times.

NO.	INDICATOR	OUTCOME(S)	CALCULATION OR EXPLANATION
2.4	Biting location	Proportion of attempted bites or successful blood–feeds by adult female vectors indoors and outdoors, per unit time.	Simultaneous use of the same sampling method(s) indoors and outdoors for an indication of endophagy and exophagy. Endophagy index = number of *Anopheles* vectors biting indoors / [number biting indoors + number biting outdoors].[b]
2.5	Resting location (indoor resting density)	Proportion of adult female vectors collected resting indoors (and outdoors in structures sampled), usually per human–hour.	Simultaneous use of similar sampling method(s) indoors (including in houses and cattle sheds) and outdoors for an indication of endophily and exophily. Endophily index = number of *Anopheles* vectors collected resting indoors (indoor resting density) / [number resting indoors + number resting outdoors].[b]

Adult vector insecticide resistance[c,d]

NO.	INDICATOR	OUTCOME(S)	CALCULATION OR EXPLANATION
3.1	Resistance frequency	Proportion of adult female vectors alive after exposure to insecticide.	100% – (number of dead or incapacitated[e] *Anopheles* malaria vectors / total number exposed to a discriminating concentration of insecticide in standard bioassays[f]).
3.2	Resistance status	Classification of adult female vector populations as confirmed resistant, possibly resistant or susceptible.	Classification based on proportion of mosquitoes dead or incapacitated[e] after exposure to a discriminating concentration of insecticide in a standard bioassay[f], whereby: < 90% = confirmed resistance; 90–97% = possible resistance; ≥ 98% = susceptibility.
3.3	Resistance intensity	Classification of adult female vector populations as having high, moderate or low resistance.	Classification based on proportion of mosquitoes dead or incapacitated[e] after exposure to 5 x and 10 x intensity concentrations of an insecticide in a standard bioassay[f], whereby: < 98% after 10 x exposure = high-intensity resistance; ≥ 98% after 10 x exposure but < 98% after 5 x exposure = moderate intensity resistance; ≥ 98% after 10 x and 5 x exposure but < 98% after 1 x exposure = low-intensity resistance.

NO.	INDICATOR	OUTCOME(S)	CALCULATION OR EXPLANATION
3.4	Resistance mechanism(s)	Mechanisms detected or not detected in adult female vectors.	Based on detection of the mechanism by molecular or biochemical tests for molecular markers (e.g. *kdr*, *Ace-1R*) or enzyme profiles (e.g. mono-oxygenases, esterases, glutathione S-transferase). Outcomes and interpretation depend on the test used.[d]
		Full involvement, partial involvement or no involvement[g] of metabolic mechanism in observed resistance in adult female vectors.	Difference between (number of dead or incapacitated[e] *Anopheles* malaria vectors / total number exposed to a synergist plus insecticide) and (number of dead or incapacitated[e] *Anopheles* malaria vectors / total number exposed to insecticide only), whereby: ≥ 10% difference and synergist + insecticide ≥ 98% = full involvement; ≥ 10% difference and synergist + insecticide > insecticide only = partial involvement; or < 10% difference = no involvement.[h]
Immature vector aquatic habitats[i]			
4.1	Habitat availability	Number of aquatic habitats present and absent, by area and habitat type.	Number of potential habitats for *Anopheles* vector egg-laying and immature stage development identified in an area.
4.2	Habitat occupancy	Larvae and pupae present and absent, by area and habitat type.	Number of aquatic habitats found to harbour *Anopheles* vector larvae or pupae / number of potential habitats for *Anopheles* vector egg-laying and immature stage development in an area, by category of habitat.
4.3	Larval density	Number of immature vectors collected, by individual habitat.	Number of immature *Anopheles* vectors collected per dip, per person per unit time. Usually recorded by stage (I–IV instars and pupae) and by habitat and reported by stage category (early instar, late instar, pupae) for an area.

NO.	INDICATOR	OUTCOME(S)	CALCULATION OR EXPLANATION
Proxies for transmission			
5.1	Sporozoite rate	Proportion of adult female vectors with sporozoites in their salivary glands.	(Number of female *Anopheles* vectors identified as sporozoite positive / total number females *Anopheles* analysed) x 100. Indicates proportion of *Anopheles* vectors present and biting that are considered infectious.
5.2	Entomological inoculation rate	Number of infectious bites by adult female vectors per person per unit time, usually per year.	Calculated as: human biting rate x sporozoite rate from human landing catches or vector density x human biting rate x sporozoite rate based on CDC light trap collection. Reported per year, season, month or night. Yearly or seasonal EIR are best calculated by adding monthly EIRs in order to account for strong seasonality in transmission. Indicates intensity of malaria parasite transmission, but there are no standard protocols *(41)*.
5.3	Receptivity[k]	Classification of areas according to transmission risk.	Receptivity is a function of the presence of competent *Anopheles* vectors, a suitable climate and a susceptible human population, and is generally based on a combination of the indicators listed above. Various methods are used to assess receptivity; these are being reviewed by WHO to provide improved guidance on this topic.

Indicators 1.1–5.2 are reported for individual vector species. The purpose of surveys is to collect data on all the principal vectors and to include secondary vectors when possible.

A worked example for calculating the entomological indicators in **Table 8** is given in reference *42*

[a] The behavioural characteristics of vector species can bias the numbers collected by different sampling methods. Combination of the results obtained with a variety of sampling methods and comparison by relative abundance can mitigate some of the inherent bias.

[b] Exophagy or exophily index is 1 – endophagy or endophily index.

[c] Other indicators of resistance have been defined for adults and larvae that are not commonly used in routine surveillance, such as resistance level (i.e. concentration required to kill 50% or 95% of test mosquitoes, LD_{50} and LD_{95}) and resistance ratio (i.e. LD_{50} for test population / LD_{50} for susceptible strain).

[d] For further information, see reference *43*.

[e] The criteria depend on the testing procedure used (e.g. WHO susceptibility test or CDC bottle bioassay).

[f] With adjustment by Abbott's formula (*43*) as required.

[g] For synergist–insecticide bioassays

[h] Where ≥ 10% difference and synergist + insecticide < insecticide only = could not be reliably assessed.

[i] Relevant for areas in which LSM is being considered or applied as a supplementary intervention (i.e. where there are few, fixed and easily accessible larval habitats).

[j] Estimates of the probability of daily survival are also informative but are not captured during routine surveillance

[k] Additional assessments are required to refine the classifications of receptivity.

The main entomological indicators can be categorized into five groups:

- adult vector composition (species occurrence and density);

- adult vector behaviour (human blood index, human biting rate, biting time, biting location, resting location);

- adult vector resistance to insecticides (resistance frequency, status, intensity and mechanisms);

- immature vector aquatic habitats (habitat availability and occupancy, larval density); and

- proxies for transmission (sporozoite rate, entomological inoculation rate, receptivity)

Indicators are usually reported by individual vector species.

5.3.1 Adult vector composition and behaviour

Various sampling techniques can be used to measure an indicator, the appropriateness of which depends on the density and behaviour of the vector species (*44,45*). For example, the human biting rate can be derived using a number of methods (e.g. human landing catches, human–baited traps, human odour–baited traps, CO_2–baited traps and CDC light traps with a conversion; see **Table 9**). Vector preference for human hosts can then be determined by molecular or enzymatic analysis of blood–engorged mosquitoes to calculate the human blood index. In areas in which malaria vectors are endophagic and endophilic, they can be collected indoors with appropriate methods; however, in areas in which the majority of vectors exit houses after feeding (exophilic), collections of outdoor–resting mosquitoes provide the best estimate of the human blood index.

5.3.2 Adult vector resistance to insecticides

Monitoring of physiological resistance is essential and should be conducted across the continuum of malaria transmission (*43*). The vector control team and public health entomologist(s) of the NMP should prepare a national plan for monitoring and managing insecticide resistance (*46*) that includes an outline of where, when and how resistance will be monitored. Representative sentinel sites will be required, the location of which should be based on the eco-epidemiological stratification, the distribution of important vectors and the types of interventions and situations likely to promote resistance, such as intensive insecticide use in agriculture (see **section 5.2**). Where insecticide resistance has been confirmed, the intensity of resistance

and/or the underlying resistance mechanisms should be determined (*43*). Tests for insecticide resistance should usually be conducted with adult malaria vectors; however, tests may be conducted with larvae when chemical or biological agents are used or planned for use in larviciding. Knowledge of resistance mechanisms is important for understanding cross-resistance, which can occur even between insecticide classes with different modes of action due to target-site, metabolic or cuticular mechanisms. Understanding intensity of resistance and the mechanism involved is essential for making operational decisions, such as the choice of an alternative insecticide for IRS and rotation of insecticides with different modes of action for resistance management. Proper interpretation of data on insecticide resistance requires understanding of the biology and behavioural ecology of the local vector species responsible for transmission (including sibling species where *Anopheles* complexes occur) (*47–50*).

5.3.3 Immature vector aquatic habitats

A number of indicators have been defined that are relevant only to surveillance in areas in which LSM is being considered or used as a supplementary intervention. These include surveys of the presence of water bodies that may serve as *Anopheles* oviposition sites and the extent to which they support the development of *Anopheles* larvae and pupae. The frequency and timing of surveys for these indicators depends on the length of the malaria transmission season; the frequency usually ranges from weekly to monthly (*51*).

5.3.4 Proxies for transmission

Sporozoite rates and entomological inoculation rates are useful for estimating transmission intensity in settings where this information is lacking and where interventions are thought to have significantly decreased transmission. Sporozoite rates are useful for assessing the relative contribution of a particular vector species to malaria transmission, if this has not been established previously. Sporozoite rates also indicate the age structure of the vector population and, in operational research, can supplement estimates of survivorship from parity rates or ovarian dilatation to monitor the impact of interventions on transmission. The entomological inoculation rate is a measure of the intensity of malaria parasite transmission, which is the number of infective bites received per person in a given unit of time. It is generally not possible to measure sporozoite rates or entomological inoculation rates with any precision when transmission rates are very low, because of either low vector densities or low infection incidence rates.

Receptivity is one component of malariogenic potential, and a number of methods have been used to assess it. WHO is evaluating available evidence and approaches in order to provide improved guidance on the appropriate approach for classifying receptivity.

5.4 FREQUENCY OF SURVEYS

The frequency of vector sampling for measuring indicators depends on the question being posed and the available resources. The length of the transmission season and other environmental conditions that influence entomological parameters and malaria transmission should be considered. The frequency and timing of sampling should be standardized to minimize sampling bias when tracking temporal trends. Sampling is usually best undertaken during times of peak vector density and/or malaria parasite transmission. Further information on frequency by transmission setting is provided below.

5.5 PRIORITIES FOR ENTOMOLOGICAL SURVEILLANCE BY TRANSMISSION SETTING

Activities must be prioritized to inform programme decisions. Guidance specific for different malaria transmission settings is given in **Table 9**, including the interventions to be implemented or considered for implementation. The table (and **Annex 16**) includes mosquito sampling methods and analytical techniques for each entomological indicator.

5.5.1 High, moderate and low transmission

In settings of high-to-moderate transmission, the density of vectors and the intensity of transmission should be sufficient for calculating many of the entomological indicators listed in **Table 9.** In these areas, routine entomological surveillance can be conducted at sentinel sites monthly, quarterly or during peak transmission seasons, augmented by spot checks in areas with specific problems (as described in **section 5.2**). For instance, if high-intensity insecticide resistance is confirmed at one sentinel site, additional spot checks can be conducted in neighbouring areas to determine the extent of resistance. Similarly, if changes in vector species composition and/or behaviour are observed at a sentinel site, it may be useful to conduct spot checks in places where similar changes could be expected.

TABLE 9.

Routine entomological surveillance by priority in different malaria transmission settings, relevance, and appropriate vector sampling methods and analytical techniques

• High priority; o, moderate priority, depending on situation; –, low priority or not relevant; +, relevant.

NO.	INDICATOR	PRIORITY BY TRANSMISSION SETTING			RELEVANCE BY INTERVENTION(S) USED OR CONSIDERED				PREFERRED METHODS AND TECHNIQUES (SEE ANNEX 16)	
		High, moderate or low	Very low to elimination	Prevention of re-establishment	LLINs	IRS	Larval source management		Sampling method(s)	Analytical technique(s)
							Larviciding or biological control	Habitat manipulation or modification		
Adult vector composition										
1.1	Occurrence	•	•	•	+	+	+	+	1–12	A,B
1.2	Density	o	o[e]	–	+	+	+	+	1–12	A,B
Adult vector behaviour										
2.1	Human biting rate	o	o	–	+	+	–	–	2–5 (or 1 as proxy)	A,B
2.2	Human blood index	o	–	–	+	+	–	–	1–6	A,B,C,D
2.3	Biting time	o	o	–	+	–	–	–	2–5 (or 1 as proxy)	A,B
2.4	Biting location	•	o	–	+	–	–	–	2–5 (or 1 as proxy)	A,B
2.5	Resting location	•	o	–	–	+	–	–	7–10	A,B
Adult vector insecticide resistance										
3.1	Resistance frequency	•	•	o	+	+	+[h]	–	13 (or 2–12)[a]	A,B,E
3.2	Resistance status	•	•	o	+	+	–	–	13 (or 2–12)[a]	A,B,E

3.3	Resistance intensity	o[c]	o[c]	–	+	+	–	–	13 (or 2–12)[a]	A,B,F
3.4	Resistance mechanism(s)	o[c]	o[c]	–	+	+	–	–	13 (or 2–12)[a,b]	A,B,G,H
Immature vector aquatic habitats										
4.1	Habitat availability	o[d]	o[d]	o[d]	–	–	+	+		
4.2	Habitat occupancy	o[d]	o[d]	o[d]	–	–	+	+	13	A,B
4.3	Larval density	o[d]	o[d]	o[d]	–	–	+[g]	+	13	A,B
Proxies for transmission										
5.2	Sporozoite rate	o	o[e]	–	+	+	+	+	2–5 (or 1 as proxy)	A,B,I,J.K
5.3	Entomological inoculation rate	o	–	–	+	+	+	+	2–5 (or 1 as proxy)	A,B,I,J.K
5.4	Receptivity[f]	●	●	●	+	+	+	+	To be determined	

[a] Preferable to test adults reared from collected immature mosquitoes; if necessary, adult progeny from collected adult females can be tested.

[b] Depending on method, should test individuals confirmed as resistant in bioassays (E,F).

[c] High priority if vector control is to be targeted on the basis of resistance profiles, such as the addition of IRS to LLINs or use of pyrethroid plus piperonyl butoxide nets.

[d] High priority only if LSM is applied or is being considered as a supplementary intervention (i.e. where there are few, fixed and easily accessible larval habitats).

[e] High priority if an invasive species is being investigated in response to a resurgence of malaria or vector composition has changed, with a secondary vector species suspected of being of increased importance in transmission.

[f] Useful for stratification.

[g] Proportion of adult emergence from pupae should also be measured where insect growth regulators are used or being considered for use.

[h] For larvae, the usual measures are resistance level (i.e. concentration required to kill 50% or 95% of test mosquitoes, LD_{50} and LD_{95}) and resistance ratio (i.e. LD_{50} for test population / LD_{50} for susceptible strain).

In low-transmission areas, surveillance should be conducted at sentinel sites during the peak transmission season. Spot checks can be conducted in areas with persistent malaria, and consideration given to establishing sentinel sites in those areas. As the vector density may be low, it may be difficult to collect sufficient numbers of mosquitoes to test for multiple indicators, and careful prioritization will be required. Measures of human blood index, sporozoite rates and entomological inoculation rates are unreliable when there are few specimens, and they are less likely to be informative and actionable in such settings. Therefore, in these areas, vector species composition and the frequency and status of insecticide resistance are the highest priorities, as is assessment of relative receptivity.

The selection of surveillance sites becomes increasingly important as transmission decreases, as the key entomological parameters will become more heterogeneous. Surveillance should therefore be targeted on the basis of epidemiological data and local knowledge of malaria risk. Areas in which transmission patterns are changing (e.g. greater vulnerability due to a humanitarian crisis that has displaced human populations) must be identified, and entomological spot checks conducted to assess receptivity and to implement vector control accordingly.

5.5.2 Very low transmission and elimination

Routine entomological surveillance must be maintained in settings of very low transmission and elimination. Priority should be given to collecting information related to measuring receptivity, to determine where interventions may be required and to determine whether surveillance should be changed, such as relocating sentinel sites to ensure that they are in the optimal position to obtain the necessary information. Sentinel sites should be located where there is ongoing and/or a significant risk of transmission, which requires periodic appraisal of information and realignment of the surveillance strategy. Surveillance might have to be intensified in the event of new, resurgent and persistent transmission, by adding sites, more frequent surveillance or measurement of additional indicators. Spot checks will be required when routine surveillance does not provide adequate information or to obtain additional data on a specific situation or risk.

As transmission decreases over large areas with effective control, it will become more focalized, and, close to elimination, transmission will be limited to small foci. In these settings, in addition to routine entomological surveillance and spot checks, focus investigations that include entomological activities might be required (see **section 5.5**). The main purpose of such investigations is to clarify the nature of transmission in the focus to guide the appropriate response to interrupt malaria transmission, such as modification of vector control to enhance its effectiveness.

Additional entomological investigations are justified where there is a possibility of local transmission (i.e. indigenous or introduced cases) in foci where transmission had been interrupted, or in foci where transmission has been reduced to a very low level but there is an upsurge and insufficient entomological data have been collected by routine surveillance or spot checks within the previous 3 years.

In areas in which transmission has been interrupted, transmission foci may re-emerge due to factors related to vectors and/or interventions, including: lapses in vector control, such as low coverage or poor quality of implementation; changes in vector populations that render interventions less effective (e.g. avoidance behaviour, insecticide resistance); increased receptivity (e.g. increased vector density or survival due to environmental changes); or introduction of infectious vectors or invasive species that are efficient vectors. Focus investigations are required to determine which of these potential factors is the cause of resurgence of transmission and, once identified, to design an appropriate response to re-interrupt transmission.

The indicators to be measured in an entomological investigation in a transmission focus depend on local factors such as knowledge of local vector species and the availability, use and quality of interventions. Initial surveys should focus on the current vector control situation and include interviews with local residents to assess the coverage of interventions (i.e. access to and use of vector control measures). If LLINs are used, assessment of coverage should include the time since distribution. If IRS

BOX 9.

Countries undertaking elimination may consider using a tiered approach in focus investigations. The first step is to assess whether the cases are indigenous, introduced or imported. If they are indigenous or introduced, the next step is to determine whether the population at risk has access to and is using recommended, high-quality vector control interventions. If not, the immediate response should be to strengthen or re-deploy a core intervention (LLINs or IRS) and/or provide heath messages to increase community compliance. When the cases are indigenous or introduced and intervention coverage is high and/or there is limited entomological information, an entomological investigation should be conducted to determine the vector species involved, its susceptibility to the insecticides used for vector control and the relevant vector bionomics. If the malaria cases are imported, induced or relapsing, the only consideration is adequate coverage and the quality of vector control in the focus to prevent onward transmission (see **section 3.3**)

was performed, the assessment should take into account the time since houses in the area were last sprayed. If coverage of vector control interventions is low or has decreased significantly, population access to LLINs should be improved or IRS should be reintroduced. If effective coverage is readily restored, no further investigations may be required; however, if vector control coverage is found to be adequate, survey teams should assess whether human behaviour, such as late-night activities or sleeping away from the house, contribute to the risk of local transmission. If the population has activities that result in an increased risk of malaria, they should be informed about the risk and, when possible, given recommendations or interventions to reduce the risk.

If vector control coverage, use and quality are high and there are no late-night or other activities that might increase the risk of malaria transmission, entomological investigations should be conducted to verify the presence of vector species according to data on previous malaria transmission. For instance, if an active focus is located in a district or province for which there are no entomological data, an entomological investigation might be required to verify the vector species present (and its relative density, if possible). If a new vector species is identified, it may be necessary to determine its behaviour and the frequency and status of resistance to insecticides. Resistance should also be determined when high-intensity resistance is suspected or if there are multiple vector control options, such as different IRS formulations or pyrethroid plus piperonyl butoxide nets. In areas with vectors that are expected to be exophilic or exophagic, assessment of vector behaviour may be justified. Where LSM is used or being considered as a supplementary intervention, a detailed map of larval habitats will be a prerequisite for effective deployment of this intervention.

A more comprehensive entomological investigation may be warranted if there is an increase in either species of *Plasmodium* parasite, such as if a new case due to *P. falciparum* is found in a focus in an area where *P. vivax* was thought to be the only endemic malaria parasite species.

While data are required to inform an appropriate response, immediate programme action should not be delayed while waiting for the results of an entomological investigation. When possible, activities should be conducted in parallel to ensure the most efficient response. Further adjustments can be made to interventions as additional information becomes available. For more guidance on focus investigations see **section 3.4**.

5.5.3 Prevention of re-establishment of transmission

Malaria transmission may be a risk in areas in which there was previously transmission that was interrupted and in areas with no history of transmission. Plans and practical approaches for preventing the introduction or re-establishment of malaria should be developed on the basis of assessment of those risks, which are the combined effect of receptivity and vulnerability (see **section 7.4**).

Past entomological data can be a good baseline of information; priority should be given to determining the occurrence of vector species, with past data used to infer vector behaviour. Routine entomological surveillance and/or spot checks should be used in areas of high receptivity and/or high vulnerability, i.e. where the risk of re-establishment is significant. Areas in which there are anticipated increases in risk due to human activities should be included, such as those in which there are current or anticipated changes in population movement, land use,[3] environment and weather conditions, such as those that increase the availability of suitable habitats for malaria vectors, contact between humans and vectors or importation of vectors.

In the event of locally acquired cases and insufficient entomological data, spot checks will be required, as outlined above (**section 5.2**).

Threat of invasive species

Vigilant monitoring should be conducted in areas that are prone to or at high risk of invasive vector species,[4] as malariogenic potential can increase as a result of the introduction of species with high vectorial capacity. Better surveillance tools are required for early detection of invasive vector species to ensure rapid response and containment before these species become established in local environments and/or spread over wide areas. Priority locations include those at high risk of vector entry, such as major ports, railway stations and rest stops along transport routes to endemic countries.

If invasive vectors have been introduced, early detection of areas in which they are present is critical for rapid introduction of mitigation measures and local elimination of the species. Aggressive vector control, such as focal IRS and LSM to target adults and larval stages, will be required. In the early

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[3] Examples of land use change include deforestation and cultivation of natural swamps in the African highlands that resulted in conditions favourable to the survival of *An. gambiae*, deforestation in South America that led to increased populations of *An. darling* and *An. aquasalis* and reforestation in India and Southeast Asia that resulted in increases in the numbers of malaria cases due to *An. fluviatilis* and *An. dirus.*

[4] For example, *An. stephensi* was recorded for the first time in Sri Lanka in 2017, posing a potential challenge to the prevention of re-establishment of malaria in the country.

phase of mosquito colonization, when it is thought that invasive mosquitoes are still limited to small foci (generally considered to be around 1 km^2), countries should conduct entomological investigations in and around the colonized areas to guide and evaluate interventions to eliminate the invasive mosquitoes.

Where invasive mosquitoes have become established and can no longer be eliminated, the emphasis should be on prevention of disease outbreaks and further spread of the vectors. As there is only limited experience with the elimination of invasive mosquitoes, countries should carefully evaluate and document the activities undertaken and their impact, for the benefit of improving guidance in this area.

5.6 MONITORING OF VECTOR CONTROL

5.6.1 Implementation

Correct deployment of vector control interventions is necessary to ensure adequate coverage of the targeted populations. This requires appropriate strategies for distributing LLINs, timely and quality-controlled IRS, and correct application of larvicides, supported by the necessary information, education and communication activities. Monitoring of progress indicators on vector control implementation in terms of coverage, access and use is addressed elsewhere in this manual, as this information is usually obtained outside entomological surveillance systems and is part of routine programme monitoring (see **section 7**).

5.6.2 Quality control of products

Malaria vector control products with a prequalification listing that are compliant with WHO specifications[5] should be procured and used (*52*). Control of the quality of products is essential to minimize any risks associated with their handling and use and also to guarantee their efficacy and stability during storage. Inspection for quality control is conducted before shipment and in some cases after shipment. It involves collection of samples, appropriate storage of these samples until shipment to an independent certified or accredited laboratory, testing against WHO specifications when possible, and reporting by the selected laboratory. Further information is provided in the *Guidelines for procuring public health pesticides* (*53*).

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[5] WHO specifications define the essential chemical and physical properties associated with the efficacy and the risk of use of a product. When WHO specifications do not exist, any other relevant internationally accepted or national specifications should be considered.

5.6.3 Performance of vector control interventions

Post-marketing surveillance is required to monitor the performance of vector control products over time to ensure that they continue to conform to their specifications and/or the performance criteria in line with their recommendation by WHO. The assessment of vector control interventions includes the durability of LLIN products and the residual efficacy of IRS formulations in the field. Countries that have no data on the LLIN or IRS products used or have some evidence of the poor performance of certain products should make post-marketing surveillance a priority.

Programmes for the distribution of LLINs should periodically monitor their durability to ascertain their "survivorship" or attrition, physical and fabric integrity and insecticidal activity (bio-efficacy) during their expected use (usually 3 years). This is best done in a prospective study within a mass distribution campaign (*54*). Durability data can inform replacement strategies and behaviour-change activities aimed at increasing bednet longevity and impact.

The quality of IRS spraying is monitored in standard WHO cone assays conducted immediately after spraying and thereafter once a month during the expected duration of residual efficacy of the insecticide formulation. Any concern about poor quality should be relayed to the operational teams immediately. Remedial measures will depend on the findings of investigations of spraying quality; they may include closer supervision of spray teams, retraining of spray operators, verifying the quality of the IRS products used or respraying houses in the target area.

Where LSM is used, its impact should be determined by monitoring changes in vector density before and after implementation. This requires effective coordination of health officers, local leaders and the community and effective monitoring of any impact to ensure that current implementation represents effective use of resources.

Monitoring the quality of interventions usually draws on entomological capacity, such as in assessing bio-efficacy. Further details of quality assurance for LLINs, IRS and LSM are given elsewhere (*51,55,56*).

5.7 USE OF ENTOMOLOGICAL DATA IN PROGRAMME RESPONSE

Entomological data and information on interventions derived from routine surveillance should have a clear purpose in decision-making, and their use in planning and implementing vector control must be well defined and

efficient. Information on several parameters should be integrated with other relevant information, such as on epidemiological and environmental factors, to ensure a complete overview of transmission dynamics and drivers.

Examples of scenarios and potential means for incorporating information from entomological surveillance are given in **Table 10**.

TABLE 10.
Examples of actions that could be guided by entomological, vector control and other information

SCENARIO	HYPOTHESIS	SURVEILLANCE RESPONSE
Increase in the number of malaria cases despite good vector control coverage.	Loss of vector control effectiveness not due to poor coverage.	Check intervention quality. Determine vector composition (and behaviour if possible). Assess insecticide resistance.
Increase in vector abundance (or reports of biting) not due to seasonality.	Loss of vector control effectiveness due to unknown reason.	Check intervention coverage. Check intervention quality. Determine vector composition (and behaviour if possible). Assess insecticide resistance.
High coverage of pyrethroid-only LLINs, but increased frequency and/or intensity of resistance to pyrethroids detected recently.	A different or supplementary intervention needed urgently to preserve effectiveness of vector control.	Assess insecticide resistance mechanisms to determine whether pyrethroid plus piperonyl butoxide nets are an option (*57*). Assess frequency and status of resistance to non-pyrethroid insecticides to determine options for IRS.
Increase in number of cases and confirmed resistance to pyrethroids and insecticide class used in IRS.	Loss of vector control effectiveness due to resistance; a different or supplementary intervention urgently needed.	Assess frequency, status and mechanisms of resistance to non-pyrethroid insecticides to determine options for IRS rotation.
Vectors found resting inside LLINs in areas with high coverage and no increase in insecticide resistance.	LLINs not effective because of poor quality.	Assess bio-efficacy and fabric integrity of LLINs. Determine LLIN usage in area. Reassess frequency and status of resistance to insecticide used on LLINs.

SCENARIO	HYPOTHESIS	SURVEILLANCE RESPONSE
Vectors found resting on interior walls in areas where IRS was conducted < 3 months previously.	IRS not effective. Re-spraying with the same or different insecticide may be required.	Check spray records and process (including supervision). Check that walls have not been replastered or painted. Check IRS residual efficacy by cone bioassays. Assess frequency and status of resistance to the insecticide class sprayed and to alternative insecticide classes that may be used for respraying.
Malaria cases continue to occur despite lack of principal vector(s).	Vector previously considered 'secondary' or those thought as invasive vectors are maintaining transmission.	Assess vector species composition (and behaviour if possible). Determine sporozoite rates for all vector species.
Upsurge in malaria despite high coverage and quality of vector control and no change in insecticide resistance.	Changes in vector behaviour or invasive species may necessitate supplementary interventions.	Assess the composition of the vector species, particularly invasive species. Assess vector biting time and biting location.
Increase in number of malaria cases towards the end of the usual transmission season, despite high IRS coverage and quality, with environmental changes or anomalies observed.	Extension of transmission season may necessitate additional spray rounds or use of long-lasting IRS formulation.	Check IRS residual efficacy by cone bioassays. Assess the composition of the vector species to determine seasonality.
Vector habitats are being significantly altered by changes in land use or other environmental changes (e.g. flooding, development).	Receptivity may increase.	Assess vector species composition (and behaviour if possible).

6. Early warning, detection and response to malaria outbreaks and epidemics

6.1 DEFINITION AND CLASSIFICATION OF EPIDEMICS

A malaria epidemic is defined as a sharp increase in the incidence of malaria in populations in whom the disease is rare, or a seasonal increase in areas of low-to-moderate transmission over and above the normal pattern (*58*). The normal pattern is defined on the basis of a threshold computed from past data (see **section 6.5.4**). "Normal" occurrence can, however, be defined only for a particular population in a specific area and time. Therefore, malaria epidemics are generally considered to be disturbances of a previous epidemiological equilibrium (*59*). Epidemics in nonimmune populations often result in higher rates of morbidity and case fatality in all age groups than those in strongly seasonal transmission. An epidemic can also be a situation in which the malaria caseload exceeds the capacity of health care facilities to handle them in areas with a stable population and stable health service provision. In countries and territories that experience a sharp decrease in malaria incidence after intensive malaria control, the "normal" conditions from which epidemics are assessed also change and evolve with time (**Fig. 14**).

A malaria outbreak is often synonymous with a malaria epidemic; however, conventionally, outbreaks are epidemics with small caseloads (and, to avoid confusion, the term "epidemic" is used throughout this document) or a sudden occurrence of malaria in areas that had never experienced the disease before or had eliminated it and are limited geographically. While large epidemics are generally easy to define, small epidemics may be difficult to distinguish from expected seasonal and periodic variations.

Countries in which there are areas prone to epidemics or that are in transition from burden reduction to elimination should have an epidemic preparedness plan that is an integral part of a comprehensive national

strategic plan. The plan should clearly define the roles and responsibilities of different actors and describe the processes of forecasting, early warning and early detection, with specific expected actions at each stage and appropriate response activities.

FIG. 14.
Classification of epidemics and geographical areas in which epidemics most frequently occur

(a) *True epidemics:* Infrequent and cyclical outbreaks in relatively non-immune populations associated with climatic anomalies (mainly in arid and semi-arid zones such as eastern Kenya, Ethiopia, Somalia and Sahelian countries).

(b) *Strongly seasonal transmission:* Variable but relatively predictable transmission influenced by variations in climate, such as in the highland fringes and in the Sahel and southern Africa.

(c) *Neglect or breakdown of control:* In receptive areas in which malaria re-emerges after scaling down of control activities, e.g. in Madagascar, the former Soviet Republics and Sri Lanka.

Complex emergencies may lead to epidemics when transmission is exacerbated by natural disasters and conflicts that lead to breakdown of services and population movement. These may include classes (a), (b) and (c).

Adapted from reference *60*.

6.2 EPIDEMIC CURVES OF *P. FALCIPARUM* AND *P. VIVAX* MALARIA

The form of epidemic curves differs by parasite species, the entomological inoculation rate and the proportion of the human population that is susceptible (*61*) (**Fig. 15**). In *P. falciparum* malaria, the gametocytes appear in the peripheral blood an average of 10 days after detection of trophoxoites (ring form), extending its incubation interval to about 35 days. In *P. vivax* malaria, gametocytes and trophoxoites develop simultaneously, so that the incubation is shorter (20 days). Therefore, epidemics due to *P. vivax* build up faster than those due to *P. falciparum*. Minor epidemics due to *P. vivax* may occur outside the transmission season due to late relapses months after infection. Epidemics due to *P. malariae* and *P. ovale* are rare owing to their very low prevalence and long incubation period.

FIG. 15.
P. vivax and _P. falciparum_ epidemic curves
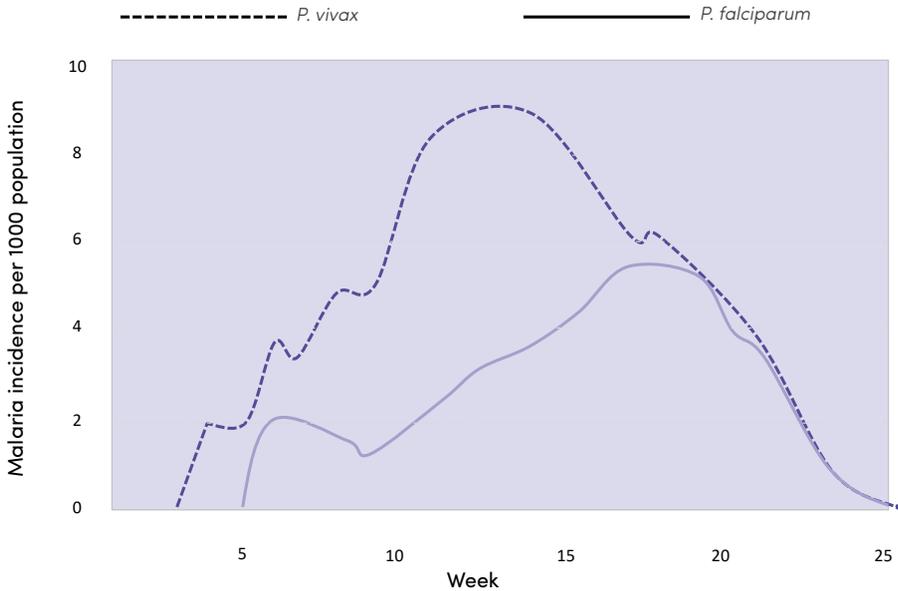
Adapted from reference *61*.

6.3 FACTORS THAT MAY CONTRIBUTE TO EPIDEMICS

The nature of malaria epidemics depends on the local epidemiology, health system and socioeconomic conditions, and these factors must be identified to ensure proper planning and response. Epidemics occur when the equilibrium between the rate of infection and the immunity of a population in a given area is disturbed or where prevention and treatment services are interrupted. Malaria epidemics do not usually occur in high-transmission areas because the population has partial immunity; however, migration of nonimmune people to these areas or breakdown of services leading to an increase in infection and severe disease in vulnerable subgroups may result in epidemics in high-transmission areas.

In summary, the following conditions make populations vulnerable to malaria epidemics:

- breakdown of prevention and treatment services, especially in highly receptive areas;

- migration of nonimmune people to areas with high malaria transmission;

- introduction of parasites and/or suitable vectors to receptive areas where transmission is low or inexistent and where the population therefore does not have a high degree of immunity;

- increased population vulnerability after a long period of drought (and famine) with no malaria transmission, followed by intensive rainfall and creation of suitable environmental conditions for epidemics; and

- resistance of the vectors and parasites to insecticides and drugs, respectively.

These conditions may be a consequence of both human-made and natural factors (**Fig. 16**).

FIG. 16.
Factors that contribute to epidemics

Human-made

Development activities

Examples
- Economic or development activities in forests that increase risks of infections.
- Agricultural irrigation, micro-dams, mining, logging, road construction.
- Poor or inappropriate water storage.
- Fast and unplanned urbanization.
- Human population movement.
- Overpopulation leading to increased pressure on land.

Breakdown of health services

Examples
- Loss or breakdown of epidemiological surveillance leading to delayed detection and inadequate response.
- Deterioration of health services (including malaria control activities).
- Increased parasite resistance to effective antimalarial medicines.
- Increased vector resistance to insecticides.

Natural

Natural disasters

Examples
- Earthquakes or cyclones leading to changes in habitat and population movements, increasing transmission and leading to infections in non-immune populations.
- Extreme drought leading to famine, increasing malnutrition and making individuals more susceptible to adverse outcomes when transmission resumes.

Climatic variations

Examples
- El Niño oscillations leading to unusual increases in rainfall, temperature and humidity may lead to rapid development of infective stages of *Plasmodium* in both aquatic and adult mosquitoes.

Information on potential contributing factors may be obtained from meteorological offices, data on population movement and displacement from local authorities and humanitarian agencies, data on infrastructure development from relevant ministries and the private sector and data on epidemiological and intervention efficacy from national surveillance systems.

6.4 DEFINITION OF AREAS THAT ARE PRONE TO EPIDEMICS

Identifying and mapping areas at high risk of epidemics in a country, both spatially and temporally, will maximize the capacity of a surveillance system to detect an unusual increase in the number of cases early and improve the preparedness of the national programme.

Factors that influence the density of anopheline mosquitoes, their distribution and biting behaviour, the species of parasite they transmit, the availability of infected human hosts, the size of nonimmune populations and their degree of exposure to infected mosquitoes all contribute to the risk of malaria epidemics. See **section 7.4** for more details on stratification.

The following are common characteristics of areas prone to malaria epidemics.

- The ecology of the area supports low, highly seasonal transmission, and the population has limited immunity. Anomalous climatic or epidemiological conditions could result in greatly increased transmission. Such areas include highlands and arid and semi-arid areas.

- The rate of parasite infection has been reduced by interventions, but receptivity remains high. A reduction in coverage, breakdown of the health system, loss of efficacy of interventions or increased importation rates may lead to a rebound.

- Sudden large-scale movement of infected populations into highly receptive areas or of nonimmune populations into areas of ongoing transmission due to conflicts or complex emergencies can result in an epidemic.

- Areas with immunologically naive populations undergoing rapid ecological (including human) changes such as deforestation, irrigation, construction of dams, flooding and earthquakes can experience epidemics.

6.5 SURVEILLANCE SYSTEM FOR EPIDEMICS

Surveillance of epidemics of infectious diseases comprises forecasting (long-range), early warning (medium-range), early detection (immediate), confirmation and response. For malaria, climatic and epidemiological parameters are used for forecasting, early warning and early detection of malaria epidemics (**Fig. 17**).

FIG. 17.
Model system for forecasting, early warning and early detection of epidemics

LONG-RANGE WEATHER FORECASTING:
- long lead times but little specificity
- warnings at national or regional scale

FLAG 1
Possible indicators: ENSO parameters, medium-range weather forecasts
Responses: Ensure that early warning and detection systems are operational; mobilize national resources.

SST threshold
Measured SST

EARLY WARNING FROM METEOROLOGICAL INDICATORS
- shorter lead times and better specificity
- warnings at district scale

Rainfall threshold

FLAG 2
Probable indicators: Meteorological parameters
Responses: Ensure that surveillance systems are functioning and local response reserves prepared.

EARLY DETECTION
- short lead times and very high specificity
- detection at sub-district scale

Case threshold

Recorded cases

FLAG 3
Indicators: Facility data
Responses: Epidemic control measures

EPIDEMIC

No. of malaria cases, magnitude of risk factors

Year 1   Year 2   Year 3   Year 4

Source: reference *62*
ENSO, El Niño southern oscillation; SST, sea surface temperature

6.5.1 Forecasting

Long-term forecasting can predict events 6–12 months or longer before the transmission season. It is based on information on cycles of climatic events such as the El Niño southern oscillation, which is a fluctuation of sea surface temperatures in the Pacific Ocean (El Niño) and in atmospheric pressure across the Pacific Basin (southern oscillation) that occurs in irregular cycles of 2–7 years and typically lasts for 12–18 months (*63*). El Niño is associated with hurricanes, floods and droughts, which affect human health. La Niña (cold events) are generally less pronounced than El Niño and have the opposite effects in most areas.

El Niño events sometimes lead to malaria epidemics (*64–66*). With improvements in climate science, El Niño events can now be predicted reasonably accurately (**Fig. 18**) and can therefore be used for broad prediction of months of epidemic risk in advance over large geographical areas or regions.

FIG. 18.
Southern oscillation index for the period January 1980 to May 2017
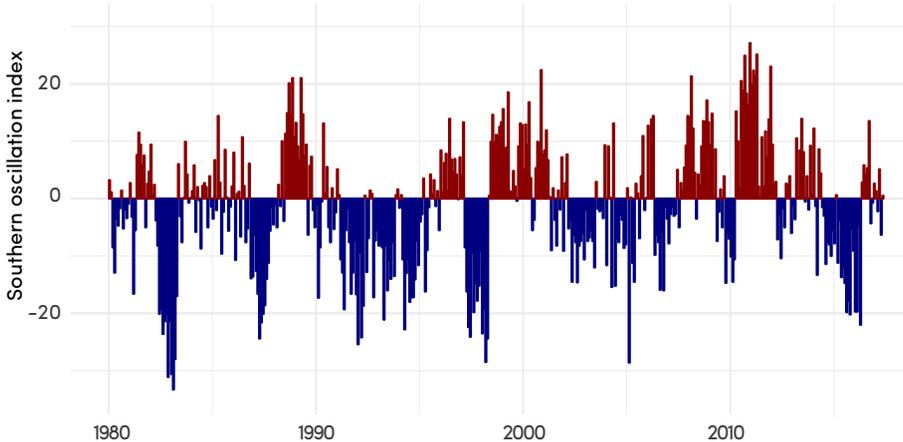
Source: reference *67*
El Niño events are associated with large negative values; La Niña events are associated with large positive values.

6.5.2 Early warning

Early warning systems rely mainly on the patterns of rainfall, humidity and temperature measured monthly or every 10 days. The warning is usually available 3 months before the transmission season. The data are available from meteorological departments and online climate libraries. **Fig. 19** shows an example of the association between climate and malaria epidemics. Other indicators that are useful in predicting the probable severity of an epidemic include mosquito and larval densities, nutritional status, drug and insecticide resistance, loss of immunity because of a recent reduction in population exposure and human population movements in and out of endemic areas (*68*).

It is during the early warning period that programmes should start more concrete planning, including:

• enhancing surveillance activities;

• increasing preventive measures;

• obtaining effective antimalarial drugs;

- ensuring that there are no stock-outs of diagnostics or drugs during the transmission season;

- ensuring that equipment (e.g. spray tanks) are in working order and response teams are well trained in insecticide spraying, LLIN distribution and other preventive and curative activities;

- informing local administrative authorities of the increased risk and ensuring funding;

- informing health workers and communities of the increased risk; and

- reactivating epidemic preparedness and response committees at national, provincial, district and lower levels to ensure readiness.

FIG. 19.
Example of associations between climatic parameters and malaria epidemics
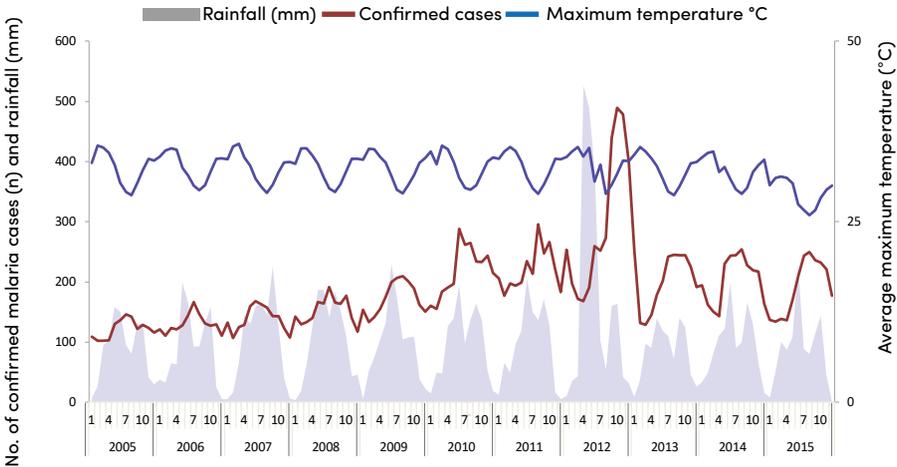
6.5.3 Early detection

Early detection requires recognition of the beginning of an epidemic by the observation of changes in local disease incidence or number of cases, mainly from surveillance data; the purpose is to detect the likelihood or the occurrence of an epidemic. There will be only a few days or at most 2 weeks to detect whether an epidemic is under way. Recognition is quickly followed by verification, and, if an epidemic is confirmed, response activities must be set in motion to avert or reduce excess morbidity and mortality (*69,70*). Epidemic thresholds that are appropriate to the epidemiological context of the area should determine their occurrence.

In epidemic-prone areas, where immunity is low, all age groups are at risk. If the majority of people attending most health facilities with fever and who are confirmed as having malaria are under 5 years of age or are pregnant, the region is probably endemic.

The most important data elements for monitoring epidemics are:

at all levels,

- weekly number of cases tested (RDT or microscopy),
- weekly number of cases positive (RDT or microscopy) and
- weekly test positivity rate; and,

in higher-level health facilities,

- weekly number of inpatient malaria cases (admissions) and
- weekly number of malaria deaths

Malaria epidemics escalate rapidly, with an average duration of 3–4 months. Monthly reporting cannot capture an upsurge of malaria cases at an early stage; therefore, the programme will be unable to deploy control resources quickly enough. As such, weekly reports on the above data elements are required to detect and control epidemics within 2 weeks of onset.

In elimination settings with high-quality case-based surveillance and rapid notification systems, epidemics are easier to detect early. The main requirement is that the right analytical system be in place to compare cases with the epidemic threshold and to send immediate alerts.

In most moderate-to-high-transmission countries with pockets of epidemic-prone areas, however, the HMIS often reports monthly aggregated data, which are not useful for early detection of an epidemic. In this situation, a more useful source might be data on both malaria and other febrile notifiable diseases like meningitis, cholera and yellow fever, which are reported weekly through the integrated diseases surveillance and response system. Other reporting of events, through the media, in the community or even rumours, may be used in the early detection of epidemics.

6.5.4 Epidemic threshold detection system

The epidemic threshold is the critical level at which the reported counts of cases or deaths in a given space and time are higher than would be considered "normal". This threshold is used to confirm the presence of an epidemic so as to accelerate appropriate control or response measures. The computation of an effective threshold requires the following:

- weekly data on confirmed malaria cases. Caution must be exercised where increased cases due to improved confirmation rates or access to health services;

- in epidemic-prone settings, the threshold that is specific to a given area or administrative unit, as malaria is highly focal (a national threshold should not be applied subnationally);

- at least 5 years of weekly data to define the expected "long-term" weekly caseload;

- as transmission decreases sharply due to recent interventions, removal of past data, which could bias trends;

- calculation of two thresholds: an alert threshold for early warning (less sensitive) and an epidemic threshold for early detection (highly sensitive); and

- exclusion of the year of interest from calculation of a threshold.

Several approaches, which are often complex, can be used to calculate thresholds. For operational purposes, the following relatively simple methods are recommended:

- constant case count,

- mean ± 2 SD,

- medium + upper third quartile and

- cumulative sum method

Where there are few data to estimate thresholds, an epidemic may be suspected from a noticeable, rapid increase in weekly numbers, a high case fatality ratio (due to late appropriate treatment at community level), overwhelming of health services (e.g. shortage of health staff and drugs) or closure of nearby health facilities. See **Table 11** and subsequent worked examples for details of the methods for computing epidemic thresholds. **Table 12** gives an example of weekly malaria data from 2011–2016 and **Fig. 20** shows the data plotted by the various methods for computing thresholds to assess whether an epidemic of malaria occurred in 2016.

TABLE 11.
Methods for calculating thresholds for early detection of malaria epidemics

METHOD	EXPLANATION	ADVANTAGE	DISADVANTAGE	REFERENCE
Constant case counts	On the basis of previous observations, an absolute count of cases per week in health facilities in a village or district can be used to alert to the initial stages of an epidemic and prompt action in the village or district. Different cut-off numbers can be used for different levels (district, province, national).	Simple to apply and communicate promptly at all levels. Appropriate in elimination settings with few cases.	The thresholds may be arbitrary and vary widely over time and place.	*70*
Mean + two standard deviations (2 SD)	The long-term mean of weekly malaria cases (derived from a minimum of 5 years of data, from which years with abnormal counts have been excluded) is calculated and an epidemic threshold set at twice the standard deviation of the mean. Once the weekly thresholds have been computed, the numbers are plotted on a graph against the year with an abnormal count (year of interest). Weeks in which the number of cases exceeded the mean + 2SD will be declared epidemic weeks.	Less sensitive to minor peaks and does not result in overreaction in stable transmission areas with minor seasonal fluctuations.	May miss important epidemics, especially in areas of low and very low transmission. Results are sensitive to years in which large numbers of cases were reported.	*71–73*
Median + upper third quartile	The median weekly value and the upper third quartile (75th percentile) are computed from a time series of weekly data. The threshold and the numbers of the year of interest are plotted on a graph, as for the mean + 2SD. If the third quartile (75th percentile) accommodates seasonal peaks poorly, the 85th percentile may be used. An initial alert should be sent out when the number of cases exceeds the median. An epidemic is declared if the number of cases is above the third quartile for 2 consecutive weeks.	Moderately sensitive and less influenced by years with abnormal counts, unlike the mean + 2SD Values are easier to calculate, as numbers are not weighted by facility.	May miss important epidemics, especially in areas of low and very low transmission or where malaria transmission has decreased rapidly	*71–73*

METHOD	EXPLANATION	ADVANTAGE	DISADVANTAGE	REFERENCE
Cumulative sum	The cumulative sum (C–SUM) method for epidemic detection is based on construction of an average or base year by calculating the expected number of cases from the average for that week (and the previous and following weeks) during the past 5 years. For example, the expected number of cases in March 2016 would be derived from the average of admissions in February, March and April of the years 2011–2015 inclusive (n=15). When a scientific calculator or computer is available, the method can be refined by adding the 95% confidence interval (1.96 times the standard deviation) for each value of the base year.	An advantage of the C–SUM method is that it smoothes out artificial variations in weekly reported data that are due to late reporting and other errors inherent to the surveillance system. Highly sensitive and can identify even minor epidemics. Most suitable in very low-transmission settings where elimination activities are initiated, and any resurgence is recognized as an epidemic Values are easier to calculate, as numbers are not weighted by facility.	Very sensitive and may raise false alarm in areas of moderate transmission with frequent epidemics. Less suitable for settings with highly seasonal malaria.	*71–73*

TABLE 12.

Weekly numbers of confirmed malaria cases and thresholds for the period 2011–2015 as compared with the trends for 2016 (year of interest) in a district of country X

WEEK	2011	2012	2013	2014	2015	2016 (EPIDEMIC YEAR)	MEAN + 2 SD	THIRD QUARTILE	C-SUM
1	402	304	1750	1,125	300	341	1420	1125	801
2	559	331	1500	1350	276	640	1383	1350	807
3	509	446	1500	1502	251	1308	1451	1500	720
4	399	470	353	744	616	341	678	616	727
5	1232	466	362	1319	743	640	1260	1232	649
6	611	490	505	884	550	704	769	611	651
7	714	100	434	706	653	1959	783	706	648
8	1290	704	476	1007	606	1987	1146	1007	818
9	2311	1190	485	797	800	2784	1830	1190	914
10	373	1461	461	849	902	2706	1241	902	855
11	325	647	583	567	1069	2564	908	647	645
12	567	–	580	556	736	3520	770	580	535
13	402	304	300	649	735		680	649	477
14	559	331	275	555	612		619	559	505
15	509	446	503	747	655		696	655	518
16	399	470	353	744	616		678	616	638
17	1232	466	362	1319	743		1260	1232	577
18	256	490	505	145	550		567	505	578
19	714	100	434	706	653		783	706	576
20	1290	704	476	1007	606		1146	1007	909
21	2311	1190	485	797	2165		2205	2165	1114
22	373	1461	461	849	2540		2031	1461	1055
23	325	647	583	567	1069		908	647	754
24	567	–	580	556	736		770	580	535
25	402	304	300	649	735		680	649	477
26	559	331	275	555	612		619	559	505
27	509	446	503	747	655		696	655	518
28	399	470	353	744	616		678	616	638
29	1232	466	362	1319	743		1260	1232	649
30	611	490	505	884	550		769	611	651
31	714	100	434	706	653		783	706	648
32	1290	704	476	1007	606		1146	1007	909
33	2311	1190	485	797	2165		2205	2165	1114
34	373	1461	461	849	2540		2031	1461	1055
35	325	647	583	567	1069		908	647	754
36	567	–	580	556	736		770	580	535
37	402	304	300	649	735		680	649	477
38	559	331	275	555	612		619	559	505
39	509	446	503	747	655		696	655	518
40	399	470	353	744	616		678	616	638
41	1232	466	362	1319	743		1260	1232	649
42	611	490	505	884	550		769	611	651
43	714	100	434	706	653		783	706	648
44	1290	704	476	1007	606		1146	1007	909
45	2311	1190	485	797	2165		2205	2165	1114
46	373	1461	461	849	2540		2031	1461	1055
47	325	647	583	567	1069		908	647	754
48	567	–	580	556	736		770	580	535
49	402	304	300	649	735		680	649	477
50	559	331	275	555	612		619	559	505
51	509	446	503	747	655		696	655	518
52	399	470	353	744	616		678	616	638
53	1232	466	362	1319	743		1260	1232	706

SD, standard deviation; C-sum, cumulative sum

FIG. 20.

Epidemic thresholds for 2011–2015 as compared with the suspected epidemic year 2016 from data in Table 12.
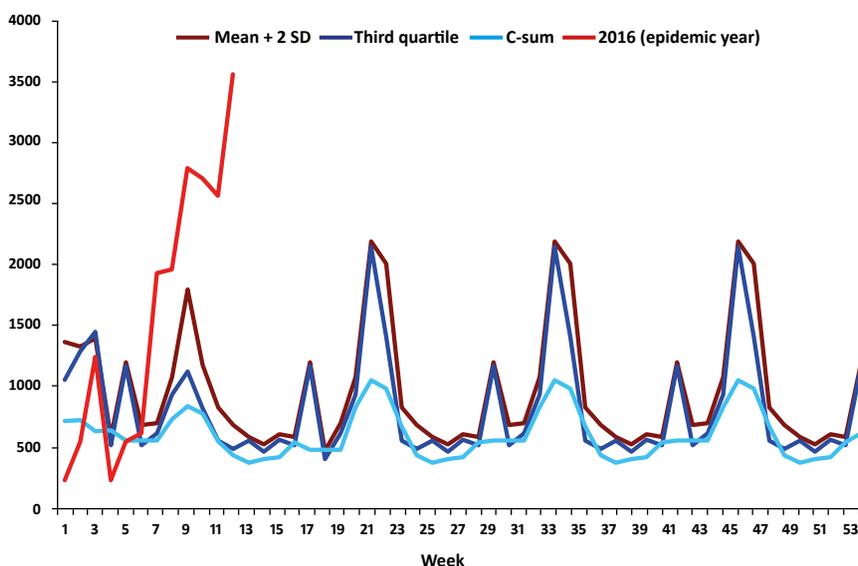
Cumulative sum is clearly the most sensitive threshold, followed by the third quartile and then mean + 2 SD. If the district staff were to use the cumulative sum, all the seasonal peaks would be categorized as epidemic. This method should therefore be used only in areas where small increases in the number of malaria cases may be considered an epidemic, as in low transmission settings.

In calculating a numerical threshold, it is important to control for wide variation in case counts that results from counting small catchment areas or short periods, such as weekly reporting from village health clinics. Other factors that can affect case counts are changes in diagnostic methods, the availability of treatment, introduction of new service providers such as CHWs and changes in reporting systems.

The threshold should be "smoothed" so that it does not change substantially from week to week. When an area has roughly the same number of cases over several weeks, a jagged alert threshold might result in on-and-off alerts that are potentially costly to investigate and erode confidence in the system.

In countries in which the prevalence of malaria is spatially highly variable, the method used to calculate the threshold should suit the underlying epidemiology of each area.

6.5.5 Verification of a malaria epidemic

A district management team or equivalent should be established in epidemic-prone areas. The team should comprise a medical officer, an epidemiologist, an entomologist and a trained laboratory technician to verify cases in the field. In areas where coverage of parasitological diagnosis is poor, malaria is often confused with other causes of fever, and additional confirmation in the field may be required to ensure that the reported fevers are the result of malaria infections. Verification of a malaria epidemic may be combined with confirmation of other notifiable febrile diseases to ensure quick response to those diseases as well. The steps in verification of a detected malaria epidemic are:

- rapid assessment to confirm that an unusual increase in the number of fever cases is due to malaria;

- laboratory investigation to confirm suspected cases with RDT or microscopy;

- in areas without recent data or the suspicion of new vector species larval and or adult mosquito surveillance is implemented to determine vector control response; and

- immediate notification to the national emergency unit by the district or equivalent monitoring centre if the team determines that there is an epidemic.

6.6 PREPAREDNESS AND RESPONSE

Epidemic preparedness is undertaken at all levels of the health system.

At national level (flags 1 and 2 in **Fig. 17**):

- use long-range forecasting (information) for preparedness in epidemic-prone areas, with resource mobilization and engagement of partners;

- coordinate and ensure intersectoral collaboration;

- strengthen the capacity of health workers to analyse and verify data;

- ensure that emergency stocks of medicines are available and can be transported to the epidemic area; and

- for a predicted epidemic, dispatch an assessment team. An example of a questionnaire for pre-epidemic assessment is given in **Annex 18**.

At district or intermediate level (flag 2 in **Fig. 17**):

- compile data and establish or update thresholds; and
- conduct entomological assessment if necessary, correlate epidemiological data with other relevant indicators, such as meteorological data, population movement or socioeconomic activities.

At peripheral health facility level (flag 3 in **Fig. 17**):

- establish a weekly reporting system;
- conduct simple analysis and graphing of weekly data, including notification to the district management team; and
- conduct quick verification with either microscopy or RDTs.

The response will depend on the stage at which the epidemic is detected, but in general the aim is to reduce transmission and mortality by treating those who are infected and preventing new infections. Access to early diagnosis and effective treatment of all malaria patients will minimize mortality. The guiding principles of treatment during epidemics are as follows:

- to reduce onward transmission:
  - o use a drug that is gametocidal;
  - o use MDA with a long-acting drug, if feasible, to reduce transmission, with good acceptability and compliance and high coverage > 80%. MDA should only be used under certain conditions (see the WHO recommendations and mass drug administration field manual (*23*)).
  - o use radical cure with primaquine (14-day regimen) in epidemics due to *P. vivax*.
- to reduce mortality:
  - o consider mass fever treatment if MDA is not appropriate;
  - o if the epidemic occurs in a remote area with poor access to health care, establish new or temporary health posts (mobile clinics);
  - o ensure early management of severe cases either at peripheral level (early pre-referral or full treatment) or in referral health facilities; and

o   in epidemics in complex emergency situations, malnutrition and other co-morbid conditions should be managed during malaria case management.

For early vector control, target adult mosquitoes to reduce transmission.

- Operationally, vector control options are viable if epidemic-prone districts are well prepared and emergency stocks are pre-disposed and maintained.

- Biologically, they are feasible when implemented at an early stage of an epidemic.

- IRS is feasible when well conducted, with > 85% coverage rate, and the vector rests indoors. IRS can be conducted within 2 weeks of epidemic onset. Similarly, use of ITNs is feasible but requires prior behavioural change in the community while recognizing that the impact is less immediate than IRS.

- In complex emergency situations, where refugee camps can be established, use of ITNs and IRS in available structures are highly effective. In some situations, larval habitats are readily identified, and appropriate larval source reduction can be used.

Malaria epidemics may affect several countries or territories within a country at the same time. Therefore, exchange of information and data should be part of the response. Examples of operational responses to different stages of malaria epidemics are given in **Annex 18**.

6.7 POST-EPIDEMIC ASSESSMENT

A post-epidemic assessment will identify successes and failures of interventions and indicate whether the early warning, detection and response systems have had the expected impact on the burden of malaria. This important exercise is frequently neglected by ministries of health and partners. Thus, lessons are not learnt for use in the event of another epidemic. The results of a post-epidemic assessment are used to improve the preparedness plan and to advocate for the necessary support at all levels of the response. Therefore, the post-epidemic report should be widely distributed to higher levels.

A post-epidemic working group, comprising an epidemiologist, an entomologist, a clinician, a laboratory technician and a statistician from district and national levels, should be set up to assess events retrospectively. The assessment addresses the impact, the response,

verification, early detection, early warning and forecasting, in that order. The working group should examine:

- the effectiveness of the early warning and detection systems,
- the availability of resources and capacity,
- the roles and responsibilities of stakeholders during and after the epidemic,
- the cost of the response and
- the impact of the epidemic and of the interventions.

An example of a checklist for a post-epidemic assessment is provided in **Annex 18** and one for a quick assessment report in **Annex 19**. **Fig. 21** illustrates the process of early detection, verification, response and post-epidemic assessment.

FIG. 21.
Early detection, verification, response and post-epidemic assessment
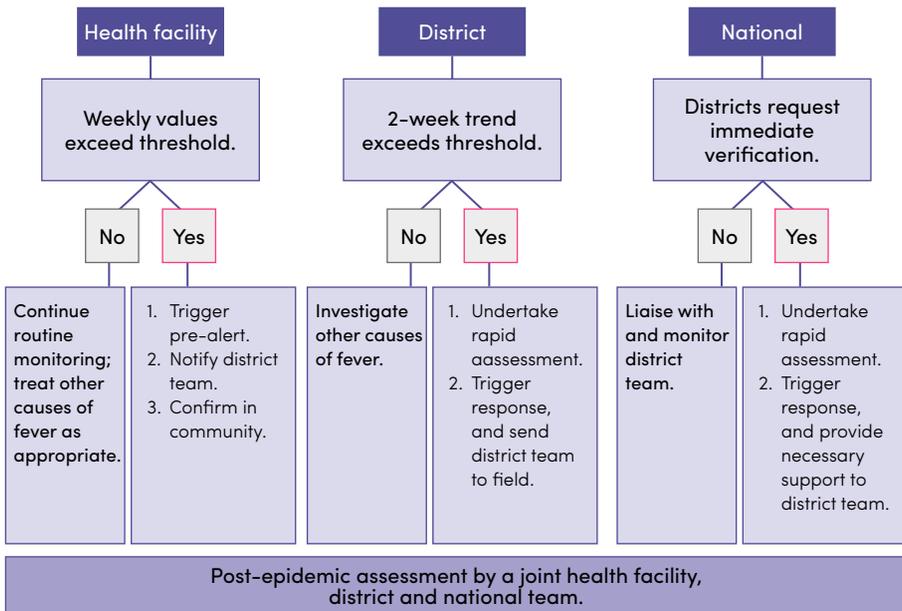
7. Monitoring and evaluation of national programmes

7.1 AIMS OF MONITORING AND EVALUATION

"Monitoring" is the gathering and use of data on programme implementation (weekly, monthly, quarterly or annually); its aim is to ensure that programmes are working satisfactorily and to make adjustments if necessary. Monitoring often includes use of administrative data to track inputs, processes and outputs; programme outcomes and impacts may also be included. "Evaluation" involves a more comprehensive assessment of a programme; it is normally undertaken at discrete times and addresses the longer-term outcomes and impacts of programmes. The goal of monitoring and evaluation is to improve the effectiveness, efficiency and equity of programmes. They are critical to achieving the goals of national programmes and tracking progress towards the objectives of the GTS (*5*). Once the malaria situation in a country or area has been assessed, plans are made to ensure the most effective use of resources to either eliminate malaria or reduce its public health impact. As plans are implemented, they should be reviewed periodically to determine whether the programme activities are achieving the desired outcomes or whether they should be adjusted (**Fig. 22**).

High-quality, timely information is essential for programme planning and implementation, and the information can also be used to lobby internal and external stakeholders for the necessary resources. The performance of malaria programmes can also be improved by making information on programme planning and monitoring more widely accessible. Public disclosure of information allows politicians, patients and other citizens to monitor the services they are financing and encourages managers to be more responsive to their clients' needs (see **Box 10**).

The primary purpose of collecting data on malaria programmes is for decision-making and action at the local level. Information generated at country level is also used to inform progress at international level, through reports produced by WHO and the United Nations. The data inform international financiers of malaria programmes and are an important determinant of future funding.

FIG. 22.
Monitoring and evaluation framework: from input to impact

Inputs	Process	Outputs	Outcomes	Impact
Financial, human, information and other resources mobilized to support activities.	Action or work to convert inputs into outputs.	Services resulting from converting inputs into outputs, e.g. RDTs, ACTs, LLINs, surveillance, staff.	Use of outputs by targeted population, e.g. people with suspected malaria receive a diagnostic test or sleep under LLINs.	Reduction in, e.g. cases of severe malaria, deaths from malaria.
Budgets, staffing, health facilities, medicines and other resources.	Delivery of supplies, staff training, supervision, logistics management systems.	Goods and services produced and delivered by main implementing agency and partners.	Programme, surveillance, surveys and census data to measure outcomes.	Analysis of surveillance, surveys, census and other contextual data to measure outcomes.

Implementation (supply)	Results (supply and demand)

ACT, artemisinin–based combination therapy; RDT, rapid diagnostic test; LLIN, long-lasting insecticidal net

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BOX 10.
Major functions of monitoring and evaluation

Monitoring and evaluation can accelerate progress towards malaria elimination if used to:

- regularly assess whether plans are progressing as expected or whether adjustments are required to the scale of the intervention or combination of interventions;

- allocate resources to the populations most in need in order to achieve the greatest possible public health impact;

- account for the funding received to allow the public, their elected representatives and donors to determine whether they are obtaining value for money;

- evaluate whether the programme objectives have been met and to learn what has worked and what has not, so that more efficient, effective programmes can be designed;

- advocate for investment in malaria programmes in accordance with the malaria disease burden in a country or subnational area; and

- track progress toward elimination.

7.2 TYPES OF INFORMATION REQUIRED FOR MONITORING

Information may be informal, semi-formal or formal.

- Informal information is learnt by observation, talking to health staff or community leaders and other informal means.

- Semi-formal information is obtained, for example, from policy documents, consultants' reports, supervisory visits, focus group discussions, official circulars and minutes of meetings.

- Formal information is acquired from ordered systems for recording and reporting information, such as routine health information and surveillance systems, accounting systems and surveys.

Formal information for programme monitoring can be obtained from:

- routine health information systems, which may either cover a number of programmes, be specific to malaria or be limited to certain activities (e.g. laboratory services, interventions, distribution, surveillance);

- health facility surveys, which usually address whether facilities have the physical and human resources necessary to provide services (especially chemoprevention, diagnostic testing and treatment), and may include whether patients receive diagnostic testing and appropriate treatment;

- household surveys, which usually cover several health interventions, especially for children under 5 years of age and women of reproductive age, although malaria-specific surveys are also common;

- operational research, which usually addresses specific questions of relevance to the malaria programme, may rely on household or health facility surveys and may include studies of drug or insecticide efficacy;

- entomological surveillance, for understanding the distribution of the main malaria vectors, their behaviour and changes in their biting habits in response to the intervention; part of sentinel surveillance by national programmes and often including vector resistance to insecticides;

- data from supervision of health services (central, intermediate, health facility and health worker levels); and

- contextual data, which are not collected routinely or during operational research but are useful for further understanding and explanation of changing trends in the malaria burden. They include population censuses and climate and socioeconomic data.

Data for programme monitoring are usually obtained from routine health information systems and programme data for continuous monitoring. Data from health facility and household surveys may complement those from routine systems (e.g. to compare values of indicators obtained in routine systems and health facility surveys). When routine systems work well, they can provide information continuously from every district or equivalent in a country, and, if other factors are constant, they can be used to detect changes in intervention coverage over time and space or serve as alerts for a possible epidemic.

Incomplete coverage of health information systems can result in a biased sample of the services used by communities (see **Box 1** and **Box 3**). Often, they do not include private clinics and other nongovernment facilities or cases treated by village health workers or at home. In addition, routine systems seldom function optimally; there is often inconsistent application of reporting definitions and irregular reporting from health facilities and districts to central level. Trends in indicators of intervention coverage are therefore prone to variations in reporting rates. It is important to track the completeness of reporting, not only as an indicator of the functioning of the information system but also for interpreting trends in other indicators.

7.3 ROLES OF ROUTINE SYSTEMS AND SURVEYS

Many data sources are used in monitoring and evaluating NMPs, including routine information systems, household and health facility surveys, sentinel sites and special data collection (**Box 11**). The role and relative importance of these data sources change as programmes proceed from high transmission to malaria elimination.

BOX 11.
Information obtained from routine health information systems, health facility surveys and household surveys

Routine health information systems capture information on:

- health facility resources,
- use of health services and disease trends and patients treated by CHWs and
- distribution of commodities such as LLINs.

Health facility surveys provide information on:

- the availability of staff, equipment and consumables;

- verification of health facility service statistics (proportion of patients tested and treated with appropriate antimalarial medicines); and

- the quality of case management.

Household surveys capture information on:

- population coverage of services (e.g. LLIN, ACTs);

- patients who do not use government health services;

- population prevalence of infection or anaemia; and

- knowledge, attitude and practices with regard to malaria.

Sentinel sites and special studies provide information on:

- treatment efficacy,

- entomological surveillance and

- demographic surveillance

7.3.1 Routine systems

In high-transmission settings, malaria accounts for a large proportion of attendance at health services, and malaria information systems are necessarily embedded within integrated HMIS. Simple, efficient recording and reporting systems are required to track vector control activities, notably ITN distribution and IRS coverage. Systems are also required to track resistance to insecticides and antimalarial drugs. In settings with lower transmission or seeking to achieve elimination, malaria-specific reporting systems are required for the additional information demands for targeting and monitoring interventions in particular risk groups and foci.

7.3.2 Surveys

Information obtained from routine information systems is complemented by data from health facility and household surveys. Surveys can provide data on indicators that cannot be measured from programme data, particularly for indicators that require population-level denominators, such as coverage of interventions and parasite prevalence. Surveys can enrich the interpretation of information from routine systems, such as in ascertaining the percentage of patients with a febrile illness who attend public sector health facilities, thus providing information on the coverage of surveillance systems. Surveys may also be used to validate or triangulate

data collected in routine systems. They also provide information on child mortality from all causes, which can be related to trends in malaria interventions, incidence and parasite prevalence to illustrate the potential impact of investment in malaria.

The design of surveys depends on the intensity of malaria transmission. In high-transmission settings, nationally representative surveys allow assessment of programme coverage and parasite prevalence throughout the country. In settings with lower transmission, it may be preferable to survey only the populations at greatest risk. Surveys in elimination settings should be limited to foci of transmission.

The relevance of indicators and the feasibility of obtaining particular information through a survey also depend on malaria transmission intensity. For example, the prevalence of parasites among children under the age of 5 years is a relevant indicator in high-transmission settings because they are at high risk for acquiring malaria. It is also practical to obtain information on children under 5 years because they are more likely to be at home during a household survey and available for a malaria test. In low-transmission settings, measuring parasite prevalence in children under 5 years of age may be less informative because, in general, these children are not a high-risk group. It may therefore be preferable to determine the prevalence in all age groups in these settings, although it might be more difficult to obtain a representative sample of schoolchildren and working adults, because they may not be at home when a survey is done. When transmission is low, however, a much larger sample is required to measure prevalence, and household surveys are no longer cost-effective. The incidence of symptomatic cases is therefore determined from routine health information systems.

A decision about whether to measure parasite prevalence and in which age groups depends on the potential benefits of obtaining the information and thus more precisely identifying the population groups most affected by malaria. These benefits should be weighed against the cost of the survey (i.e. the large sample required), the available diagnostic tools, whether particular population groups can be reached and the other uses to which such resources could be put.

7.4 USE OF INFORMATION AT NATIONAL LEVEL

Malaria control may progress more rapidly in some parts of a country than in others, and the strategies for surveillance will vary. For example, some districts may report only aggregated cases, while others may add details of individual cases. Some parts of the country may be pursuing elimination and must identify the origin of each case in order to intensify control

measures in specific localities and ensure that transmission is halted at the earliest possibly opportunity.

The information collected must be used to improve the impact of the programme. Two major uses of this information are for planning programmes and for monitoring and evaluating them.

7.4.1 Programme planning

A principal use of information is in preparing a national strategic plan that defines the goals and objectives of a malaria programme, how they will be achieved and the resources required. The plan should include the roles of different stakeholders in its implementation and set targets for monitoring progress and ensuring accountability. Resources should be allocated to the most effective interventions and to the populations in greatest need in order to maximize reductions in malaria incidence and mortality and minimize wastage of resources. One approach to optimizing responses to malaria in a country or territory is stratification, whereby the area is divided into smaller units in which different combinations of interventions are delivered.

A strategic plan for malaria typically covers 5 years (**Fig. 23**). It is usually preceded by a review of the malaria situation in the country, to identify the population groups most severely affected by malaria, changes in disease incidence, coverage of malaria interventions and the resources required and available for achieving the targets, as discussed below.

FIG. 23.
Timeframe of a national strategic plan for malaria and programme reviews
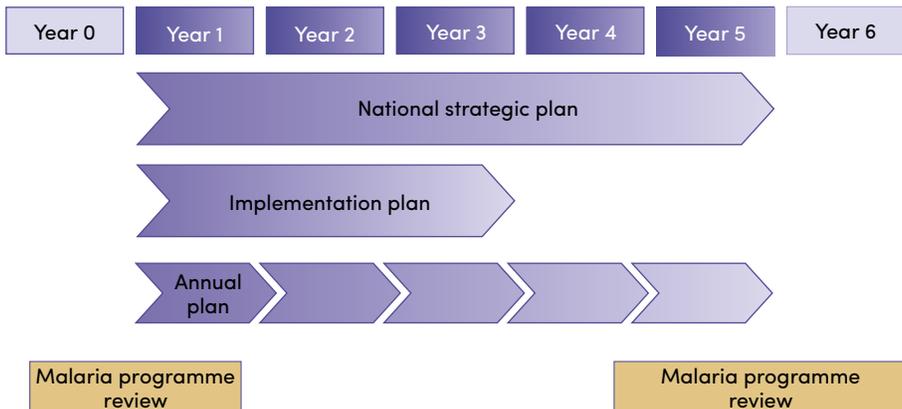
Stratification and population at risk

The purpose of stratification is to identify the population groups most severely affected by malaria, the determinants of the malaria risks to which they are exposed in order to target appropriately malaria interventions. Stratification involves identifying the extent of malaria transmission in space and time and the population at risk at any given place or time to better target interventions.

Stratification may require indicators such as parasite prevalence, reported cases, annual parasite incidence and test positivity rates; temperature, rainfall and seasonality; socioeconomic conditions (e.g. poverty and occupation); demographic factors (e.g. age and gender); and access to health care (**Fig. 24**). Countries usually use a combination of epidemiological, climatic and environmental data for such stratification *(74)*. This information can be presented as tables, graphs and maps.

The usefulness of the data described in this framework (**Fig. 24**) depends on the country context. Often, knowledge of the vector species and its distribution, proportion of population infected, trends in and seasonality of cases and data on rainfall and temperature are sufficient to define areas at risk of malaria.

FIG. 24.
Framework for stratifying malaria risk
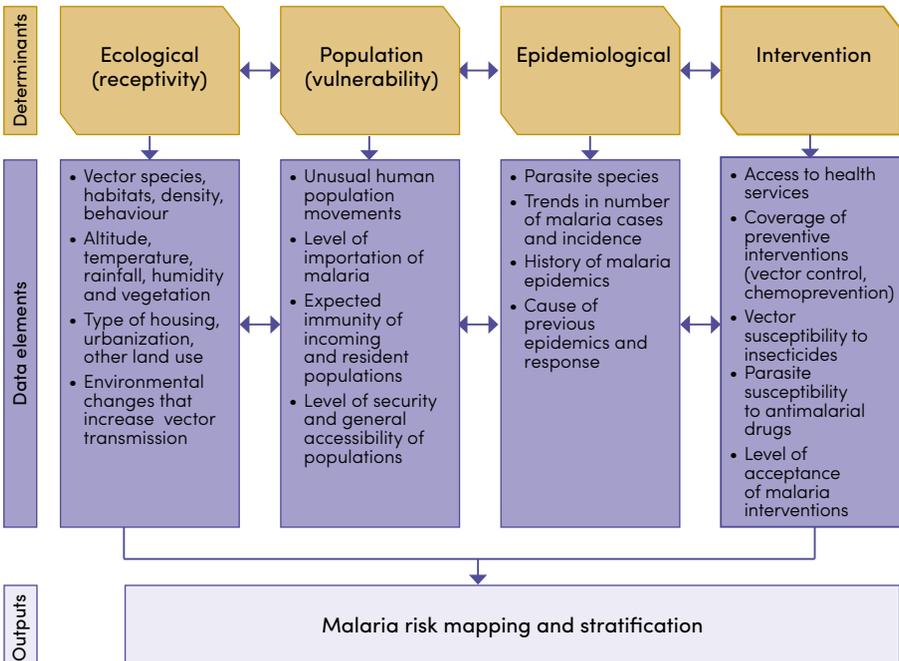
In elimination settings with a high-quality surveillance system, analysis of case data and receptivity may be all that is needed to stratify focal transmission. Foci may then be stratified as: with active transmission; receptive and vulnerable; receptive but not vulnerable; and not receptive. Data and potential sources of data for stratifying malaria risk are listed in **Table 13**.

Understandably, malaria risks are affected by highly variable situations such as conflicts and complex emergencies that may lead to epidemics. These require a more dynamic approach, with several data elements for key determinants. Common GIS methods can be used to map epidemic risk with this framework. National programmes that do not have GIS capacity should consult WHO and local partners for assistance.

An example of stratification of annual parasite incidence in a province and in districts in the Lao People's Democratic Republic is shown in **Fig. 25**.

FIG. 25.
District-level stratification by annual parasite incidence in 2017 in Lao People's Democratic Republic

To further demonstrate heterogeneity of annual parasite incidence within a province, the example of districts within Champasak province is presented (inset).

API per 1000 population
- 0–0
- 0–10
- 10–20
- 20–30
- 30–40
- 40–50
- > 50

API per 1000 population
- 0–1
- 1–3
- 3–5
- 5–7
- > 7
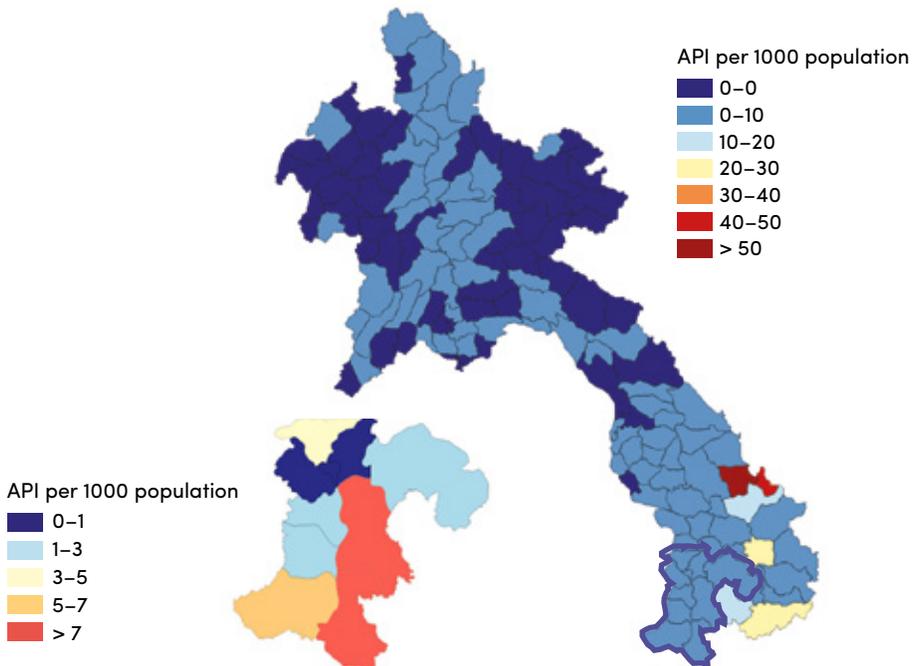
Source: Mekong Malaria Elimination Regional Database
API, annual parasite incidence

TABLE 13.
Data elements and potential sources of data for stratifying malaria risk

DETERMINANT	DATA ELEMENT	DATA SOURCE
Ecological (receptivity)	Vector species, habitat, density	Entomological surveillance data
	Altitude, temperature, rainfall, humidity and vegetation	Meteorological offices, freely available satellite data
	Type of housing, urbanization	Household surveys, national censuses, relevant government ministries
	Environmental changes that may increase transmission	Environmental agencies, satellite data, private sector, local communities
Population (vulnerability)	Unusual human population movement	Relevant government ministries, humanitarian agencies, local communities
	Level of importation of malaria	Surveillance data, humanitarian agencies, local communities
	Expected immunity of incoming and resident populations	Surveillance data, research institutions, malaria transmission maps
	Level of security and general accessibility of populations	Relevant government ministries, humanitarian agencies, local communities
Epidemiological elements	Parasite species	Surveillance and other epidemiological data (including community surveys)
	Trends in malaria cases and incidence in the area	Surveillance data
	History of malaria epidemics	Surveillance data
	Causes of previous epidemics and subsequent response	Past surveillance and response reports
Intervention	Access to health services	Distribution of ministry of health facilities, latest information on antimalarial products, household surveys
	Coverage of preventive interventions (vector control, chemoprevention)	National malaria programme, household surveys
	Vector susceptibility to insecticides	Entomological surveillance
	Parasite susceptibility to antimalarial drugs	Therapeutic efficacy surveillance

When interpreting geographical variation in routinely reported malaria incidence or mortality rates, account must be taken of the variation in the proportion of the population that uses public health facilities, the extent of diagnostic testing and health facility reporting rates and the number of new health facilities that have been built and are operational. Hence, it may be useful to tabulate or map general patient attendance, annual blood examinations and health facility reporting rates with tables or maps of disease incidence. It may also be useful to examine geographical variation in test positivity rates or proportional malaria attendance, as these measures may be less distorted by variation in general patient attendance, diagnostic testing or health facility reporting rates.

If available, data from household surveys can provide information on:

- whether and where patients seek care for fever and thus the extent to which routine surveillance systems capture all malaria cases;

- parasite prevalence, to identify the populations most severely affected by malaria; and particular risk factors associated with areas of higher incidence or mortality, including predominant vector and parasite species and population behaviour.

Changes in disease incidence

Trends in the number of malaria cases, admissions and deaths reported may reflect changes in malaria transmission and disease incidence in the population. As trends can be influenced by changes in access to health services, diagnostic testing practices and health facility reporting, WHO recommends examining a set of six "control" charts that show not only changes in malaria incidence but also factors that might influence the observed trends (**Fig. 26**). If there are too many gaps in routinely reported data to assess trends in malaria, a study might have to be undertaken to retrospectively examine the records of patient attendance in a sample of health facilities. If available, data from ≥ 2 years of household surveys provide information on changes in care–seeking behaviour and parasite prevalence.

Fig. 26 shows various charts of malaria trends. It is useful to examine trends in general patient attendance, annual blood examination rate, health facility reporting rates and new health facilities with trends in malaria disease incidence. It is also useful to examine trends in test positivity rates or proportional malaria attendance, as these may be less distorted by changes in general patient attendance, diagnostic testing or health facility reporting rates. In the example in **Fig. 26**, there are fewer malaria cases, inpatients and deaths in the most recent months (graph 1); however, this trend could be due to less reporting and diagnosis in the same period

(graphs 4 and 5). Such a pattern is common, suggesting that the timeliness of reporting should be improved. Furthermore, the proportion of patients with suspected malaria who receive a diagnostic test should be increased.

FIG. 26.
Charts for analysis of malaria trends

1. Malaria incidence rates

- Confirmed cases per 1000
- Inpatients per 10 000
- Deaths per 100 000

2. Proportional malaria incidence

- Slide positivity rate
- Proportion of inpatients due to malaria
- Proportion of deaths due malaria

3. General patient attendance

- Outpatients per 1000
- Inpatients per 10 000
- Deaths per 100 000

4. Diagnostic effort

- Annual blood examination rate

5. Quality of diagnosis and reporting

- Proportion of health facilities reporting
- Proportion of suspected cases tested

6. Proportion of cases due to *P. falciparum*

Fig. 27 presents the example of Rwanda to show how the geographical distribution of malaria can be examined. Mapping of indicators allows programme managers to assess whether programme performance or malaria trends vary by geographical area and to determine whether malaria prevention, testing or treatment activities should be focused in particular geographical areas. Regional differences in the numbers of cases and deaths due to malaria might reflect the underlying epidemiology, the extent of malaria interventions or diagnostic and case reporting practices. In the example below, higher case incidence rates

FIG. 27.
Geographical distribution of malaria in Rwanda in 2015

Incidence of confirmed malaria cases

Malaria test positivity rate

Per 1000 population
< 100
100–200
> 200

< 30
30–50
> 50

Annual blood examination rate

Percentage of suspected cases tested

< 40
40–80
> 80

< 50
50–80
> 80

Rate of completeness
of reporting by health facilities

< 50
50–80
> 80
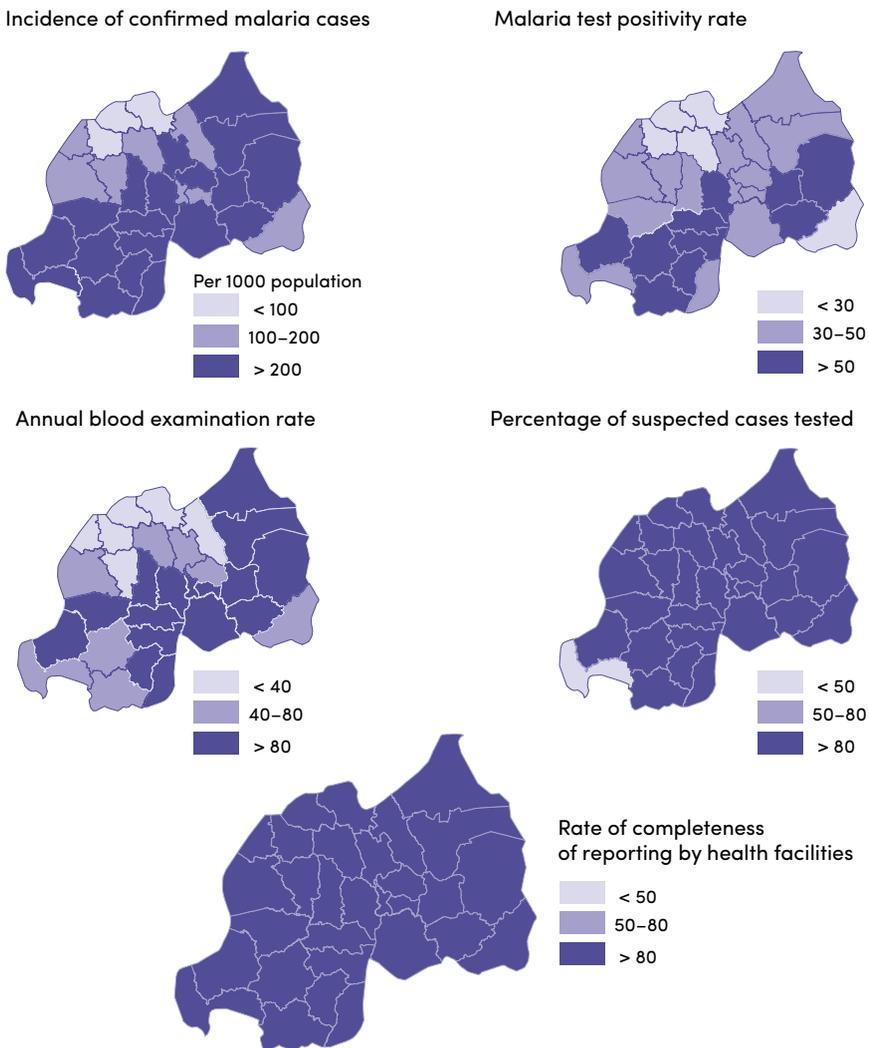
An example of a surveillance bulletin is provided in **Annex 15**.

are observed in eastern parts of the country, with higher annual blood examination rates and percentages of cases tested. Nonetheless, the same areas have a higher incidence rate, as suggested by higher test positivity rates. Variation in the completeness of reporting may be due to communication delays or resource gaps in particular regions.

Coverage of malaria interventions

It is useful to determine intervention coverage by geographical area or population risk group, to assess whether interventions have been targeted appropriately. It is also useful to examine different stages in the delivery of interventions to identify any bottlenecks that hinder service provision. In the two scenarios shown in **Fig. 28,** the proportions of pregnant women receiving four or more doses of intermittent preventive treatment are the same – and low, but the reasons for the low coverage differ. In the scenario on the left, although use of antenatal care services is good, women do not receive multiple doses of preventive treatment, suggesting that the services offered at antenatal clinics should be improved. In the second scenario, use of antenatal clinics is poor, suggesting that more fixed or mobile antenatal clinics should be provided. Information on the coverage of malaria interventions can be obtained from routine reporting systems, household surveys and health facility surveys.

FIG. 28.
Identifying bottlenecks in malaria programmes
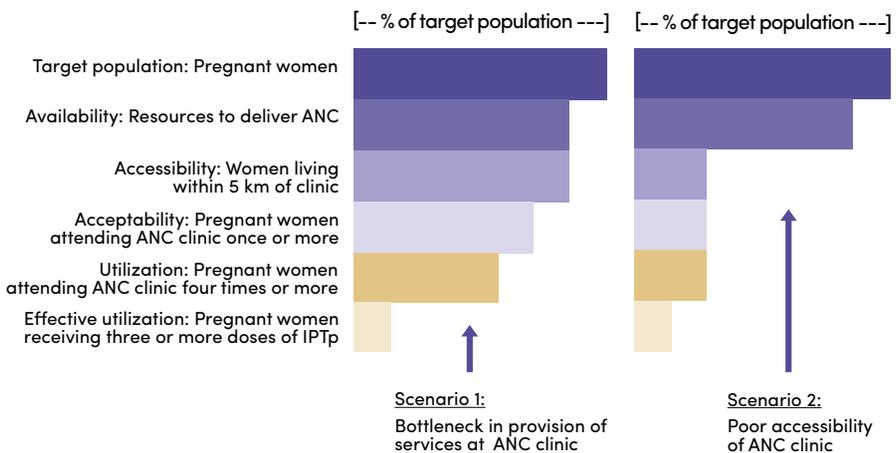
ANC, antenatal care; IPTp, intermittent preventive treatment in pregnancy

Resources required and available for achieving programme targets

Information on programme fina ncing should include both domestic and international financing. All malaria-specific expenditure should be included; for example, on commodities (e.g. ITNs, RDTs and ACT), equipment (e.g. microscopes and vehicles), staffing (malaria managers and indoor residual sprayers) and activities (e.g. training and supervision). If expenditure that is shared with other programmes can be readily apportioned to malaria programmes, they should be added to malaria-specific expenditures. If not, a focus on malaria-specific expenditures is often sufficient for assessing trends in malaria investments and their impact on programme coverage. It is also useful to examine programme financing by geographical area or population risk group.

7.4.2 Programme monitoring and evaluation

The national malaria strategic plan should be monitored at regular intervals to assess coverage of interventions, their impact and determine whether programmes are proceeding as intended or adjustments are required. Managers at national level should review the indicators at least every quarter. Annual reviews should also be undertaken before budgets are prepared, mid-term reviews may be conducted to assess interim progress, and a final programme review should be undertaken before the next strategic plan is developed. The final malaria programme review (and mid-term review) benefits from data from health facility surveys, household surveys and other special studies; therefore, these surveys and studies should be timed to contribute to the review(s).

In reviewing indicators, managers should ask specific questions regarding the progress of malaria programmes. The precise questions will depend on the local operational context, but are likely to include the following:

- Are programme coverage targets being met, or are particular interventions (e.g. target for percentage of suspected cases tested) experiencing problems? Are there stock-outs of commodities?

- Have there been important changes in the values of indicators over time? For example, has there been a decrease in the number of children receiving ITNs through immunization clinics? Of particular interest is whether the numbers of cases and deaths are being reduced or whether problems are being experienced in some locations, necessitating modification of the programme. Managers should also be alert to potential epidemics.

- Are there particular bottlenecks in the delivery of services? For example, is there a large difference in the number of pregnant women receiving first and third doses of intermittent preventive treatment?

- Are particular health facilities or geographical areas experiencing problems (e.g. low testing rate, prescription of inappropriate drugs, low reporting rates) or doing well?

- Is the surveillance system working well, or are there problems in case detection, reporting completeness, timeliness and coverage, registration of foci?

- Are management and human resource challenges at all levels of the programme?

These questions can be answered easily if data are presented in such a way that indicators can be compared with targets, across time, with other indicators and between geographical areas. Other comparisons may also be informative; for example, those between different types of facilities or providers of services.

Managers at health facility and district levels should review indicators each month, or more frequently in the case of elimination. Feedback on the status of selected key indicators should be communicated to districts and health facilities weekly, monthly or quarterly, depending on the epidemiological context and should include private health facilities when possible.

Health facility and intermediate-level (e.g. district) teams should be engaged in data analysis, presentation and interpretation to improve their involvement, performance and programme capacity. Data should be summarized in ways that allow staff in health facilities and districts to readily assess their facilities' performance. Data may be presented on a dashboard, by ranking districts or facilities or by colour-coding indicators according to their value.

Programmes should not be monitored only by malaria programme managers and implementers. Other government departments, elected leaders, community members and donors have a stake in ensuring the high quality of malaria programmes and should be able to assess the operations they are supporting. When these stakeholders are involved in the review process, they can help to ensure that malaria programmes are responding to the population's needs and that malaria control and elimination are promoted as a development priority.

7.4.3 Monitoring and evaluation of surveillance systems

Surveillance systems that function well are the backbone of effective malaria interventions at all levels of transmission intensity. Surveillance systems support planning, budgeting, evaluation and tracking of programme activities and disease trends. The better the surveillance system, the more likely it is that a programme will have an impact for the resources invested.

The purpose of monitoring and evaluating surveillance systems is to track the progress of the system and to identify any bottlenecks that impede its efficient functioning. This information should be the basis for investments to improve the surveillance system. Monitoring and evaluation involve critical assessment of the four main components of a surveillance system: structure, core functions, support functions and quality (**Fig. 29**). Various elements of each component are measured during surveillance; a few are presented in **Table 14**.

Monitoring and evaluation of surveillance should be used to determine whether the objectives and approaches defined in the national surveillance SOP have been achieved. The SOP should include the broad governing structures of the surveillance system, the processes, sources of information, methods and frequency of data collection, data quality and analysis and use of information and should be specified in the monitoring and evaluation plan.

The surveillance system can be evaluated in four stages: planning, preparation, evaluation and dissemination *(1)*. During planning, decide on the scope of the evaluation and the general timing, and explore the broad resource requirements for the assessments. The preparatory stage includes deciding on the indicators to be measured and the assessment protocol, methods and tools. Quantify in greater detail the resources required according to the type of assessment, and identify people to conduct the evaluation. The evaluation stage includes field work and data entry, cleaning, verification and analysis. At this stage, a summary report of the evaluation is prepared, which includes the background of the evaluation, objectives, methods, results, conclusions and recommendations. The results of the evaluation should be disseminated to all stakeholders and should used as a basis for improving the surveillance system.

The status of surveillance systems should be assessed periodically (at least every 2 years) in settings in which the burden of malaria is being reduced and once a year in elimination settings, if not more frequently. This will provide input for effective systems for surveillance, monitoring and evaluation.

FIG. 29.

Components of a surveillance and response system to be assessed by monitoring and evaluation *(1)*

Structure of surveillance system	Core functions of surveillance system
• Legislation for surveillance • Surveillance strategy • Implementers and stakeholders • Networking and partnership	• Case detection • Case registration • Case confirmation • Reporting • Data analysis and interpretation • Epidemic preparedness • Response and control • Feedback
Quality of surveillance	**Support functions of surveillance system**
• Completeness • Timeliness of reporting • Usefulness of data and surveillance system • Simplicity of system • Acceptability of system • Flexibility of system • Sensitivity in surveillance • Specificity in surveillance • Positive predictive value • Representativeness of system	• Standards and guidelines • Training • Supervision • Communication facilities • Resources • Monitoring and evaluation • Coordination

TABLE 14.

Recommended indicators for monitoring malaria programmes and implementation of the GTS

			TRANSMISSION INTENSITY			DATA SOURCE		
INDICATOR			High	Low and very low	Elimination or prevention of re-establishment	Routine reporting system	Health facility survey	Household survey
INPUTS								
Financing	1.1	Expenditure per capita for malaria control and elimination	●	●	●	●		
	1.2	Funding for research relevant to malaria	●	●	●	●		
	1.3	Number of "top-10" registered corporations that invest in malaria	●			●		
OUTCOME								
Vector control	2.1	Proportion of population at risk sleeping under an ITN or living in house sprayed by IRS in the previous 12 months	●	●		©		©
	2.2	Proportion of population at risk that slept under an ITN the previous night	●	○				●
	2.3	Proportion of population with access to an ITN in their household	●	○				●
	2.4	Proportion of households with at least one ITN for every two people	●	○				●
	2.5	Proportion of households with at least one ITN	●	○				●
	2.6	Proportion of available ITNs used the previous night	●	○				●
	2.7	Proportion of population at risk potentially covered by distributed ITNs	●	○		●		

Category	#	Indicator	1	2	3	4	5	6
	2.8	Proportion of targeted risk group receiving ITNs	●	●	●	●		
	2.9	Proportion of population at risk protected by IRS in the previous 12 months	●	○		●		
	2.10	Proportion of targeted risk group receiving IRS	●	●	●	●		
Chemoprevention	3.1	Proportion of pregnant women who received three or more doses of IPTp	●			●		●
	3.2	Proportion of pregnant women who received two doses of IPTp	●			●		●
	3.3	Proportion of pregnant women who received one dose of IPTp	●			●		●
	3.4	Proportion of pregnant women who attended an antenatal clinic at least once	●			●		●
	3.5	Proportion of children aged 3–59 months who received the full number of courses of SMC per transmission season	●			●		
Case detection	4.1	Proportion of children < 5 years with fever in the previous 2 weeks for whom advice or treatment was sought	●	○				●
	4.2	Proportion of detected cases that contacted health services within 48 h of symptoms			●	●		
Diagnostic testing	5.1	Proportion of patients with suspected malaria who received a parasitological test	●	●		●	●	
	5.2	Proportion of children < 5 years with fever in the previous 2 weeks who had a finger or heel stick	●					●
	5.3	Proportion of health facilities without stock-outs of key commodities for diagnostic testing	●	●		●	●	

INDICATOR			TRANSMISSION INTENSITY			DATA SOURCE		
			High	Low and very low	Elimination or prevention of re-establishment	Routine reporting system	Health facility survey	Household survey
Treatment	6.1	Proportion of patients with confirmed malaria who received first-line antimalarial treatment according to national policy	•	•	•	•	•	
	6.2	Proportion of treatments with ACT (or other appropriate treatment according to national policy) among febrile children < 5 years	•	○		•	•	•
	6.3	Proportion of patients with *P. vivax* or *P. ovale* malaria who received radical cure treatment	•	•	•	•	•	
	6.4	Proportion of months without stock-outs of first-line treatments	•	•		•	•	
Surveillance	7.1	Proportion of malaria cases detected by surveillance systems	•	•	•	©		©
	7.2	Proportion of expected health facility reports received	•	•	•	•		
	7.3	Annual blood examination rate	•	•	•	•		
	7.4	Proportion of cases investigated and classified			•	•		
	7.5	Proportion of foci investigated and classified			•	•		
	7.6	Proportion of cases who had treatment supervised			•	•		
	7.7	Proportion of cases who had treatment supervised and who had complete cure verified at day 28 (or day 42)			•	•		
	7.8	Percentage of case reports received < 24 h after detection			•	•		

IMPACT

Category	No.	Indicator					
Prevalence	8.1	Parasite prevalence: proportion of population with evidence of infection with malaria parasites	•	o			•
Incidence	9.1	Malaria case incidence: number and rate per 1000 people per year	•	•	•	•	
	9.2	Malaria admissions: number and rate per 10 000 people per year	•	o	o	•	
	9.3	Malaria test positivity rate	•	o		•	
	9.4	Proportion of admissions for malaria	•	o		•	
	9.5	Number of foci by classification			•	•	
Mortality	10.1	Malaria mortality: number and rate per 100 000 people per year	•	o	o	•	
	10.2	Proportion of inpatient deaths due to malaria	•	o		•	
	10.3	All cause under–five mortality	•	o			
Elimination	11.1	Number of areas and countries that have eliminated malaria since 2015			•	•	
Prevention of re–establishment	12.1	Number of areas and countries that were malaria–free in 2015 in which malaria has been re–established			•	•	

• Indicator highly relevant to the setting; o Indicator potentially relevant to the setting; © requires data from both routine systems and household surveys
Indicators among minimal set of 12 recommended indicators in GTS are highlighted in grey. The applicability of an indicator in different settings and the source of data are shown by closed or open circles. More detailed specifications of the indicators are provided in **Annex 17**.
ACT, artemisinin–based combination therapy; ANC, antenatal care; IPTp, intermittent preventive treatment in pregnancy; IRS, indoor residual spraying; ITN, insecticide–treated mosquito net; SMC, seasonal malaria chemoprevention

7.5 RECOMMENDED INDICATORS ON THE CONTINUUM TO ELIMINATION

This document defines a set of 46 indicators that can be used to track malaria programmes, as shown in **Table 14.** The indicators take into account:

* the resources available for malaria control (programme financing, commodities);

* levels of service provision (intervention coverage) and the performance of systems for surveillance, monitoring and evaluation; and

* trends in infection and disease.

Twelve of the 46 indicators are considered to be core indicators (shaded), and the other 31 are supporting indicators. The applicability of an indicator in a programme settings is shown as generally highly relevant (a closed circle) or potentially relevant (an open circle). The settings considered include the level of transmission, whether a country is in sub-Saharan Africa and the administrative level.

Although some interventions are important at all stages of malaria control and elimination (e.g. ensuring that all patients with suspected malaria receive a diagnostic test), a particular indicator may have lower priority than others as the programme evolves. Thus, if 100% of suspected cases routinely receive a diagnostic test, this indicator may not be considered as strong in routine monitoring of an elimination programme as one that reflects the proportion of cases investigated. The recommended indicators for programmes close to elimination reflect this reprioritization. Eight indicators (7.1–7.8) concern the performance of systems for surveillance monitoring and evaluation.

7.6 USE OF INFORMATION AT REGIONAL AND GLOBAL LEVELS

Global progress in reducing mortality and morbidity due to malaria and its eventual elimination will be tracked on the basis of countries' surveillance, monitoring and evaluation systems. Progress will be monitored from the indicators listed in **Table 14**. Countries and partners are encouraged to ensure that data for these indicators are available at appropriate times during implementation of the GTS by ensuring adequate investment in routine information systems and in household and health facility surveys.

WHO and other partners will support countries that are endemic for malaria in strengthening their surveillance, monitoring and evaluation systems, in line with the requirements of the GTS. The aim of the support will be to improve the quality, availability and management of data on malaria and to optimize use of such data in decision-making and programmatic responses. Countries will also be supported in identifying nationally appropriate targets and indicators for subregional monitoring of progress.

WHO, in line with its core role, will monitor regional and global trends in malaria and make these data available to countries and to global malaria partners. WHO will monitor implementation of the GTS and regularly evaluate progress towards the milestones and goals set for 2020, 2025 and 2030 (**Table 15**) in annual and other periodic reports. It will also support monitoring of the efficacy of medicines and vector-control interventions; to this end, WHO will maintain global databases for the efficacy of medicines and insecticide resistance. WHO will regularly report to the regional and global governing bodies of WHO, the United Nations General Assembly and other United Nations bodies.

By 2030, malaria morbidity and mortality are expected to have been reduced dramatically in comparison with 2016, with future eradication of malaria in sight. In this context, it will be increasingly necessary to establish a global monitoring system to systematically track and eliminate the remaining cases and foci of malaria.

TABLE 15.
Goals and milestones of the *Global technical strategy for malaria 2016–2030 (2)*

Vision – a world free of malaria

GOALS	MILESTONES		TARGETS
	2020	**2025**	**2030**
1. Reduce malaria mortality rates globally compared with 2015	≥ 40%.	≥ 75%	≥ 90%
2. Reduce malaria case incidence globally compared with 2015	≥ 40%	≥ 75%	≥ 90%
3. Eliminate malaria from countries in which malaria was transmitted in 2015	At least 10 countries	At least 20 countries	At least 35 countries
4. Prevent re-establishment of malaria in all countries that are malaria-free	Re-establishment prevented	Re-establishment prevented	Re-establishment prevented

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Annexes

ANNEX 1. GLOSSARY

Case detection	One of the activities of surveillance operations, involving a search for malaria cases in a community *Note: Case detection is a screening process in which the indicator is either the presence of fever or epidemiological attributes such as high-risk situations or groups. Infection detection requires use of a diagnostic test to identify asymptomatic malaria infections.*
Case detection, active	Detection by health workers of malaria cases at community and household levels, sometimes in population groups that are considered at high risk. Active case detection can consist of screening for fever followed by parasitological examination of all febrile patients or as parasitological examination of the target population without prior screening for fever. *Note: Active case detection may be undertaken in response to a confirmed case or cluster of cases, in which a population potentially linked to such cases is screened and tested (referred to as "reactive case detection"), or it may be undertaken in high-risk groups, not prompted by detection of cases (referred to as "proactive case detection").*
Case detection, passive	Detection of malaria cases among patients who, on their own initiative, visit health services for diagnosis and treatment, usually for a febrile illness

Case investigation	Collection of information to allow classification of a malaria case by origin of infection, i.e. imported, indigenous, induced, introduced, relapsing or recrudescent
	Note: Case investigation may include administration of a standardized questionnaire to a person in whom a malaria infection is diagnosed and screening and testing of people living in the same household or surrounding areas.
Case, imported	Malaria case or infection in which the infection was acquired outside the area in which it is diagnosed
Case, index	A case of which the epidemiological characteristics trigger additional active case or infection detection. The term "index case" is also used to designate the case identified as the origin of infection of one or a number of introduced cases.
Case, indigenous	A case contracted locally with no evidence of importation and no direct link to transmission from an imported case
Case, induced	A case the origin of which can be traced to a blood transfusion or other form of parenteral inoculation of the parasite but not to transmission by a natural mosquito-borne inoculation
	Note: In controlled human malaria infections in malaria research, the parasite infection (challenge) may originate from inoculated sporozoites, blood or infected mosquitoes.
Case, introduced	A case contracted locally, with strong epidemiological evidence linking it directly to a known imported case (first-generation local transmission)

Case, locally acquired	A case acquired locally by mosquito–borne transmission *Note: Locally acquired cases can be indigenous, introduced, relapsing or recrudescent; the term "autochthonous" is not commonly used.*
Case, malaria	Occurrence of malaria infection in a person in whom the presence of malaria parasites in the blood has been confirmed by a diagnostic test *Note: A suspected malaria case cannot be considered a malaria case until parasitological confirmation. A malaria case can be classified as imported, indigenous, induced, introduced, relapsing or recrudescent (depending on the origin of infection); and as symptomatic or asymptomatic. In malaria control settings, a "case" is the occurrence of confirmed malaria infection with illness or disease. In settings where malaria is actively being eliminated or has been eliminated, a "case" is the occurrence of any confirmed malaria infection with or without symptoms.*
Case, relapsing	Malaria case attributed to activation of hypnozoites of *P. vivax* or *P. ovale* acquired previously. *Note: The latency of a relapsing case can be > 6–12 months. The occurrence of relapsing cases is not an indication of operational failure, but their existence should lead to evaluation of the possibility of ongoing transmission.*
Entomological inoculation rate	Number of infective bites received per person in a given unit of time, in a human population *Note: This rate is the product of the "human biting rate" (the number of bites per person per day by vector mosquitoes) and the sporozoite rate (proportion of vector mosquitoes that are infective). At low levels of transmission, the estimated entomological inoculation rate may not be reliable, and alternative methods should be considered for evaluating transmission risk.*

Focus, malaria	A defined circumscribed area situated in a currently or formerly malarious area that contains the epidemiological and ecological factors necessary for malaria transmission

Note: Foci can be classified as active, residual non-active or cleared. |
| **Malaria elimination** | Interruption of local transmission (reduction to zero incidence of indigenous cases) of a specified malaria parasite in a defined geographical area as a result of deliberate activities. Continued measures to prevent re-establishment of transmission are required.

Note: The certification of malaria elimination in a country will require that local transmission is interrupted for all human malaria parasites. |
| **Malaria eradication** | Permanent reduction to zero of the worldwide incidence of infection caused by human malaria parasites as a result of deliberate activities. Interventions are no longer required once eradication has been achieved. |
| **Malaria reintroduction** | Malaria reintroduction is the occurrence of introduced cases (cases of the first-generation local transmission that are epidemiologically linked to a confirmed imported case) in a country or area where the disease had previously been eliminated

Note: Malaria reintroduction is different from re-establishment of malaria transmission (see definition). |
| **Malaria-free** | Describes an area in which there is no continuing local mosquito-borne malaria transmission and the risk for acquiring malaria is limited to infection from introduced cases |
| **Mass drug administration** | Administration of antimalarial treatment to all age groups of a defined population or every person living in a defined geographical area (except those for whom the medicine is contraindicated) at approximately the same time and often at repeated intervals |

Monitoring and evaluation	Monitoring is a continuous process of gathering and using data on programme implementation (weekly, monthly, quarterly or annually), with the aim of ensuring that programmes are proceeding satisfactorily, and making adjustments if necessary. The monitoring process often uses administrative data to track inputs, processes and outputs, although it can also consider programme outcomes and impacts.

Evaluation is a more comprehensive assessment of a programme; it is normally undertaken at discrete points in time and is focused on the longer term outcomes and impacts of programmes. The overall goal of monitoring and evaluation is to improve programme effectiveness, efficiency and equity. |
| **Population at risk** | Population living in a geographical area where locally acquired malaria cases have occurred in the past 3 years |
| **Receptivity** | Receptivity of an ecosystem to transmission of malaria

Note: A receptive ecosystem should have e.g. the presence of competent vectors, a suitable climate and a susceptible population. |
| **Recrudescence** | Recurrence of asexual parasitaemia of the same genotype(s) that caused the original illness, due to incomplete clearance of asexual parasites after antimalarial treatment

Note: Recrudescence is different from reinfection with a parasite of the same or different genotype(s) and relapse in P. vivax *and* P. ovale *infections.* |

Surveillance	Continuous, systematic collection, analysis and interpretation of disease-specific data and use in planning, implementing and evaluating public health practice.
	Note: Surveillance can be done at different levels of the health care system (e.g. health facilities, the community), with different detection systems (e.g. case-based: active or passive) and sampling strategies (e.g. sentinel sites, surveys).
Transmission, re-establishment of	Renewed presence of a measurable incidence of locally acquired malaria infection due to repeated cycles of mosquito-borne infections in an area in which transmission had been interrupted
	Note: A minimum indication of possible re-establishment of transmission would be the occurrence of three or more indigenous malaria cases of the same species per year in the same focus, for 3 consecutive years.
Transmission, residual	Persistence of malaria transmission following the implementation in time and space of a widely effective malaria programme
	Note: The sources of and risks for "residual transmission" may vary by location, time and the existing components of the current "effective malaria programme".
Vectorial capacity	Number of new infections that the population of a given vector would induce per case per day at a given place and time, assuming that the human population is and remains fully susceptible to malaria
Vulnerability	The frequency of influx of infected individuals or groups and/or infective anopheline mosquitoes
	Note: Also referred to as "importation risk". The term can also be applied to the introduction of drug resistance in a specific area.

ANNEX 2. EXAMPLE OF INDIVIDUAL CASE INVESTIGATION FORM FOR A NATIONAL MALARIA CASE REGISTER

This form is to be completed for all laboratory–confirmed (microscopy or RDT) malaria cases.

Section 1. Characterization of the case

1. Malaria case ID:

2. Is this case linked to a larger focus?

    - Yes ◯ If so, indicate the ID number of the focus:

    - No ◯

3. Date:

4. Facility:

5. Information about the case patient

    5.1 Name

    5.2 Present home address, including contact details

    5.3 Permanent address if different from the above

    5.4 Age

    5.5 Gender

    5.6 Occupation or other aspects that may have influenced malaria risk

    5.7 Date of confirmation of malaria diagnosis

    5.8 Date of notification of malaria case

    5.9 *Plasmodium* species identified

    5.10 Recent travel history within the country, i.e. to other malaria-endemic settings (past 2 weeks, 6 months and for 1 year)

    5.11 Recent travel history outside the country to malaria–endemic settings (past 2 weeks, 6 months and for 1 year)

    5.12 Blood transfusion within past 3 months

    5.13 Possible origin of malaria infection (place where malaria infection is likely to have been acquired) with GPS coordinates, if possible

    5.14 History of malaria, if any (when, where, parasite species, treatment given, etc.)

    5.15 Recent contact with known imported case(s); provide details

6. Case detection and treatment

    6.1 Method of diagnosis (passive case detection, active case detection, mobile malaria clinic, other)

    6.2 Main symptoms

    6.3 Date of onset of first symptoms

    6.4 Test used (microscopy or RDT)

    6.5 Parasite species (if microscopy is used: parasite density and presence of gametocytes reported)

    6.6 Treatment (drugs, dosage, dates)

    6.7 Treatment outcome (follow-up visits, confirmation of clearance, dates)

Section 2. Classification of the case

7. The case is classified as:

    7.1 Parasite species:

P. falciparum	O	*P. vivax*	O	*P. malariae*	O
P. ovale	O	Mixed	O	(specify:)	
Other	O	(specify:)			

    7.2 Classification:

Imported*	O	Introduced	O	Indigenous	O
Relapsing	O	Recrudescent	O	Induced	O
Other**	O				

    Comment on evidence used for case classification:

    * Outside the district/province, from other country (please specify)

    **This may be poor compliance or failure to follow up.

Section 3. Follow-up of the case, household and neighbourhood

Date of investigation

8. Case household visit (done, dates, map):

    8.1 Household location (GPS)

    8.2 Household members listed, screened (e.g. fever), tested, results

9. Neighbourhood visit (done, dates, map)

    9.1 Household locations (GPS)

    9.2   Household members listed, screened (e.g. fever), tested, results

        Note: If additional infections are identified in the case or neighbouring households, continue to focus investigation protocols.

10. Vector control and preventive measures taken, if any

11. Follow-up measures taken, if any

12. Name and title of responsible officer who investigated the case

13. Reference to relevant case or focus investigation records and record numbers

Refer to **Fig. 7** for case classifications.

ANNEX 3. EXAMPLE OF INDIVIDUAL FOCUS INVESTIGATION FORM FOR A NATIONAL MALARIA CASE REGISTER

This form is to be completed for all confirmed malaria foci.

Section 1. Characterization of the focus

1. Malaria focus ID:

2. List all case ID numbers that are part of this focus ID:

3. Date of this report: Date of focus identification:

4. District and health facility catchment area:

5. Information about the focus

   5.1 Geographical map of focus and its limits

   5.2 Size of population, number of houses

   5.3 Administrative map of houses, heath facilities and other important structures, as well as access routes within the focus

   5.4 Distribution of parasites (species, number and location of infections identified)

   5.5 Distribution of vector species within the focus (principal and secondary malaria vectors and their behaviour, including breeding sites with presence or absence of larvae)

   5.6 Type of environment in relation to receptivity (urban or rural population, altitude, main geographical features, environmental changes as a result of development, original and current endemicity, etc.) and vulnerability (close proximity to endemic areas within the country or across international border, refugees, etc.) within the focus

   5.7 Population characteristics in relation to vulnerability (migration patterns, presence and numbers of temporary workers, typical travel histories, etc.) within the focus

6. Focus history

   6.1 Total number of malaria cases by species reported within the focus during the past five years

   6.2 Results of malaria surveys, including active case detection within the focus during the past five years

   6.3 Dynamics of the focus status during the past five years (active foci versus residual non-active foci versus cleared foci)

6.4 Types and dates of vector control and other preventive measures applied within the focus during the past five years (provide details)

Section 2. Classification of the focus

7. Focus classification

Focus classified as:

7.1 Parasite species:

P. falciparum O	*P. vivax* O	*P. malariae* O
P. ovale O	Mixed O	(specify:)
Other O	(specify:)	

7.2 Classification at time of detection   (date:):

Active   O   Residual non–active   O

Cleared   O   Other   O

Comment on evidence used for focus classification:

7.3 Classification at time of specified follow up   (date   ):

Active   O   Residual non–active   O

Cleared   O   Other   O

Comment on evidence used for re–classification of focus:

7.4 Relation of the focus to the malaria case that prompted focus investigation (in time, space and circumstance, e.g. the person in residence, work, etc.)

7.5 Location and total number of households with inhabitants where malaria cases were registered within the focus

Section 3. Follow–up of the focus households and neighbourhoods, and response

Measures taken to clear infections and stop transmission within the focus and prevent possible onward spread of the current malaria infections from the focus, if any (provide details)

8. Follow–up actions taken (provide details)

For example:

8.1 Neighbourhood visits (done, dates, map)

Household locations (GPS)

Household members listed, screened (e.g. fever), tested, results

Household members treated (case management, prevention)

8.2   Vector control and preventive measures taken, if any

8.3   Other follow-up measures taken, if any

9.   Reference numbers to relevant focus investigation records and case investigation records

10. Name, title and signature of responsible officer who investigated the focus and completed the form

Refer to **Table 4** and **Fig. 9** for focus classifications.

ANNEX 4. FORM FOR UPDATING REGISTRATION OF FOCI

Focus ID	Focus Name	Province	District	Latitude	Longitude	Population count	Number of household	Number of structures for IRS	Number of LLIN distributed	Number of structures sprayed	Date of LLIN distribution	Date of last cycle of IRS	Date focus investigated	Classification		
														Active	Residual non-active	Cleared

Note: the data fields presented here are not exhaustive and additional information may be included in focus register as appropriate.

ANNEX 5. GEOGRAPHICAL RECONNAISSANCE DURING FOCUS INVESTIGATION

Stage	Purpose	Activities
Planning	Identify the target area to conduct the mapping operations	Assemble baseline GIS data layers, including administrative boundaries, topographic (e.g. waterways and elevation) and infrastructure (e.g. roads) and potential breeding sites.
		Acquire paper topographic maps from local mapping authorities or ministries to confirm identification of target areas for geographical reconnaissance, especially if electronic maps do not give a clear picture.
		Digitize paper maps when possible, including any maps showing distribution of previous cases and focus limits.
		Draw maps showing the preliminary limits of the focus on the basis of these geographical features and the excepted flight distances of the main vector, to delimit the extent of the focus.
	Data collection considerations	Select the appropriate data collection hardware (e.g. smart-phone, tablet, GPS) and associated data collection software.
		Identify the data collection forms; include a unique household ID field in each form.
		Upload data collection forms and field maps to the hardware chosen; test the system before field work. The data should include the distribution and classification of previous cases, interventions (LLINs, IRS, larviciding) and entomology within the focus.
		If portable computers are not available, use paper forms and maps, or collect coordinates with a GPS and record them on paper forms.
	Operational planning	Select field workers (field officers, supervisors and data managers).
		Prepare a detailed schedule for field work, including timelines for data submission.
		Prepare training modules, and train field workers before starting investigation.
		Provide the appropriate equipment, materials, transport and accommodation.
		Prepare a budget for the above items.

Stage	Purpose	Activities
Field investigations	Notify communities and authorities.	Contact local health and administrative authorities to inform them of the planned activities.
		During the focus visit, contact village leaders to discuss the purpose of the visit and the benefits to the community; once a relationship has been developed with communities, residents will become used to further focus investigations.
	Initial reconnaissance and assessment of village(s)	Walk around the focus or village to familiarize the field team with the environment and to validate field maps.
	Geographical reconnaissance and enumeration activities	Acquire coordinates, and use unique identifiers for each household or dwelling.
		Record the number, and make line lists of people in each household or dwelling.
		Identify and map additional important structures (e.g. health facilities and schools) and significant geographical features (e.g. ponds and roads).
	Data back-up and storage	Establish procedures to back-up and store data collected in the field (depends on hardware and software selected for geographical reconnaissance); real-time submission of data is possible with good Internet connectivity.
Mapped products	Display geographical data on maps, showing the limits of the focus.	Produce a map illustrating: • all households and other significant structures within the focus; • relevant environmental features such as rivers, streams, bodies of water and mountains; • relevant infrastructure, including roads, walking tracks and ports; and • location of recent and past malaria cases. Prepare summaries of households and population for planning response activities. Prepare detailed lists of households for implementation and evaluation of response activities.

Stage	Purpose	Activities
Analysis	Refine the limits of the focus.	Use the new mapped information to refine the limits of the focus.
	Risk factor analysis	Use GIS to analyse the distribution of cases within foci, by classification in relation to risk factors
	Analysis of case clustering	Use GIS to analyse the distribution of imported cases relative to natural breeding sites, to assess the risk of onward transmission

GIS, geographical information system; GPS, geographical positioning system; IRS, indoor residual spraying; LLIN, long-lasting insecticidal net.

ANNEX 6. PROPOSED REGISTER FOR COMMUNITY HEALTH WORKERS, HEALTH POSTS AND OUTPATIENT DEPARTMENTS IN HEALTH CENTRES AND HOSPITALS

No.	Date	Name	Residence (village, neighbourhood)	Sex	Age in years	Provisional diagnosis	New visit?	Malaria test result	Final diagnosis	Treatment
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

(6)   Age in years: age should be recorded as < 1 or 0 for children aged < 1 year.
(7)   Provisional diagnosis: may be amended in column 10 if the result of a malaria diagnostic test result is negative.
(9)   Malaria test result: the result should be recorded as +ve, –ve or not done. If more than one species might be involved, the parasite species (*P.f., P.v., P.m.* or *P.o.*) should be recorded for positive test results.
(11) Final diagnosis: will include presumed malaria cases if no test was performed.
(12) Treatment: specify whether antimalarial treatment was given and whether the case was referred.

The number of suspected malaria cases can be derived from column 7. The number of confirmed cases can be derived from column 9. The number of presumed malaria cases can be derived by subtracting the number of confirmed malaria cases in column 9 from the number of malaria diagnoses in column 10, Counts should apply only to new visits, which are indicated in column 8; sometimes, columns for repeat visits are added to the right of column 11.

ANNEX 7. TALLY SHEET FOR OUTPATIENT ATTENDANCE AT HEALTH CENTRES AND HOSPITALS

PATIENT ATTENDANCE											TOTAL
Suspected malaria	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØOOO OOOOO	47
MICROSCOPY											
Patients tested by microscopy	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØOOO OOOOO	OOOOO OOOOO	42
P. falciparum	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	16
P. vivax	ØØØØØ OOOOO	ØOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	6
P. malariae	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	
P. ovale	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	
Mixed	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	
Positive tests (confirmed malaria) <5	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	12
Positive tests (confirmed malaria) ≥5	ØØØØØ OOOOO	ØØØØØ OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	10
RDT TESTING											
Patients tested with RDT	ØØØØO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	4
Positive tests (confirmed malaria) <5	ØOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	1
Positive tests (confirmed malaria) ≥5	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	
TREATMENT											
Confirmed cases receiving antimalarial	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØØØØ OOOOO	ØØOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	22
Presumed cases receiving antimalarial *(presumed cases = cases not tested)*	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	OOOOO OOOOO	

RDT, rapid diagnostic test

A tally sheet can be used to make counts from records in registers or to keep a running total of patients in clinics. Each circle can be viewed as a patient's head, and a circle is crossed when a patient satisfies particular criteria. The tally sheet can be used for daily or weekly totals. At the end of the day or week, the crossed circles are added and the totals transferred to a daily or weekly summary book or chart.
The tally sheet should be locally adapted. For example, if there is no *P. vivax* or *P. ovale* malaria, those can be removed. In settings where a multi–species RDT is used, the RDT section should be adapted to report those results.

ANNEX 8. DAILY AND WEEKLY RECORDS OF OUTPATIENT ATTENDANCE AT HEALTH CENTRES AND HOSPITALS

Month: April 2012		1	2	3	3	4	6	7	Weekly	8	9
Day:		S	M	T	W	T	F	S	Total	S	M
PATIENT ATTENDANCE											
Suspected malaria		8	59	47							
MICROSCOPY											
Patients examined			56	42							
P. falciparum			18	16							
P. vivax			3	6							
P. malariae											
P. ovale											
Mixed											
Positive tests (confirmed malaria) <5			8	12							
Positive tests (confirmed malaria) 5+			13	10							
RDT TESTING											
Patients tested with RDT		8	2	4							
Positive tests (confirmed malaria) <5		2	0	1							
Positive tests (confirmed malaria) 5+		1	0	0							
TREATMENT											
Confirmed cases receiving antimalarial		2	0	1							
Presumed cases receiving antimalarial *(presumed cases = cases not tested)*		1	0	0							

RDT, rapid diagnostic test

Totals from tally sheets can be copied into a daily and weekly summary book, so that there is a permanent record of the daily counts of outpatient attendance. These can be used to assess daily or weekly changes in the incidence of disease and to calculate monthly totals, to be transcribed onto a monthly report. The order of rows and their height should be the same as those of the tally sheets to facilitate transcription. The tally sheet should be locally adapted. For example, if there is no *P. vivax* or *P. ovale* malaria, those can be removed. In settings where a multi-species RDT is used, the RDT section should be adapted to report those results.

ANNEX 9. DISCHARGE REGISTER FOR INPATIENT DEPARTMENTS OF HEALTH CENTRES AND HOSPITALS

No.	Date	Name	Residence (village, neighbourhood)	Sex	Age	YMD	Diagnosis	Length of stay (days)	Reason for leaving
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

(7)   YMD (years, months, days): units in which age is recorded; days should be used for children aged < 1 month, months for children aged < 1 year, and years for children aged ≥ 1 year.

(8)   Diagnosis: should follow the International Classification of Diseases (ICD) as far as possible; some facilities may add a column for the ICD code

(10) Reason for leaving: discharged, died, transferred or absconded.

The total number of malaria inpatient cases should be the number discharged plus those who died (i.e. excluding transferred and absconded), as a final diagnosis will not have been made.

ANNEX 10. REPORTS FROM HEALTH POSTS AND COMMUNITY HEALTH WORKERS TO HEALTH FACILITIES

Community worker or health post

Patient attendance

Suspected malaria

Testing

Patients tested with RDT

Confirmed malaria in child < 5 years

Confirmed malaria in person ≥ 5 years

Treatment

Confirmed malaria treated with antimalarial medicine

Cases not tested treated with antimalarial medicine

Cases referred

RDT, rapid diagnostic test

The number of variables to be reported each month should be kept to a minimum to ensure the completeness and quality of reporting. All health workers should understand the terms used; for example, cases of "confirmed malaria" are cases of suspected malaria with a positive test. Notes can be placed at the bottom of a form and in standard treatment manuals as reminders.

ANNEX 11. REPORTS FROM HEALTH FACILITIES TO DISTRICT LEVEL

Areas with P. falciparum only

Outpatients

Suspected malaria

Total outpatients

Testing

Patients tested by microscopy

Confirmed malaria <5 years

Confirmed malaria 5+ years

Patients tested with RDT

Confirmed malaria <5 years

Confirmed malaria 5+ years

Discharges

Malaria <5

Malaria 5+

Total discharges <5

Total discharges 5+

Deaths

Malaria <5

Malaria 5+

Total deaths <5

Total deaths 5+

Treatment

Confirmed malaria treated with antimalarial medicine

Cases not tested treated with antimalarial medicine

Case negative but treated with antimalarial medicine

Areas with more than one species of Plasmodium

Outpatients

Suspected malaria

Total outpatients

Testing

Patients with microscopic slide examination

P. falciparum

P. vivax

P. malariae

P. ovale

Mixed

Total confirmed malaria <5 years

Total confirmed malaria 5+ years

Patients tested with RDT

Confirmed malaria <5 years

Confirmed malaria ≥5 years

Discharges

Malaria <5

Malaria ≥5

Total discharges <5

Total discharges ≥5

Deaths

Malaria <5

Malaria ≥5

Total deaths <5

Total deaths ≥5

Treatment

Confirmed malaria treated with antimalarial medicine

Cases not tested treated with antimalarial medicine

Case negative but treated with antimalarial medicine

RDT, rapid diagnostic test

The number of variables to be reported each month should be kept to a minimum to ensure the completeness and quality of reporting. All health workers should understand the terms used; for example, a case of "confirmed malaria" is a case of suspected malaria with a positive test. Notes can be placed at the bottom of a form and in standard treatment manuals as reminders.

The tally sheet should be locally adapted. For example, if there is no *P. vivax* or *P. ovale* malaria, those can be removed. In settings where a multi-species RDT is used, the RDT section should be adapted to report those results.

ANNEX 12. LINE LISTS OF MALARIA CASES AND DEATHS AMONG INPATIENTS TO BE REPORTED TO DISTRICT LEVEL IN LOW-TRANSMISSION SETTINGS

	Monthly line list of inpatient malaria cases and deaths								Malaria prevention			Antimalarial treatment					
No.	Date admitted	Name	Residence (village, suburb)	Sex	Age	Pregnant (Y/N?)	Type of test (RDT/ micr.)	Species	ITN owned by household (Y/N)?	ITN used in 2 weeks before admission all nights (some/ none)?	House received IRS (Y/N)?	Date of onset of symptoms	Date contacted health system	Received antimalarial treatment (Y/N)	Date started	Medicines used	Reason for separation (discharged, died, absconded, transferred)
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)

(7)   Type of test: rapid diagnostic test (RDT), microscopy or none.

(8)   Species: if only *P. falciparum* is present, this column is not needed. If more than one species might be involved, the parasite species (*P.f., P.v., P.m., P.o.*) should be recorded for positive test results.

(9–10) ITN: insecticide-treated mosquito net.

(11)   IRS: indoor residual spraying.

(16)   Medicines used: specific details to be provided to determine possibility of expired or counterfeit medicines.

ANNEX 13. LINE LISTS OF ALL CONFIRMED MALARIA CASES TO BE REPORTED TO DISTRICT LEVEL IN LOW-TRANSMISSION SETTINGS

	Monthly line list of malaria cases							Malaria prevention			Antimalarial treatment			
No.	Date admitted	Name	Residence (village, suburb)	Sex	Age	Type of test (RDT/ micr.)	Species	ITN owned by household (Y/N)?	ITN used in 2 weeks before admission (all nights some/ none)?	House received IRS (Y/N)?	Date of onset of symptoms	Date contacted health system	Received antimalarial treatment (Y/N)	Date started	Type of treatment (ACT, CQ, others)
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)

(6)   Type of test: rapid diagnostic test (RDT), microscopy or none.

(7)   Species: if only *P. falciparum* is present, this column is not needed. If more than one species might be involved, the parasite species (*P.f., P.v., P.m., P.o.*) should be recorded for positive test results.

(8–9)   ITN: insecticide-treated mosquito net.

(10)   IRS: indoor residual spraying.

(15)   ACT, artemisinin-based combination therapy; CQ, chloroquine

ANNEX 14. SUPERVISORY CHECKLIST FOR COUNTRIES WITH HIGH OR MODERATE TRANSMISSION

During visits to health facilities, supervisors should check that registers are kept up to date, with all fields completed, that data on report forms correspond to information in registers and tally sheets, that core analysis graphs and tables are up to date and that interpretation of the trends and potential action has been discussed. Health facility staff should be encouraged to investigate all malaria inpatient cases and deaths. An example of a supervisory checklist for surveillance for malaria is shown below.

Record keeping	Not present	Present but not up to date	Present and up to date	Present, up to date and no mistakes
Outpatient register				√
Discharge register				√
Daily attendance summary book				√
Monthly attendance summary book				√
Graph of suspected cases	√			
Graph of number of tests performed	√			
Graph of number of confirmed cases				√
Graph of test positivity rate			√	
Reporting	None	1	2	3
Number of monthly reports sent on time in last 3 months				√
Investigations performed in past 3 months	Not done	Done	Done and action taken	
Malaria deaths			√	
Malaria inpatients			√	
Malaria cases	√			
Disease or progamme delivery issues that need attention				
Large number of inpatient cases still from Lacienda village.				
Recommendations				
Calculate test positivity rates as demonstrated.				
Work with Lacienda village chief to encourage residents to use LLINs and attend health centre promptly if ill with fever.				

ANNEX 15. MODEL MONTHLY SURVEILLANCE BULLETINS FOR COUNTRIES WITH HIGH OR MODERATE TRANSMISSION

A national feedback bulletin should be produced each quarter, with data by district. The bulletin should be widely circulated, not only as feedback to districts but also as information for other government departments and institutions. Elected leaders should also be given the bulletin on malaria, possibly showing the malaria situation according to political boundaries, to instil understanding and support for malaria control at the highest level of leadership.

Bulletins can draw on the control charts shown in **Fig. 26** but should be tailored to country circumstances, such as programme priorities or availability of data. In addition to surveillance charts, country bulletins should include some measure of intervention coverage. An example of the first page of a country bulletin is shown on the following page (other pages give tables of indicators calculated for districts). The format allows sharing of a large amount of information in a small space. It should be noted that figures with more than three trend lines may be difficult to interpret.

National Malaria Control Programme
## Monthly surveillance and logistics report
## Based on data available at the end of December 2017

Commentary:

Stock for public sector at national level			Estimated national coverage (possession) with LLIN		
ACT	Stock at end of month		No. of persons at risk of malaria		9.3 mil
	Stock for public sector at national level		No. of LLIN distributed in past 2 years		2,176,691
LLIN	Stock needed for next month	Data collection in process during 2018	No. of LLIN district this year (year-to-date)		161,4577
	Stock needed for next month		Estimated coverage with LLIN		25%
RDT	Stock at end of month		**National-level surveillance data, 2008, Year-To-Date (YTD)**		
	Stock needed for next month			Reference period 2013	YTD 2017	% Reduction

National IRS data, 2008				Reference period 2013	YTD 2017	% Reduction
No. houses targeted for ?1 round	152,072		In-patient malaria cases, all ages	136,446	37,557	72
No. houses sprayed for ?1 round	152,072		In-patient malaria cases, <5 yo	50,931	18,424	64
No. of persons at risk of malaria	9,292,654		In-patient malaria deaths, all ages	1,933	624	68
No. of persons protected with ?1 round	705,035		In-patient malaria deaths, <5 yo	857	220	74
% protected with ?1 round	8%		Out-patient malaria test positivity rate		18%	

TRENDS IN SURVEILLANCE INDICATORS

### Out-patient : Malaria test positivity rate, by age group

- Health facility, <5 years
- Health facility, all ages
- Community, all ages
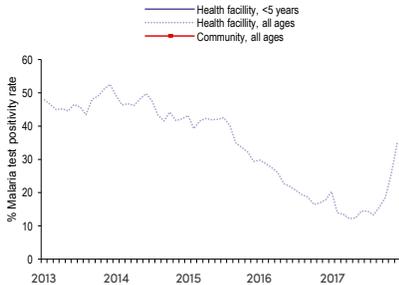
In-patient malaria and non-malaria cases and deaths

- In-patient malaria cases, <5 years
- In-patient malaria cases, all ages (/2)
- All-cause In-patient, all ages (/2)
- In-patient malaria deaths, <5 years (x10)
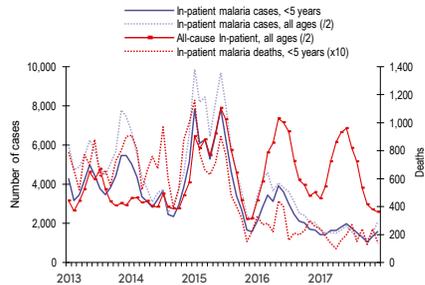
Out-patient: Confirmed cases and % of suspected cases

- Out-patient confirmed malaria cases
- % suspected cases tested
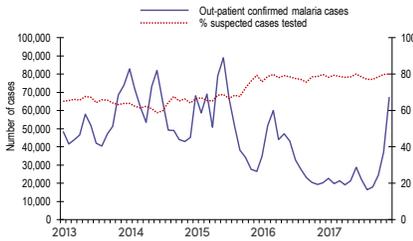
Out-patient: all causes and suspected malaria

- Out-patient all-cause cases
- Suspected cases (x2)
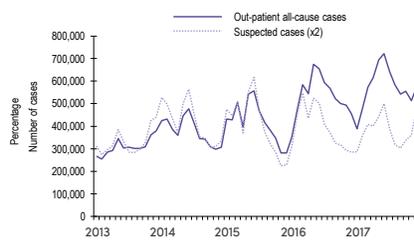
TRENDS IN LOGISTICS AND REPORTING COMPLETENESS INDICA TORS

Coverage of % ACT, LLIN, IPT

- % cases treated by ACT
- % LLIN / ANC1

2017
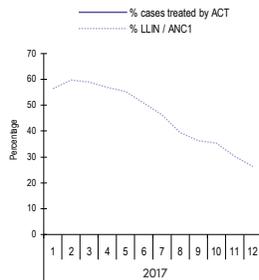
Proportion health facilities with stock-outs

- % HF with stock-out of ACT*
- % HF with stock-out of RDT
- % HF with stock-out of LLIN

Data collection in process during 2009

2017

Reporting completeness

- % of HF reporting (OPD)
- % of HF reporting (IPD)
- % of districts reporting(OPD/IPD)

Notes
- Health facillity, all ages: data collection in process
- Community, all ages: data collection in process
- Cases treated by ACT: data collection in process
* % HF with stock-out of ACT any day during the month

HF: Health Facillity
ANC1: 1st antinatal care visit
LLIN: Long lasting insecticide nets
RDT: Rapid diagnostic test

IRS: Indoor residual spraying
OPD: Out-patient department
IPD: In-patient deparmtnet

ANNEX 16. SAMPLING METHODS AND ANALYTICAL TECHNIQUES IN ENTOMOLOGICAL SURVEILLANCE

List of vector sampling and analysis techniques with associated codes referred to in **Table 9**.

	Vector sampling method		Vector analysis technique
1.	CDC light trap	A.	Morphological identification from Anopheles keys
2.	Human landing catch	B.	Molecular identification, such as by polymerase chain reaction (PCR) or barcoding
3.	Human–baited trap	C.	Blood–meal host detected by enzyme–linked immunosorbent assay (ELISA)
4.	Human odour–baited trap	D.	Blood meal host detected by PCR
5.	CO2–baited trap	E.	WHO susceptibility assay or CDC bottle bioassay with discriminating concentration (1x) of insecticide
6.	Animal –baited trap, such as with a cow	F.	WHO susceptibility assay or CDC bottle bioassays with intensity concentrations (1x, 5x, 10x) of insecticide
7.	Indoor resting collection by pyrethrum spray catch	G.	WHO susceptibility assay or CDC bottle bioassay with discriminating concentration (1x) of insecticide and pre-exposure or non-exposure to synergist
8.	Indoor resting collection by aspiration	H.	Molecular and/or biochemical assay(s)
9.	Outdoor resting collection by aspiration	I.	Salivary gland dissection and examination for sporozoites under microscope
10.	Outdoor resting collection by other method, such as pit trap, barrier fence, ceramic pot	J.	Circumsporozoite protein detection by ELISA
11.	Gravid trap for oviposition–seeking females	K.	*Plasmodium* spp. detection by PCR
12.	Window exit trap		
13.	Larval survey by dipping		

Entomological indicators can be estimated by various vector sampling and analytical techniques (**Table 9**). The characteristics of the vectors collected with each sampling method should be considered. For example, older *Anopheles* mosquitoes are likely to be overrepresented in light traps, resulting to higher sporozoite rates than from human bait catches (*1,2*). Data should ideally be collected in a standardized way at all sites and times to ensure comparability. Techniques that can be used to mitigate bias include use of automated sampling techniques whenever possible, rotation of sample collectors among sites and separation of teams conducting interventions from those conducting surveillance.

References

1. Onyango SA, Kitron U, Mungai P, Muchiri EM, Kokwaro E, King CH et al. Monitoring malaria vector control interventions: effectiveness of five different adult mosquito sampling methods. J Med Entomol. 2013;50:1140–51.

2. Wong J, Bayoh N, Olang G, Killeen GF, Hamel MJ, Vulule JM et al. Standardizing operational vector sampling techniques for measuring malaria transmission intensity: evaluation of six mosquito collection methods in western Kenya. Malar J. 2013;12:143.

ANNEX 17. CORE INDICATORS FOR SURVEILLANCE, MONITORING AND EVALUATION

No	Indicator name	Numerator	Denominator
INPUT INDICATORS			
1.1	Malaria expenditure per capita for malaria control and elimination	Malaria expenditure (domestic and international)	Population at risk of malaria
1.2	Funding for research relevant to malaria	Expenditure on research relevant to malaria	
1.3	Number of "top-10" registered corporations that invest in malaria	Number of registered corporations that invest in malaria	
OUTCOME INDICATORS			
2.1	Proportion of population at risk sleeping under an ITN or living in a house sprayed by IRS in the previous 12 months	Number of people at risk sleeping under an ITN or living in house sprayed by IRS in the previous 12 months	Population at risk of malaria
2.2	Proportion of population that slept under an ITN the previous night	Number of individuals who slept under an ITN the previous night	Total number of individuals who spent the previous night in surveyed households
2.3	Proportion of population with access to an ITN in their household	Total number of individuals who could sleep under an ITN if each ITN in the household were used by two people	Total number of individuals who spent the previous night in surveyed households
2.4	Proportion of households with at least one ITN for every two people	Number of households with at least one ITN for every two people	Total number of households surveyed
2.5	Proportion of households with at least one ITN	Number of households surveyed with at least one ITN	Total number of households surveyed
2.6	Proportion of existing ITNs used the previous night	Number of ITNs in surveyed households that were used by someone the previous night	Total number of ITNs in surveyed households
2.7	Proportion of population at risk potentially covered by ITNs distributed	Number of ITNs distributed in past 3 years	Population at risk of malaria
2.8	Proportion of targeted risk group receiving ITNs	Number of ITNs distributed to risk group	Number of people in risk group
2.9	Proportion of population at risk protected by IRS during previous 12 months	Number of people protected by IRS in the previous 12 months	Population at risk of malaria

Source	Breakdown	Comments
Routine administrative systems	Source (domestic government, private sector, household, international), programme area, geographical area, time (year)	Direct malaria expenditure is sufficient if expenditure shared with other programmes cannot be readily apportioned to malaria.
Routine administrative systems	Source (government, private sector, philanthropic), programme area, time (year)	
Routine administrative systems		
Household survey and routine reporting system	Geographical area, urban or rural	The indicator can be calculated directly from a household survey but is better estimated by combining national programme information on IRS coverage with household survey data.
Household survey	Geographical area, urban/rural, wealth index, educational status, gender, pregnancy status, age group (< 5, 5–19, 20–45, ≥ 45), household size	
Household survey	Geographical area, urban or rural, wealth index, household size	
Household survey	Geographical area, urban/rural, wealth index, household size	
Household survey	Geographical area, urban/rural, wealth index, household size	
Household survey	Geographical area, urban/rural, wealth index, household size	
NMP records, census	Geographical area, time	
NMP records, census	Geographical area, risk group (e.g. antenatal clinic attenders, migrant populations)	
NMP records, census	Geographical area, time (year)	

No	Indicator name	Numerator	Denominator
OUTCOME INDICATORS			
2.10	Proportion of targeted risk group protected by IRS	Number of people in the targeted risk group protected by IRS in the past 12 months	Number of people in risk group
3.1	Proportion of pregnant women who received three or more doses of IPTp	Number of pregnant women who received three or more doses of IPTp	Number of expected pregnancies
3.2	Proportion of pregnant women who received two doses of IPTp	Number of pregnant women who received two doses of IPTp	Number of expected pregnancies
3.3	Proportion of pregnant women who received one dose of IPTp	Number of pregnant women who received one dose of IPTp	Number of expected pregnancies
3.4	Proportion of pregnant women who attended antenatal care at least once	Number of first antenatal clinic visits	Expected number of pregnancies
3.5	Proportion of children aged 3–59 months who received the full number of courses of SMC per transmission season	Number of children aged 3–59 months who received the full number of courses of SMC in a transmission season	Number of children aged 3–59 months requiring SMC
4.1	Proportion of children aged < 5 years with fever in the previous 2 weeks for whom advice or treatment was sought	Number of children aged < 5 years with fever in the previous 2 weeks for whom advice or treatment was sought	Total number of children aged < 5 years with fever in the previous 2 weeks
4.2	Proportion of detected cases that contacted health services within 48 h of appearance of symptoms	Number of cases contacting health services within 48 h of appearance of symptoms	Total number of passively detected malaria cases
5.1	Proportion of patients with suspected malaria who received a parasitological test	Number of suspected malaria cases who received a parasitological test	Number of suspected cases of malaria
5.2	Proportion of children aged < 5 years with fever in previous 2 weeks who had a finger or heel stick	Number of children aged < 5 years with fever in the previous 2 weeks who had a finger or heel stick	Total number of children aged < 5 years who had fever in the previous 2 weeks
5.3	Proportion of health facility months with no stock–outs of key commodities for diagnostic testing	Number of health facility months with no stock–outs of key commodities for diagnostic testing	Number of health facility months
6.1	Proportion of patients with confirmed malaria who received first–line antimalarial treatment according to national policy.	Number of patients with confirmed malaria who received first–line antimalarial treatment according to national policy.	Total number of confirmed malaria cases, fiund by both passive and active surveillance.

Source	Breakdown	Comments
NMP records, census	Geographical area, risk group (e.g. population in periurban areas, those living in active focus)	
Routine health information system, census	Geographical area, time (year and month)	
Routine health information system, census	Geographical area, time (year and month)	
Routine health information system, census	Geographical area, time (year and month)	
Routine health information system, census	Geographical area, time (year and month)	
Routine health information system, census	Geographical area, time (year and month)	
Household survey	Geographical area, urban or rural, wealth index, educational status, gender	
Routine health information system	Geographical area or focus, risk group, time (year and month), type of facility	
Routine health information system, health facility surveys	Geographical area, type of facility, time (year and month)	
Household survey	Geographical area, urban or rural, wealth index, educational level of mother, gender	
Routine health information system, health facility surveys	Geographical area, type of facility, time (year and month)	Includes stock-outs of RDTs and microscopy consumables that make diagnostic testing impossible. A stock-out is defined as ≥ 7 days (not necessarily consecutive) of stock-out. This may depend on the strength of the supply system
Routine health information system, health facility surveys	Geographical area, type of facility, parasite species, time (year and month)	

No	Indicator name	Numerator	Denominator
OUTCOME INDICATORS			
6.2	Proportion of all malaria treatment of febrile children aged < 5 years that was ACT (or other appropriate treatment according to national policy)	Number of children aged < 5 years with fever in the previous 2 weeks who received ACT (or other appropriate treatment according to national policy)	Total number of children aged < 5 years with fever in the previous 2 weeks who received any antimalarial medicine
6.3	Proportion of patients with *P. vivax* or *P. ovale* infection who received radical cure treatment	Total number of patients with a confirmed *P. vivax* or *P. ovale* infection who received radical cure treatment	Total number of poeple with confirmed *P. vivax* or *P. ovale* infection
6.4	Proportion of health facility months without stock-outs of first-line treatment	Number of health facility months without stock-outs of first-line treatment	Number of health facility months
7.1	Proportion of malaria cases detected in surveillance systems	Number of confirmed malaria cases identified through active and passive surveillance over 1 year x 1000	Estimated number of malaria cases over 1 year x 1000
7.2	Proportion of expected reports from health facilities received	Number of reports received from health facilities	Number of reports expected from health facilities (number of health facilities multiplied by number of reports expected per health facility during period)
7.3	Annual blood examination rate	Number of patients receiving a parasitological test during 1 year	Mid-year number of people at risk for malaria
7.4	Proportion of cases investigated and classified	Total number of malaria cases in the national case register with fully completed case investigation forms	Total number of malaria cases in the national case registry
7.5	Proportion of foci investigated and classified	Total number of new potential and active foci in the national focus register that were fully investigated in the previous year	Total number of foci in the national focus register

Source	Breakdown	Comments
Household survey, health facility surveys	Geographical area, urban or rural, wealth index, educational level, gender	
Routine health information system	Geographical area, type of facility, time (year and month)	
Routine health information system, health facility surveys	Geographical area, type of facility, time (year and month)	Stockout defined as ≥ 7 days (not necessarily consecutive) of stockout. This may depend on the strength of the supply system.
	Geographical area, time (year)	Estimated total number of cases should include proportion of patients who seek care, proportion who receive a diagnostic test and proportion of health facility reports received.
Routine health information system	Geographical area, type of facility, time (year and month)	Some countries include reporting by CHWs. Systems should include 0 reporting. A due date is implied by the indicator; for example, by the 15th of the following month for reports from health facility to the district level.
	Geographical area, type of facility, time (year and month)	Some guidance has suggested that the annual blood examination rate should be about 10% in order to calculate reliable trends, but the empirical evidence for that target is not strong. In high-transmission settings, the rate is likely to greatly exceed 10% due to PCD alone.
	Geographical area or focus, risk group, time (year and month), type of facility	
	Geographical area or focus, time (year)	

No	Indicator name	Numerator	Denominator
OUTCOME INDICATORS			
7.6	Percentage of case reports received < 24 h after detection	Number of case reports received < 24 h after detection	Total number of malaria case reports
IMPACT INDICATORS			
8.1	Parasite prevalence	Number of people with malaria infection detected by RDT or microscopy	Total number of people tested for malaria parasites by RDT or microscopy
9.1	Malaria case incidence: number and rate per 1000 people per year	Number of confirmed malaria cases identified by active and passive surveillance during 1 year x 1000	Mid-year number of people at risk for malaria infection during reporting year
9.2	Malaria admissions: number and rate per 10 000 people per year	Number of inpatient cases with a discharge diagnosis of malaria x 10 000	Mid-year number of people at risk for malaria infection during reporting year
9.3	Malaria test positivity rate	Number of confirmed malaria cases	Number of patients who received a parasitological test
9.4	Proportion of admissions for malaria	Number of inpatient admissions for malaria	Total number of inpatient admissions
9.5	Number of foci by classification (active, residual, cleared and pseudo)	Number and population of foci by classification (active, residual, cleared and pseudo)	
10.1	Malaria mortality: number and rate per 100 000 people per year	Number of malaria-specific deaths reported in the previous year x 10 000	Mid-year number of people at risk for malaria infection during the reporting year
10.2	Proportion of inpatient deaths due to malaria	Number of inpatient deaths due to malaria	Total number of inpatient deaths
11.1	Number of areas and countries that have eliminated malaria since 2015	Number of areas and countries with malaria in 2015 that subsequently reported zero indigenous cases for 3 consecutive years	
12.1	Number of areas and countries that were malaria-free in 2015 in which malaria has been re-established	Number of areas and countries that were malaria-free in 2015 that have subsequently reported epidemiologically linked indigenous cases for 3 consecutive years	

Source	Breakdown	Comments
	Geographical area or focus, risk group, time (year and month), type of facility	
	Geographical area, urban or rural, wealth index, educational level, gender	In high–transmission settings, this indicator is usually measured only for children aged < 5 years
	Geographical area or focus, risk group, ACD versus PCD, age, sex and species When approaching elimination: indigenous, introduced, imported by nationality, induced	May report numbers of cases when incidence is low
	Geographical area or focus, risk group, age, sex and species	May report numbers of admissions when incidence is low
	Geographical area or focus, risk group, ACD versus PCD, age, sex and species	Test positivity of PCD and ACD and microscopy; RDTs should always be reported separately.
	Geographical area, age, sex	
Focus registry		
	Geographical area, age, sex, risk group and species	May report numbers of cases when mortality rate is low
	Geographical area, age, sex	

ACD, active case detection; ACT, artemisinin–based combination therapy; IPTp, intermittent preventive treatment in pregnancy; IRS, indoor residual spraying; ITN, insecticide–treated mosquito net; LLIN, long-lasting insecticidal net; NMP, national malaria programme; PCD, passive case detection; RDT, rapid diagnostic test; SMC, seasonal malaria chemoprevention

ANNEX 18. EXAMPLE OF QUESTIONNAIRE FOR ASSESSMENT BEFORE AND AFTER A MALARIA EPIDEMIC

The following questionnaire should provide an analytical framework to assess the level of preparedness or success in responding to the epidemic.

1. **Epidemic-prone areas:**
   a. Demarcated? If yes, is/was the epidemic in a high-risk area?
   b. Is/was the epidemic in refugee camps?
   c. Is/was the epidemic related to population movement?

2. **Forecasting and warning systems: with El Niño, real-time and satellite weather data:**
   a. Are/were forecasting data made available, used and shared by national teams?
   b. Do/did the data predict a possible epidemic in the region?
   c. Is/was the regional malaria control station aware of the risk?
   d. Is/was this information disseminated to all levels of malaria control?
   e. Are/were early warning indicators validated over space and time?
   f. Is/was there adequate planning for source reduction measures if the predictions were confirmed?

3. **Early detection system:**
   a. Is/was a well-functioning surveillance system in place for early detection in epidemic-prone districts?
   b. Are/were these data recorded, analysed with set-up thresholds at district level with regular feedback/update to peripheral health care facilities?
   c. Are/were records of previous years available for comparison?
   d. What method is/was used to analyse anomalies and define/validate thresholds (i.e. mean + two standard deviations, third quartile, cumulative sum, etc.)?
   e. Are/were these data regularly reported to a central facility?
      If yes, communication channels used.

4. **Recognition of anomalies and preliminary action taken at the periphery:**
   a. Are/were anomalies detected at the periphery and action immediately taken?
   b. If yes, what action was taken at the periphery first and then at district level?
   c. How was the verification process? Fast enough (in days)?
   d. How is/was notification to district made? and lag time (days)? If more than 2 days, what caused the delay?

5. **Preparedness plan of action:**
   a. Is/was there a plan of action
   b. If yes, is/was it technically and operationally appropriate?
   c. Are/were partners involved in preparing the plan of action? If yes, list.

d. Is/was a budget allotted for malaria epidemic response?

e. Is/was the budget translated into actual disbursements for response?

f. Are/were adequate drugs and medical supplies pre-positioned at district level for rapid distribution? Specify the missing commodities.

g. Are/were there sufficient trained personnel to handle the epidemic?

6. Response:

a. Is/was there effective communication between the local and district level and above?

b. What is/was the lag time between confirmation of the epidemic and local response?

c. Were there sufficient trained personnel to handle the epidemic?

d. Which vector control measures are/were applied?

e. Is/was mass drug administration considered for transmission reduction? If yes, specify the type of medicine, coverage in the affected population.

f. Are/were community mobilization and engagement activities adequate?

7. Disease and economic burden:

a. Length of the epidemic in weeks?

b. Population size affected?

c. Lives lost (excess number of deaths) over the threshold?

d. Morbidity (excess number of cases) over the threshold?

8. If the situation required mobilizing national emergency support:

a. What was the time lag for communication between district and national levels?

b. Who alerted the national level to stimulate a national response (district office, newspaper or other media, other source)?

c. Was national support necessary? Was partners' support necessary?

d. If so, was it effective in curbing the epidemic? [give some rationale]

ANNEX 19. EXAMPLES OF OPERATIONAL RESPONSES TO VARIOUS STAGES OF A MALARIA EPIDEMIC

No.	Intervention or operational measure	Starting epidemic	Accelerated epidemic	Epidemic peak
1	Ensure that all clinics and health facilities are operational and have sufficient drugs, equipment and trained staff.	✓	✓	✓
2	Establish treatment centres (temporary clinics or mobile clinics) where access is a problem or health facility coverage is low.	✓	✓	✓
3	Ensure that the correct diagnosis and treatment are provided at all health facilities and at community level.	✓	✓	✓
4	Promote proactive case detection and management or referral.			
5	Reinforce referral system and consider introduction of artesunate suppositories and intramuscular artemether as temporary measures when these are not already used.	✓	✓	✓
6	Intensify or maintain effective preventive measures for pregnant women.	✓	✓	✓
7	Reinforce health information systems for reporting and epidemic monitoring, preferably weekly.	✓	✓	✓
8	Conduct specific epidemic health education campaigns.	✓	✓	✓
9	Organize regular press releases, press conferences and articles for public information.	✓	✓	✓
10	Conduct IRS if the area was previously sprayed.	✓ With high coverage and quality of IRS	✓ Same as for starting epidemics Change chemicals for IRS if observed susceptibility is low.	✓ Less public health impact at this stage if the previous spraying was not effective.
11	IRS in areas previously not sprayed.	✓ Malaria epidemiology, type of houses or structures, rapid deployment of logistics and effective IRS in target areas.	✓ Same as for starting epidemics	X
12	ITNs	✓ If there is a history of ITN use in the area or capacity to enforce a programme in a short time.		

IRS, indoor residual spraying; ITN, insecticide–treated net