Systems for the early detection of malaria epidemics in Africa

– An analysis of current practices and future priorities

For further information, please contact:

Global Malaria Programme
World Health Organization
20. avenue Appia – CH-1211 Geneva 27
infogmp@who.int

www.who.int/malaria
Systems for the early detection of malaria epidemics in Africa

An analysis of current practices and future priorities

Jean-Olivier Guintran, Charles Delacollette and Peter Trigg
Acknowledgment

The following country staff have specially contributed to this report: Asnakew Kebede and Ambachew Medhin (WCO Ethiopia), Luciano Tuseo (WCO Madagascar), Jean-Désiré Rakotoson (National malaria control programme, Madagascar), Guido Sabatinelli (WR Sudan), Wasailat Zaroug Ibrahim (national malaria control programme, Sudan). Compilation of country reports has been made possible thanks to the support of national staff from Ethiopia, Madagascar and Sudan. Aafje Rietveld from the Global Malaria Programme in Geneva has critically reviewed the document. In addition, valuable technical inputs to this report resulted from informal discussion in WHO Headquarters Geneva with Allan Schapira (RBM/MSP), Jean-Pierre Meert (CDS/GIS), Shiva Murugasam pillay (RBM/MCO), Katelijn Vandermaele (CDS/CSR/LYO/EPs), Maru Aregawi (RBM/MCO), Eline Korenromp (RBM/MME) and Andrea Bosman (RBM/MSP).

Regional malaria advisers from AFRO and EMRO, Dr Magda Robalo and Dr Hoda Atta, have encouraged and supported country missions which have generated needed information to develop this manual.

The report was edited by Mary Roll.

Cover photo credit: WHIB/Pierre Virot
## Contents

Executive summary ................................................. 1  

Chapter 1. This report and its context ........................................... 5  

Chapter 2. Country experiences in implementing malaria in early detection systems ........................................................................ 11  

Chapter 3. Challenges to moving from routine surveillance system to early detection system ............................................................ 17  

Chapter 4. Indicators for an early detection system .................................................. 33  

Chapter 5. Constraints to defining epidemic thresholds ............................................. 48  

Chapter 6. Planning and implementation of early detection systems – future priorities ........................................................................ 58  

Chapter 7. Providing an enabling environment .................................................. 84  

References ................................................................. 89
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR</td>
<td>Adult-to-child ratios</td>
</tr>
<tr>
<td>ACT</td>
<td>artemisinin-based combination therapy</td>
</tr>
<tr>
<td>CDS</td>
<td>communicable diseases</td>
</tr>
<tr>
<td>CFR</td>
<td>case-fatality rate</td>
</tr>
<tr>
<td>CMR</td>
<td>crude mortality rate</td>
</tr>
<tr>
<td>C-SUM</td>
<td>cumulative sum</td>
</tr>
<tr>
<td>DHS</td>
<td>demographic and health survey</td>
</tr>
<tr>
<td>EDS</td>
<td>early detection systems</td>
</tr>
<tr>
<td>EIR</td>
<td>entomological inoculation rates</td>
</tr>
<tr>
<td>EWAR</td>
<td>early warning and response</td>
</tr>
<tr>
<td>GFATM</td>
<td>Global Fund to fight AIDS, Tuberculosis and Malaria</td>
</tr>
<tr>
<td>GIS</td>
<td>geographical information system</td>
</tr>
<tr>
<td>HIMAL</td>
<td>Highland Malaria Project</td>
</tr>
<tr>
<td>HMIS</td>
<td>health management information system</td>
</tr>
<tr>
<td>HRP2</td>
<td>histidine-rich protein-2</td>
</tr>
<tr>
<td>IHR</td>
<td>International Health Regulations</td>
</tr>
<tr>
<td>IMCI</td>
<td>Integrated Management of Childhood Illness</td>
</tr>
<tr>
<td>ITN</td>
<td>insecticide-treated net</td>
</tr>
<tr>
<td>LOAS</td>
<td>lot quality assurance sampling</td>
</tr>
<tr>
<td>MCPSS</td>
<td>malaria control programme surveillance system</td>
</tr>
<tr>
<td>MEWS</td>
<td>malaria early warning system</td>
</tr>
<tr>
<td>MSF</td>
<td>Médecins Sans Frontières</td>
</tr>
<tr>
<td>NDVI</td>
<td>normalized difference vegetation index</td>
</tr>
<tr>
<td>NMCP</td>
<td>national malaria control programme</td>
</tr>
<tr>
<td>PHEIC</td>
<td>public health emergencies of international concern</td>
</tr>
<tr>
<td>pLDH</td>
<td>plasmodium lactase dehydrogenase</td>
</tr>
<tr>
<td>QA</td>
<td>quality assurance</td>
</tr>
<tr>
<td>RDT</td>
<td>rapid diagnostic test</td>
</tr>
<tr>
<td>SOP</td>
<td>standard operating procedures</td>
</tr>
<tr>
<td>SPR</td>
<td>slide positivity rate</td>
</tr>
<tr>
<td>VMH</td>
<td>village malaria workers</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Executive summary

The development and implementation of effective early detection systems (EDS) for malaria epidemics are both of high priority and urgent in Africa south of the Sahara. Most of these epidemics have occurred in highland and desert-fringe areas where malaria transmission is unstable, the population has little immunity, and increases in temperature and abnormal rainfall have resulted in vector proliferation. Other epidemics have occurred as a result of environmental and social changes as well as of the failure of control measures.

It is not widely understood that malaria epidemics are serious public health emergencies that have a major impact on health and the economy. The most important factor in reducing their impact is a timely response, with the implementation of effective preventive or control measures once an epidemic has been predicted or detected. A malaria EDS aims to detect the early stages of an epidemic by measuring changes in the incidence of malaria cases. The basic concepts and guidelines for building national capacity for the early detection and control of malaria epidemics were developed by WHO during the period 1998–2003. This report reviews in detail the literature and country experiences gained from the implementation of these recommendations in Africa, with particular reference to Ethiopia, Madagascar and Sudan, three of the most epidemic-prone countries in Africa. It identifies major technical and operational constraints and suggests actions that may contribute to the development of more effective EDS in the future.

Delimitation and mapping of epidemic-prone areas is an important step in the development of an EDS. None of the various models proposed to designate levels of endemicity is fully applicable in all situations. A more pragmatic approach is to map epidemic-prone districts according to historical reports of previous epidemics and recent point estimates of childhood parasite prevalence (values < 25% could define areas prone to epidemics). In addition, the report provides some tentative guidance to adapt EDS strategies to different epidemiological situations by proposing a “qualitative risk stratification” to determine “unpredictable” exaggerated seasonal transmission that occurs in highland-fringe areas, and a malaria early warning system (MEWS) for predictable “true” epidemics that predominantly occur in semi-arid desert-fringe areas.

Countries have set the goal that national EDS should detect malaria epidemics within two weeks of their onset. This can only be achieved if the data collected are representative, their collection and notification punctual, their analysis prompt and their interpretation able to provide an accurate indication of a developing epidemic. Recent experience has shown that currently operated surveillance systems in most countries do not meet the criteria to reach
this goal. The reasons vary between countries. These include administrative structures that are not conducive to rapid communication, inconsistent guidelines, inconsistent case definitions, lack of standard operating procedures (SOPs), unsuitable formatting and registration of data, lack of representative data, and inappropriate aggregation of data. Where reporting is suitable, it is often compromised by monthly reporting that is unable to detect epidemics fast enough to enable an effective response. These constraints are compounded by the lack or poor quality of laboratory services at the peripheral level that renders difficult the confirmation of malaria disease.

The report proposes the following to assist countries in overcoming these constraints:

• A simple basic structure for an EDS consisting of three levels: (i) a limited number of peripheral health services acting as sentinel sites for data collection; (ii) the district or intermediate level (for data analysis and response); and (iii) the central/provincial level (for policy, planning and coordination).

• A sentinel-site approach with 2–3 strategically situated sites per district and a mobile emergency team to confirm epidemics in the surrounding areas. Specific criteria for selection of these sites are given. Such an approach is considered to be the most cost-effective way in the short term of strengthening the peripheral health services to fulfil the needs of EDS. As financial and trained human resources become more widely available, the sentinel-site system can be expanded if required.

• The adoption of standardized mutually-exclusive malaria case definitions throughout the health services and standardized operating procedures for patient registration in the clinic, diagnosis by the clinic and supporting laboratory services, and for the analysis and reporting of data (for which detailed proposals are made).

• The adoption throughout the system of weekly reporting, since monthly reporting is not able to detect the development of an epidemic in time for an effective response.

• Simple methods for transforming monthly into weekly data to allow the calculation of epidemic thresholds.

• The involvement of private and nongovernmental health-care facilities.

Implementation of these measures should improve the quality of the data collected and reduce the current biases of potential indicators of epidemic risk. Once implemented however, it is likely to take another five years to gather the required minimal set of reliable baseline data to provide better accuracy and timeliness for detecting malaria epidemics. Meanwhile, work should proceed using the available data.
In the absence of quality data, the most reliable indicator that is both readily available from outpatient departments and can be used as a basis to determine the development of an epidemic is “the proportion of outpatient department attendance attributable to cases of uncomplicated malaria, regardless of laboratory results”. This would be the aggregate of the not-tested, tested negative and confirmed categories, divided by the total number of outpatient consultations.

More specific indicators may be used once quality data are available, based on reliable parasite confirmation and standardized patient registration. The suitability and constraints of these indicators are discussed in detail.

Experience shows that determining whether there is an abnormal incidence of malaria in a specific area is not easy. It requires the availability of historical prevalence data over at least five years, from which a baseline of normal incidence and threshold values that are applicable to the specific area can be determined. The potential utility of the following methods to determine epidemic thresholds is discussed in detail: (i) constant case-count thresholds; (ii) mean number of malaria cases plus standard deviations; (iii) percentiles over the median; and (iv) the cumulative sum (C-SUM) method. Based on a comparative analysis of the suitability of these methods to confirm past epidemics in Ethiopia and Sudan, algorithms for the determination of both alert and epidemic thresholds are proposed. These require further evaluation.

The implementation of malaria EDS is taking place at a time of administrative change in which health infrastructures are being decentralized, and vertically-organized malaria control programmes are being integrated into the general health services. As part of this reorganization, it has also been proposed that malaria EDS be organized as a part of integrated disease surveillance systems. This is logical and potentially cost-effective in the long term. However, routine disease surveillance systems are not able to meet the needs for the early detection of malaria epidemics since their objectives and the nature, flow and formatting of data are different. The report identifies discrepancies and required modifications in the Integrated Disease Surveillance and Response (IDSR) guidelines to be compatible with the needs of a malaria EDS.

Implementation of an effective EDS is a long-term activity. It requires not only financial investments in excess of currently available budgets for disease surveillance, but also an increased commitment of decision-makers and public health staff throughout the EDS system so that all have a sense of ownership and responsibility. An enabling environment should be provided. Proposals to this end are given in the report.
1. This report and its context

1.1 Purpose of the report

The purpose of this report is to:
- document current experiences in the implementation of malaria early detection systems (EDS) in epidemic-prone countries of Africa south of the Sahara;
- evaluate current WHO recommendations on malaria EDS in light of these experiences;
- capitalize on the “lessons learnt” from these experiences by identifying common technical and organizational constraints; and
- identify strategies to overcome these constraints in order to improve the design and implementation of malaria EDS in African countries.

The report is mainly based on experiences from Ethiopia, Madagascar and Sudan, three of the most epidemic-prone countries in Africa (1–3).

These countries were chosen for an in-depth study since each country has:
- an estimated 50% of its population living in malaria epidemic-prone areas (this represents more than 63 million people, i.e. almost 50% of the total population at risk of epidemic malaria in the whole of Africa south of the Sahara);
- a long history of malaria epidemics that has been used to delimit epidemic-prone areas;
- developed a strategy for malaria epidemic detection;
- implemented early detection systems for malaria epidemics, based on available methods and technologies;
- planned to decentralize and integrate its surveillance systems with the general health services, or is in the process of doing so; and
- received extensive technical and financial support for malaria epidemic detection and control from WHO and the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM).

1.2 Contents of the report

This report:
- describes the context in which malaria EDS are being developed and implemented in Africa;
- analyses the experiences in the implementation of EDS in the selected countries;
- reviews current disease surveillance systems and their potential for meeting the needs of malaria EDS;
• identifies models and indicators that can be used to identify epidemic-prone areas and the emergence of malaria epidemics;
• reviews and identifies the limitations of available methods for defining epidemic thresholds;
• provides a set of recommendations for more effective planning and implementation of malaria EDS that should have wider application to other epidemic-prone countries of Africa south of the Sahara; and
• proposes actions for providing an enabling environment for the more effective planning and implementation of malaria EDS in Africa.

It is mainly based on travel reports (2,3) that give more details of on-site analyses of malaria epidemic detection and surveillance in the three countries. The report also reviews published data of experiences in other African countries.

1. 3 Context of the report

1.3.1 Malaria epidemics in Africa

Impact of malaria epidemics

Malaria epidemics are common in Africa. During the period 1999 to 2004, a total of 119 were reported from 17 countries south of the Sahara (4). These epidemics have varied in their magnitude depending on the situation and the causes. Their true size, extent and impact have generally been inadequately documented because of difficulties in obtaining accurate data. However, it has been estimated that each year 11 million cases and 110 000 deaths may result from epidemic malaria in Africa (4,5).

In addition to the direct health impact, epidemic malaria also results in economic losses at the household, community and country levels. In many rural communities of Africa, epidemics occur during planting and harvesting seasons when the demand for labour is greatest (6,7).

Causes of malaria epidemics

Epidemics may be caused by many factors, but in Africa most are the result of an unusual increase in vector abundance caused by climate change, e.g. increased temperature or abnormal rainfall. This occurs frequently in highland and semi-arid areas where malaria transmission is unstable and the population has little or no immunity. Such climate-driven epidemics generally occur in 2–7-year cycles, following the periodicity of abnormal meteorological conditions. In the Sahel, decades of prolonged drought have resulted in significant reductions in incidence and consequent reductions in population immunity to malaria (8). Thus, areas that were previously highly endemic are now vulnerable to epidemics (9).
Non-climatic factors may also play a role in the development of malaria epidemics, either of themselves or superimposed upon climatic factors. These include:

- an influx of non-immune populations into endemic areas;
- massive environmental changes such as deforestation, irrigation projects and flooding;
- interruption of effective surveillance and control;
- parasite resistance to the drug;
- high incidence of other diseases or poor nutritional status; and
- unplanned urbanization.

It has been recently estimated that 200 million people (24.6% of the total population of Africa) live in urban settings where they are at risk of contracting malaria (10). Organized urban development reduces these risks of malaria. Comparative analyses of urban and rural sites in Africa have demonstrated 10-fold decreases in entomological inoculation rates (EIR) in urban centres compared to their rural peripheries (11,12). However, the risk of malaria is increasing in many African cities, particularly in sprawling and disorganized periurban areas where urban settlements encroach on the rural habitats of malaria vectors not normally found in city environments. As a consequence, major cities surrounded by high transmission areas or irrigated agricultural schemes, such as Khartoum in Sudan which was severely affected in 1988 in the aftermath of massive floods, should be considered as potentially prone to epidemics (13).

1.3.1.1 The need for early detection of malaria epidemics

The most important factor in reducing the impact of an epidemic is a timely response, with the implementation of effective preventive or control measures once an epidemic has been predicted or detected. The longer an epidemic remains undetected with no control measures, the higher will be the costs in terms of morbidity and mortality (in the case of falciparum epidemics). Thus, the maximum impact is obtained when control measures are implemented at the very early stages. The key to a decisive reaction for the prevention and control of malaria epidemics is “to be prepared” (14). This requires the development of robust early warning and early detection systems that are directly linked to prevention and control programmes for a rapid response.

1.3.1.2 WHO technical support network

In 1998, WHO established a technical support network (TSN) for the prevention and control of malaria epidemics (15). This initiative was taken in response particularly to epidemics that had been reported in the mid-1990s from eastern and southern Africa and certain Sahelian countries.

The basic concepts for building national capacity for the early detection and control of epidemics were developed following a historical overview and analysis of malaria epidemics (16). These concepts were subsequently adopted by the 20th WHO Expert Committee on Malaria which recommended that national authorities in all epidemic-prone countries should develop a strategic plan for
epidemic prediction, detection and control that can be used as a basis for a preparedness plan of action to be implemented by the regional/provincial health services in epidemic-prone areas (14, 17, 18).

It was recommended that this preparedness plan of action should have the following complementary objectives:

- identification of epidemic-prone areas and the populations at risk;
- where feasible, forecasting and prevention of malaria epidemics; and
- early detection and control of epidemics by rapid case management and, where possible, vector control.

Most countries in Africa with highly seasonal or epidemic malaria now include epidemic preparedness in their malaria control policies (4).

Guidelines to establish and implement long-range forecasting, malaria early warning systems (MEWS) and early detection systems were developed by the technical support network in 2001 and reviewed in 2002 (19, 20). These guidelines provide the concepts, indicators and planning required for the continuum of activities that can be used to monitor the escalation of the malaria situation towards a possible epidemic with increasing lead-times and decreasing accuracy and spatial resolution of prediction (21). Long-range forecasting is based on ENSO\(^1\) indices and climate forecasting (19). For those areas where future climates can be predicted, such measurements can very broadly forecast malaria epidemic risk many months in advance, allowing countries time to ensure the availability of resources, should an epidemic occur in the coming season. Early warning is based on monitoring of climatic indicators, population vulnerability factors, and operational and environmental factors in order to detect when conditions suitable for an epidemic have already appeared at a given time and place (24). It has the potential of predicting epidemics weeks to months in advance, allowing surveillance to be enhanced, and preventive and control measures to be directed to specific areas. The purpose of early detection is to detect the beginning stages of an epidemic by measuring changes in the incidence of malaria cases.

Although at least eight African countries are developing a malaria early warning system (MEWS) (4), at present it is accepted that long-range forecasting remains predominately research-based. Many, if not most, programmes do not have sufficient resources to implement a MEWS, since the capacity of countries in malaria epidemiology and planning of malaria epidemic prevention and control is generally weak. Few countries are able to collect and analyse the relevant data and report in a timely manner to implement effective control or prevention (20). Rapid assessment guidelines (14) and new training models have been produced to aid countries develop their EDS (25, 26).

---

1 ENSO or the El Niño Southern Oscillation is a seesaw of atmospheric pressure between the eastern equatorial and Indo-Australian areas of the Pacific Ocean that can produce serious weather disturbances in wide areas throughout the world (22, 23). El Niño events occur about every 2–7 years and are associated with severe floods in some areas and drought in others.
The main objectives of the fourth meeting of the technical support network in 2003 were to translate policy into practice, linking epidemic detection to options for prevention and control by rapid diagnosis, case-management and vector control. With respect to epidemic detection, it was concluded that it was more realistic that countries give priority to developing early detection systems, based on improving surveillance with a limited number of validated indicators. These systems could increase in complexity as staff capabilities improve, new information and techniques become available from research and collaboration with other partners, and sources of information are established (14).

1.3.1.3 The context in which EDS are being implemented

Administrative change

Recent decades have been a period of administrative change in the malaria-endemic countries of Africa. National governments are decentralizing their health infrastructures and vertically-organized malaria control programmes, where they existed, are being integrated into the general health services. As part of a decentralized system, federal ministries of health define broad health policy orientations and develop technical guidelines, and many regional health bureaus are empowered to take major decisions on the organization, planning, implementation, evaluation and monitoring of disease-control programmes. Although progress is being made, implementation of these changes is a difficult and politically-influenced process and so it may not be surprising that change has been slow and major problems still remain to be resolved. This has important implications for the detection and control of malaria epidemics. African countries are attempting to implement malaria early detection systems in this context of administrative change.

Resources allocated for surveillance

Without a detailed audit to determine the actual costs of the prevention and control of epidemics and the specific resources allocated to EDS, it is difficult to ascertain any figures. However, most malaria-endemic countries of Africa have low incomes and limited financial resources, and the proportion of GNP allocated to health is generally limited below 5% of GNP in spite of the recommended 15%. Thus the implementation of an EDS requires financial resources well in excess of currently available budgets. Nevertheless, most epidemic-prone countries of Africa have included prompt recognition and control of epidemics in their plans of action for malaria prevention and control and, more recently, in proposals for external funding. For example, the malaria control programmes in Ethiopia, Madagascar and Sudan receive unprecedented financial benefits from the GFATM, of which a significant proportion should be allocated to epidemic detection and response (Table 1).
1.4 Rationale and goals of a malaria EDS

A malaria EDS aims to detect the emergence of an epidemic by measuring changes in the incidence of malaria morbidity and mortality (19, 20). This method offers very little lead-time (days to weeks) for the preparation of containment measures, with the result that it is not sufficiently timely to allow for the preparation and implementation of effective malaria prevention measures. However, if the epidemic is detected early in its development and the response is rapid and effective, the peak of morbidity and mortality can be averted.

This requires the identification of:
- epidemic-prone areas and the population at risk in order to target surveillance and response;
- epidemic risk factors;
- where and how surveillance needs to strengthened;
- identification of epidemic thresholds to verify an emerging epidemic; and
- the timing of decisions and actions needed to verify and control the epidemic.

The strategies adopted to achieve these goals vary according to the specific context in each country and national capabilities for the implementation of EDS that are determined by a variety of factors including financial and human resources, administrative structure, epidemiological situation and external support.

### Table 1. Financial and administrative context of EDS development in Ethiopia, Madagascar and Sudan

<table>
<thead>
<tr>
<th></th>
<th>Ethiopia</th>
<th>Madagascar</th>
<th>Sudan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population in 2001 (million)</td>
<td>64.5</td>
<td>16.4</td>
<td>31.8</td>
</tr>
<tr>
<td>Per capita GDP in 2001 (US$)</td>
<td>366</td>
<td>846</td>
<td>1 171</td>
</tr>
<tr>
<td>Administrative areas</td>
<td>State</td>
<td>Province</td>
<td>State</td>
</tr>
<tr>
<td></td>
<td>Zone</td>
<td>District</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>District</td>
<td>Commune</td>
<td>Sector</td>
</tr>
<tr>
<td></td>
<td>Parish</td>
<td>–</td>
<td>Locality</td>
</tr>
<tr>
<td>Expenditure on health in 2002*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total % of GDP</td>
<td>5.7%</td>
<td>2.1%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Total per capita ( intl. US$)</td>
<td>21</td>
<td>18</td>
<td>58</td>
</tr>
<tr>
<td>Government per capita ( intl. US$)</td>
<td>9</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Funding of malaria control in 2003* (million US$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>5.0</td>
<td>5.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Others</td>
<td>–</td>
<td>1.0</td>
<td>2.4</td>
</tr>
<tr>
<td>GFATM approved (2-year budget)</td>
<td>37.9 (round 2)</td>
<td>26.1 (rounds 1,3,4)</td>
<td>27.0 (round 2)</td>
</tr>
</tbody>
</table>

* Source: WHO and UNICEF

*b Source: UNICEF
2. Country experiences in implementing malaria early detection systems

Although the goal of all countries prone to malaria epidemics in Africa is to detect and respond adequately to epidemics within two weeks of their onset, the degree, nature and geographical distribution of epidemic risk and the capacity of countries to respond varies greatly. Thus each country should adapt, design and implement an EDS that is suitable to its particular epidemiological situation and financial, human and administrative capabilities. This is illustrated by the following case studies in Ethiopia, Madagascar and Sudan, three countries that have different epidemiological patterns of epidemic malaria (Table 2).

Table 2. Development of early detection systems for malaria: epidemiological context in Ethiopia, Madagascar and Sudan

<table>
<thead>
<tr>
<th></th>
<th>Ethiopia</th>
<th>Madagascar</th>
<th>Sudan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population at risk of epidemics (million)</td>
<td>32.2</td>
<td>8.2</td>
<td>15.9</td>
</tr>
<tr>
<td>Proportion of total population (%)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Epidemic-prone areas</td>
<td>Highlands Semi-arid</td>
<td>Highlands Semi-arid</td>
<td>Along rivers Semi-arid Urban areas</td>
</tr>
<tr>
<td>Proportion of <em>P. falciparum</em> (countrywide) (%)</td>
<td>60</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Main vectors</td>
<td><em>An. arabiensis</em>(^a)</td>
<td><em>An. arabiensis</em>(^b) An. <em>funestus</em>(^c)</td>
<td><em>An. arabiensis</em>(^c)</td>
</tr>
</tbody>
</table>

\(^{a}(27)\) – \(^{b}(28, 29)\) – \(^{c}(30)\)

2.1 Ethiopia

In Ethiopia, the determinants of malaria transmission are diverse and localized, but altitude linked to temperature is certainly a major limiting factor in the highland plateau region, and rainfall in the semi-arid areas. Recurrent epidemics have been reported from the densely populated highlands since the 1930s. The Dembia plain near Lake Tana was affected in 1953, with an estimated 7000 deaths. A broader and more devastating epidemic was documented in 1958, affecting most of the central Amhara highlands between 1600 m and 2100 m with an estimated 3 million cases and 150 000 deaths (31). Subsequently, cyclic epidemics of various dimensions have been reported from other highland areas, with intervals of approximately 5–8 years, in 1965, 1972, 1980 and 1987. Most of these epidemics were attributed to climatic abnormalities. During the 1990s, localized epidemics occurred more frequently and in 1992 (32), 1998 (33, 34) and 2003 (35), they were widespread and severe.
2.2 Madagascar

As in Ethiopia, malaria epidemics in Madagascar have occurred in the central highlands and semi-arid areas in the south. The first recorded epidemic was in 1878 in the highlands around Tananarive, from which it spread to the whole of the high plateau, causing devastating mortality in non-immune workers brought from the west coast to work on construction projects and irrigated rice cultivation. A second, particularly virulent, epidemic occurred in the same area in 1895, after which falciparum malaria became endemic in the high plateau areas. Malaria control, based on the chemoprophylaxis of children with chloroquine and on indoor residual spraying (IRS) of DDT, was initiated countrywide in 1949. While the results in the coastal areas were disappointing, those on the plateau were considered so successful that control measures were discontinued in 1961. This success was attributed to the disappearance of the major vector, Anopheles funestus, from most of the area.

Following the neglect of surveillance and control of the residual foci and the closure of treatment centres, there was a resurgence of malaria from the mid-1970s, culminating in devastating epidemics in 1986–1988, during which it was estimated that 10 000–25 000 people died from malaria (8, 36–39). IRS was re-established focally in 1988 and generalized by 1993 to every locality situated at an altitude between 1000 m and 1500 m, resulting in a dramatic impact on morbidity and mortality.

Epidemics in the southern semi-arid areas are poorly documented. Investigations after a late “epidemic” alert in Ampaniihy and Ankilimivory during 1994 indicated that the malaria indices in Ankilimivory were 45%, compared to 15% a year later. However, this could not be correlated with any obvious risk factors such as abnormal rainfall (40, 41).

2.3 Sudan

Owing to the lack of health statistics, the history of malaria epidemics and epidemic risk in Sudan is poorly documented. However, reports of the Blue Nile Health Project refer to a major epidemic in 1974–1975 in Wad Medani. The collapse of this project in the late 1980s resulted in the cessation of malaria control activities in the project area and an epidemic resurgence of malaria between 1989 and 1992. Epidemics also occurred in Khartoum in 1988, and in Khartoum and Gezira in 1994 (30).

Epidemics continued to be reported during the past decade although they have not been adequately confirmed nor the risk factors identified. Epidemic-prone areas are in the hypoendemic desert-fringe areas of Northern State and North Darfour, the poor savannah areas of Greater Darfour, Khartoum State, North
Kordofan and Sinnar with seasonal transmission, the hypoendemic urban areas of Khartoum, and around all large-scale irrigation projects such as those in Geriza (13, 42, 43).

In contrast to the scarcity of health information, there are well-kept detailed meteorological and hydrological records in the country (e.g. of river levels). These allowed Najera to demonstrate that the peaks in total annual rainfall and yearly maximum levels of the river Nile at Khartoum and of the Blue Nile at Wad Medani correspond with the known epidemic years of 1988 and 1994 in Khartoum, end of 1975 and 1993–1994 in Wad Medani (16, 30). Large influxes of vulnerable populations into areas of hyperendemic malaria, leading to an overload of health services and high malaria mortality, have also been identified as an epidemic risk factor in Sudan (43).

2.4 Different types of epidemics – analysis of historical data

The analysis of historical health-facility data has shown that explosive “true” epidemics, epidemics due to exaggerated seasonal transmission and epidemics due to upward trends in transmission occurred in Ethiopia, Madagascar and Sudan during 1980-2003 (1–3). A fourth type was also identified in the highland plateau areas of Madagascar during 1986–1988 (26, 38, 39) and in the area of the Blue Nile project in Sudan in the early 1990s (16) where there were explosive resumptions of transmission in areas that were susceptible to transmission, but where malaria had been eliminated and surveillance and control activities discontinued (Table 3).

2 Defined as follows by WHO (20):

Explosive true epidemics are classic or “true” epidemics that occur infrequently or cyclically in relatively non-immune populations exposed to malaria transmission as a result of climatic abnormalities. They occur mainly in arid and semi-arid areas where there is little or no seasonal fluctuation in malaria transmission and infections are rare.

Epidemics due to exaggerated seasonal transmission occur when there are cases in excess of what is generally expected for the season in areas where malaria is endemic but shows strong seasonal or periodic variation. Such variations are relatively predictable and influenced by variations in the normal climate.

Epidemics due to a general upward trend in transmission occur when malaria transmission is increased by population movements, permanent environmental changes, the breakdown of control operations and/or political instability. In cases of large population movements, intense civil disturbances and war, these situations may develop into complex emergencies. The pattern can be either explosive or exaggerated seasonal variation.
Table 3. Documented history of epidemics in Ethiopia, Madagascar and Sudan

<table>
<thead>
<tr>
<th>Type of Epidemic</th>
<th>Ethiopia</th>
<th>Madagascar</th>
<th>Sudan</th>
</tr>
</thead>
</table>

* (40, 41); † (36–39); ‡ (16)

These analyses also highlighted many limitations in the use of routine surveillance data for both the identification of epidemic-prone areas and the detection of emerging epidemics. In the latter case, this led to the reporting of “false” epidemics. These limitations are discussed in more detail in sections 3–5.

2.5 Strategies and goals for EDS

The various strategies used by Ethiopia, Madagascar and Sudan for implementing EDS are summarized in Table 4.

Table 4. Early detection systems in Ethiopia, Madagascar and Sudan

<table>
<thead>
<tr>
<th></th>
<th>Ethiopia</th>
<th>Madagascar</th>
<th>Sudan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Started</td>
<td>1999</td>
<td>1997</td>
<td>2001</td>
</tr>
<tr>
<td>Date</td>
<td>Sentinel sites since 2004</td>
<td>Universal</td>
<td>Sentinel sites</td>
</tr>
<tr>
<td>Coverage</td>
<td>8 regional states 385 districts 61 sites (first year)</td>
<td>3 provinces 35 districts 866 sites</td>
<td>16 states 144 sites</td>
</tr>
<tr>
<td>Level of data analysis</td>
<td>District</td>
<td>Cluster of 3-4 districts</td>
<td>State</td>
</tr>
<tr>
<td>Dedicated staff</td>
<td>5</td>
<td>12</td>
<td>2</td>
</tr>
</tbody>
</table>
2.5.1 Ethiopia

It was originally proposed that the EDS system should be based on the weekly monitoring of malaria morbidity incidence by every peripheral health facility. However, after the vast epidemics in 2003, this strategy was changed to a sentinel-site approach for which new resources were allocated. The selection of a first set of 61 sentinel sites, activated in 2004, was based on an analysis of morbidity data collected in 2002 from more than 2000 health facilities in the major epidemic-prone areas. These historical morbidity data provide the baseline for current analyses at the district level.

The development of a MEWS was also proposed but this has only been initiated recently as a research project in the east Showa zone of the Rift valley.

2.5.2 Madagascar

An epidemiological surveillance system for malaria, incorporating an EDS, was established in 1997 by the Malagasy Service for the Control of Malaria and Plague (SLPP) in collaboration with the Italian government and the Pasteur Institute. A strategy of full coverage, as opposed to a sentinel-site approach, was chosen because of the substantial heterogeneity in malaria transmission over time and space and within epidemic-prone areas. Initially, the EDS involved over 700 health facilities in 27 districts populated by more than 5 million people, i.e. over 60% of the population at risk of malaria epidemics.

Coverage has been increased gradually during the past six years so that now more than 850 sites, including some from the private and non-profit sectors, report morbidity data to the district level. Initially, reporting was on a monthly basis but since 2004, additional funding from the GFATM has allowed the implementation of weekly reporting of malaria cases and the expansion of the EDS to cover the two semi-arid provinces in the south of the country.

Analysis is performed at district level with the support of specifically assigned officers, each of whom is responsible for a cluster of 3–4 districts. These officers also perform field investigations to confirm an epidemic when abnormal incidences are reported.

2.5.3 Sudan

The development and implementation of an adequate EDS in Sudan is relatively recent.

Following the collapse of malaria control in Sudan in the late 1980s, malaria control was incorporated into the general medical services in which malaria surveillance became the responsibility of the department of communicable diseases surveillance (CDS). It was decided that malaria cases should be reported weekly by more than 500 health facilities, with analyses being performed at
the state level and raw data, aggregated by the state, shared weekly with the national malaria control programme (NMCP).

In practice, this integrated system has only been implemented in Khartoum State where mortality and morbidity data are reported from about 150 health units, including some private and non-profit sectors. These data are first compiled in each of the 25 localities/sectors and forwarded after aggregation to the state level for compilation, computerization and analysis.

Owing to the poor performance of the integrated CDS system and the concern that the CDS data may obscure local epidemics, in 2001 the NMCP initiated a parallel reporting system based on 144 sentinel sites in 16 epidemic-prone states. The reporting system is designed to provide both the state malaria departments and the federal NMCP with weekly data on monitoring of epidemic risk factors in addition to surveillance data concerning morbidity and mortality. District-level staff are not directly involved in the EDS since the aggregation and analysis of data for epidemic detection is carried out by the state malaria department. As part of this system, an intensified project for early warning/early detection was initiated in 2002 in 25 sentinel sites in the epidemic-prone states of Khartoum, North Kordafan, Kassala, Northern and Sennar.
3. Challenges to moving from routine surveillance to an early detection system

3.1 The functions of surveillance and early detection systems for malaria

3.1.1 Public health surveillance

Public health surveillance is the ongoing systematic collection, analysis, interpretation and dissemination of data concerning health-related events for use in public health action to reduce morbidity and mortality and to improve health in the affected populations (44, 45).

Most African countries have routine surveillance systems that collect and report health data, including those for malaria. The objectives of these systems are primarily to:

• estimate the burden of diseases and determine their distribution;
• evaluate the impact of prevention and control measures; and
• facilitate planning and replanning of activities.

However, it is increasingly accepted that surveillance systems are also required for the continuous monitoring and evaluation of specific health programmes to provide data to assess the process, quality, coverage and impact of prevention and control measures within the concept of health management information systems (HMIS) (46).

These increasing demands for surveillance data are major challenges, both to the health staff who have to plan and implement effective surveillance systems to meet the various programme needs and to the district and peripheral staff responsible for the generation of the data on which these systems are based.

In order to meet these challenges, the following guiding principles on surveillance and monitoring have been developed (47):

• Too many data = poor data. Consensus is needed on a minimum set of data/indicators to be collected, analysed and reported officially according to interventions and objectives.
• Standardized case definitions based on consensus should be applied at all levels of services and in all countries.
• Data flow should, as much as possible, be integrated within the routine surveillance system.
• Data should be incorporated into user-friendly geographical information system (GIS) software.
• Data should be relevant to guide/orient/reorient interventions, planning and management, including allocation of resources at the level where data are collected, in order to achieve the main objectives.
• Additional data and indicators may be added according to particular interventions, needs or objectives.
• Feedback is continuously provided to those who generate the data.

3.1.2 Early detection of malaria epidemics

Experience shows that malaria epidemics develop relatively quickly and have an average duration of 3–4 months. Thus, in addition to the above functions, surveillance systems for epidemic-prone diseases such as malaria have an additional function, i.e. to detect the emergence of an epidemic early enough for the response to be cost-effective. This led African Heads of State and Ministers of Health at a meeting in Abuja, Nigeria, to agree that countries should aim “to detect and control epidemics within two weeks of onset” (48). Ideally, malaria EDS should be a part of the detection system for other epidemic communicable diseases.

3.1.3 Integrated disease surveillance and response

Many disease control programmes in Africa, including those for malaria, have developed their own surveillance systems. These systems have similar functions, structures and procedures and may involve the same personnel, particularly at the district and peripheral levels. Unfortunately for a variety reasons, these vertically-organized systems have not been totally effective in meeting the control needs of the specific diseases. As specific disease-control programmes have been increasingly integrated into the general health services, it is a logical step that disease surveillance is also integrated to rationalize the use of health service staff and improve effectiveness, without compromising the capacity of specific disease programmes to measure their own programme performances (see also section 7.6).

An integrated disease surveillance system (IDSR) for strengthening both surveillance systems and response capacities was initiated by WHO in 2001 for implementation in countries of the WHO African and South-East Asia regions (49, 50). It was proposed that all components of surveillance activities for priority diseases should be integrated at all levels of the health services. Technical guidelines for integration that can be adapted to country-specific needs have been developed in which diseases are classified according to the following three categories:
• epidemic-prone diseases;
• diseases targeted for eradication/elimination; and
• diseases of public health importance.

An EDS component included in these guidelines targets the first two categories exclusively, and is based on routine weekly reporting with, where possible, detailed case reports including laboratory data.
3.2 Limitations in the use of surveillance data for malaria EDS

In spite of the abundant data routinely generated by health-care facilities, these have to date been unsuitable for the epidemiological analyses required to determine the trends and variation in malaria incidence that would provide reliable indicators for the early detection of malaria epidemics. This is seldom appreciated. Surveillance data may be used for the early detection of a potential epidemic only if:

• data collection and notification are punctual and occur on a weekly basis;
• data collection is representative of malaria incidence in the whole community;
• data interpretation is prompt and occurs on a weekly basis; and
• data interpretation provides an accurate indication of an epidemic occurring (19).

In addition, it has been recently recommended (14) that the implementation of EDS should be based on the following:

• parasitological confirmation of febrile cases;
• selection and use of sentinel sites; and
• preliminary data analysis and interpretation at the periphery.

Table 5 lists a significant number of differences between routine surveillance and malaria EDS.

### Table 5. Basic characteristics of routine surveillance and early detection systems for malaria

<table>
<thead>
<tr>
<th></th>
<th>Surveillance</th>
<th>Malaria EDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functions</strong></td>
<td>Distribution of diseases over space and time</td>
<td>Early detection of epidemics</td>
</tr>
<tr>
<td></td>
<td>Planning and replanning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evaluation of control measures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitoring of programmes</td>
<td></td>
</tr>
<tr>
<td><strong>Operator</strong></td>
<td>CDS&lt;sup&gt;a&lt;/sup&gt;</td>
<td>MAL&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Representativeness</strong></td>
<td>Health facilities</td>
<td>Communities and health facilities</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>District/region/country</td>
<td>Subdistrict and district</td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td>Monthly/quarterly</td>
<td>Weekly</td>
</tr>
<tr>
<td><strong>Reported cases</strong></td>
<td>Fever (probable malaria)</td>
<td>Confirmed malaria</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>All health care facilities, including public, private and nongovernmental sectors</td>
<td>Sentinel sites</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>District and central levels</td>
<td>District-based plus initial rough analysis at the periphery by well-trained health workers</td>
</tr>
<tr>
<td><strong>Interpretation</strong></td>
<td>Monthly/quarterly/annual trends in case-load</td>
<td>Weekly incidence over thresholds</td>
</tr>
</tbody>
</table>

<sup>a</sup> Communicable diseases surveillance department; <sup>b</sup> Malaria control department.
Many limitations affect the ability of routine surveillance to meet the needs of a malaria EDS. These include:

- unrepresentative data;
- incomplete reporting with inappropriate aggregation of data;
- monthly reporting of malaria incidence;
- poor coverage and unacceptable quality of laboratory services;
- lack of standardized diagnosis and case management;
- inconsistent registration and classification of cases;
- inappropriate guidelines; and
- organizational limitations and inappropriate structures.

These issues, many of which are interrelated, are discussed in detail below.

3.2.1 Unrepresentative data

Routine surveillance generally uses attendance figures at health facilities as a proxy for the burden of disease in the population. This is based on the assumption that the population attending health services reflects the health problems of the population at large. This is generally not the case. Most malaria patients in endemic countries do not seek treatment or are treated outside the formal health sector. Consequently, the proportion of febrile children aged under 5 years who are treated with antimalarial drugs in Africa south of the Sahara may range from approximately 2.5% to a maximum of 65% \(^5\). In addition, most malaria deaths occur at home and are not captured at all by routine health information systems.\(^3\)

Moreover, the true burden in the formal health sector is underestimated because routine surveillance systems usually only collect data from governmental and not from private and nongovernmental health facilities. For example, a pilot health information system in one state of Ethiopia recorded 2.4 million malaria cases by including reports from private and nongovernmental facilities in 2002, while the government surveillance system reported only 614 000 cases \(^1\).

3.2.2 Incomplete reporting with inappropriate aggregation of data

The aggregation of incomplete data at various levels without intermediate analysis is a common problem in centralized health surveillance systems. It seriously reduces the accuracy of routine surveillance of any disease but, when surveillance is used to detect localized epidemics of diseases such as malaria, its effect can be catastrophic. Data become increasingly biased at each administrative level where aggregation takes place by the variable proportion of missing reports. Moreover, the analysis of trends in indicators such as disease incidence is also jeopardized if the level of incompleteness varies over time.

An additional problem, although less frequently observed, is the practice of aggregating malaria cases reported by community health workers with figures of

\(^3\) Sick people do not attend, or are repelled by, the formal health services for many reasons. These include difficult access in terms of distance and time, high cost and low quality of these services, lack of drugs as well as local practices and beliefs.
An analysis of current practices and future priorities

3.2.3 Monthly reporting of malaria incidence

Routine disease surveillance systems generally report on a monthly and sometimes quarterly basis. The time taken to report these data to a higher level, e.g. from the peripheral health facilities to the district level, should be at most seven days, but is usually significantly longer (14). It is obvious therefore that such a reporting system cannot capture at an early stage an increase in malaria cases that is indicative of an emerging epidemic.

In 2003, WHO recommended that a weekly reporting system for malaria should be introduced wherever possible, but recognized that not all countries are currently able to carry this out. In many cases, monthly reporting and a concerted effort to improve the quality of data collection and reporting would be a better starting-point (14). While some countries, such as Botswana and Swaziland, have made the change successfully, others are having problems in establishing and implementing this system. For example, monitoring charts are widely available in Ethiopia but only used to plot monthly morbidity figures. The main reason is that weekly figures are not available through available historical records (1). As a consequence, epidemic thresholds are often not calculated and epidemic alerts remain qualitative. A similar problem emerged in Madagascar and Sudan when the national malaria control programme decided to change from monthly to weekly monitoring (2, 3).

3.2.4 Poor coverage and unacceptable quality of laboratory services

It has been recognized that there is added value in having laboratory services available at the peripheral level to confirm whether malaria is the primary cause of any unusual rise in febrile illness (14). In addition, it is current WHO policy that all those in epidemic-prone areas that are suspected of suffering from malaria should have the diagnosis confirmed by either microscopy or rapid detection tests (RDTs) before treatment with an artemisinin-based combination therapy (ACT). In highly endemic areas, this only applies to children aged under 5 years (51). The current limitations of microscopy for malaria are well recognized and documented (52–55). They include:

- lack of political commitment and funds to support the development of laboratory services;
- poor quality of microscopy, particularly at the peripheral level;
- difficulties in maintaining microscopy facilities in good order;
- logistic problems and high costs of maintaining adequate supplies and equipment;

The need and importance of accurate microscopical diagnosis of malaria has become acute with the spread of drug resistance and of multidrug-resistant P. falciparum in particular. A good microscopical service is one that is cost-effective, consistently accurate and timely enough to have a direct impact on treatment, and able to provide data for surveillance including EDS. Guidelines to improve the quality, and quality assurance, of malaria microscopy have been developed by WHO (57–59).
• lack of adequate training and retraining of laboratory staff;
• delays in providing results to clinical staff; and
• lack of quality assurance (QA) and supervision of laboratory services.

As a consequence, laboratory services are rarely found at the community level of the health services, and sometimes not even at the district hospitals in many countries in Africa south of the Sahara. Even when available, the quality of the laboratory services for malaria are often poor, so that confidence in the diagnosis of malaria (and of other diseases) is lacking, laboratory-confirmation of malaria fevers inaccurate, and analyses of trends in malaria incidence questionable. For example, only 66% of the slides taken in 10 hospitals in the United Republic of (UR) Tanzania were subsequently shown by careful controls to have been read correctly (56).

3.2.5 Lack of standardized diagnosis and case-management

The adoption of standard case definitions and standard operating procedures for diagnosis is a prerequisite for any surveillance system. It ensures that:
• data collected from various sources are comparable over time; and
• notification is more consistent and interpretation more reliable.

Experience has shown that the appropriateness of clinical diagnostic criteria varies from area to area according to the intensity of malaria transmission, the prevalent malaria species, the incidence of other causes of fever, the qualifications of the health-care staff and the health service infrastructure (17). Each national malaria control programme should therefore adapt definitions to be applicable to the local situation. Usually, national guidelines for diagnosis and treatment classify malaria disease as either uncomplicated or severe, with different lists of symptoms adapted to each level of the health services.

Standardized case definitions of uncomplicated severe malaria and malaria deaths, which vary according to whether laboratory diagnosis is available, were produced by the 20th WHO Expert Committee on Malaria in 1998 (17). Subsequently, these were included as WHO recommended surveillance standards (45) and endorsed as references for the development of tools for monitoring and evaluation of malaria interventions (60). These are shown in Table 6, together with those developed by the programmes for integrated disease surveillance and response (IDSR) and the integrated management of childhood illness (IMCI).

Although these definitions are relatively precise, each of the four types of malaria cases listed below is dependent on numerous criteria that are subject to substantial variability among various health care providers and health facilities. These criteria include:
• questioning and clinical examination of the patient;
• definition of signs and symptoms for uncomplicated and severe malaria;
• selection for treatment;
• availability of quality laboratory diagnosis;
• selection criteria for laboratory testing; and
• selection criteria for hospitalization.
In addition, clinical manifestations of malaria overlap with those of pneumonia, bacteraemia and meningitis. For example, children hospitalized with a positive malaria slide and severe malaria still have a substantial risk of concomitant invasive bacterial infection requiring antibiotic treatment (61). The following sections discuss how the definition of each of these malaria cases can affect the accuracy of recorded incidence and its comparability over time.

3.2.5.1 Probable uncomplicated malaria

Since laboratory confirmation is currently impossible in a large majority of health facilities in Africa, a syndromic approach should be used, and diagnosis and case management should largely rely on clinical algorithms. Signs and symptoms of uncomplicated malaria are variable and non-specific. Most patients experience fever, headache, back pain, chills, sweating, myalgia, nausea or vomiting. Splenomegaly is common in children (62) and anaemia is common in children and pregnant women (63). Studies have identified certain signs and symptoms which, especially in combination, have diagnostic value in specific epidemiological and operational situations (64–66). However, it is not possible to apply any one set of clinical criteria to the diagnosis of all types of malaria in all situations. Clinical criteria vary according to age, the perception of malaria and local patterns of transmission (67).

Sensitivity and specificity of case definitions are best measured by age-specific population attributable fractions (PAF) calculated from cross-sectional, community-based surveys (69, 70). Compared to high-transmission settings, the PAF in epidemic-prone areas are lower, particularly among children, resulting in clinical case definitions with both low specificity and low positive predictive value. For instance, a study in the western Ugandan highlands showed that “history of fever” within the previous week had only an overall specificity of 25% and a PAF of 15% for children aged less than 5 years (71). In contrast, more restrictive definitions such as “documented fever” or those combining several symptoms would decrease sensitivity in such epidemic situations, with unacceptable fractions of malaria cases not being identified and treated.

In order to address these issues from a case-management perspective, WHO has developed a strategy for the integrated management of childhood illness (IMCI) based on an algorithm to improve diagnosis and treatment of the common diseases in children aged under 5 years. This algorithm has been designed for use by health-care workers in peripheral facilities without access to laboratories or special equipment (68). The operational definition of uncomplicated malaria in this algorithm differs according to the level of transmission. In areas of stable transmission (where more than 5% of the fever cases in children are due to malaria), any fever (by history, “feels hot”, or axillary temperature $\geq 37.5 ^\circ C$) is considered to be malaria and should be treated as such. In low-risk areas, the definition is more specific, excluding cases with runny nose, measles and other obvious cause of fever such as cellulitis, abscess or ear infection. In this case, the 5% cut-off is based on a mortality risk assessment, estimating that only a prevalence below 5% would lead to a situation where more children would die.
from being false-positives than from being false-negatives. With prevalence levels higher than 5%, the number of deaths caused by false-negatives would increase proportionally with prevalence, while false-positives would decrease. However, it has been suggested that these definitions are likely to lead to significant overdiagnosis of malaria in areas with low to moderate transmission (72).

Table 6. Malaria case definitions according to WHO surveillance standards, IDSR and IMCI

<table>
<thead>
<tr>
<th></th>
<th>WHO surveillance standards&lt;sup&gt;a&lt;/sup&gt;</th>
<th>IDSR&lt;sup&gt;b&lt;/sup&gt;</th>
<th>IMCI&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable uncomplicated</td>
<td>A person with symptoms and/or signs of malaria who receives antimalarial treatment</td>
<td>Any person with fever or fever with headache, back pain, chills, sweats, myalgia, nausea, and vomiting diagnosed clinically as malaria</td>
<td>In areas of stable transmission, any child with fever (by history feels hot or temperature &gt; 37.5°C). In areas of unstable transmission, any child with fever excluding cases with runny nose, measles, and any other obvious cause of fever</td>
</tr>
<tr>
<td>malaria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable severe malaria</td>
<td>A patient requiring hospitalization for symptoms and signs of severe malaria who receives antimalarial treatment</td>
<td>Not included</td>
<td>Any child with fever with a stiff neck and any one of the following danger signs - not able to drink or breastfeed, vomits, has convulsions or is lethargic or unconscious</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confirmed uncomplicated</td>
<td>A person with symptoms and/or signs of malaria who receives antimalarial treatment, with laboratory confirmation of diagnosis</td>
<td>Any person with fever or fever with headache, back pain, chills, sweats, myalgia, nausea and vomiting, and with laboratory confirmation by malaria blood film or other diagnostic test for malaria parasites</td>
<td>In areas of unstable transmission, any child with fever excluding cases with runny nose, measles and any other obvious cause of fever, with laboratory confirmation of malaria. In areas of stable transmission, laboratory confirmation is optional</td>
</tr>
<tr>
<td>malaria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confirmed severe malaria</td>
<td>A patient requiring hospitalization for symptoms and signs of severe malaria who receives antimalarial treatment, with laboratory confirmation of diagnosis</td>
<td>Any person hospitalized with a primary diagnosis of malaria and confirmed by a positive blood smear or other diagnostic test for malaria</td>
<td>As above for probable severe malaria but also with positive laboratory diagnosis of <em>P. falciparum</em> or <em>P. vivax</em></td>
</tr>
</tbody>
</table>

<sup>a</sup> WHO surveillance standards

<sup>b</sup> IDSR

<sup>c</sup> IMCI
3.2.5.2 Probable severe malaria

At the periphery, the priority requirement is the rapid recognition of the signs and symptoms of severe malaria that should lead to emergency care or referral to a higher level of care.

The WHO guidelines for the treatment of severe malaria in epidemic situations define a probable severe malaria case as a history of fever plus at least one of the following: prostration, altered consciousness, lethargy or coma; respiratory distress; severe anaemia; convulsions; inability to swallow; persistent vomiting; dark or limited urine (adults only) (14). The IMCI algorithm classifies a case of severe malaria as a patient with “a very severe febrile disease” that justifies an urgent referral to hospital for more specific diagnosis and treatment, “a very severe febrile disease” being defined by a fever with a stiff neck or one of the general danger signs, e.g. not able to drink or breastfeed, vomits everything, had convulsions or is lethargic or unconscious (68).

3.2.5.3 Confirmed uncomplicated malaria

Confirmed malaria cases are defined in the WHO guidelines for both case-management and surveillance by the presence of asexual parasite stages in patients with fever (14). The demonstration of parasites in the peripheral blood increases the chance that a fever is attributable to malaria infection. However, research studies in Africa south of the Sahara have shown that the minimum parasite densities that can be used to distinguish malaria clinical attacks from coincidental infection are age-dependant and may vary from 1000 to 10 000 parasites per µl depending on the prevalence of asymptomatic infections. High parasitaemia is more likely to cause illness than low densities (73). Hence, demonstrating the presence of malaria infection during a clinical event increases the likelihood that symptoms are due to the infection, but the high prevalence of asymptomatic infections makes it difficult to exclude other diagnoses in areas of high transmission.

The light microscopy with careful examination with a 100x oil-immersion objective of a well-stained thick blood smear remains the “gold standard” for detecting malaria parasites (59). It can detect densities as low as 5–10 parasites per µl when used by skilled technicians or 100 parasites per µl under general field conditions by a typical microscopist (53, 55). However, the process is time-consuming and depends on good reagents, microscopes and, most importantly, well-trained and supervised technicians. These conditions are often not met, particularly at the more peripheral levels of the health-care system.

When parasite-based diagnosis is essential, rapid diagnostic tests (RDTs)\(^5\) may be an alternative to light microscopy in situations where normal laboratory services are non-existent or overworked. RDTs produce results within 15 min and need a lower level of training of staff/skilled personnel. All types of RDT reflect recent and not necessarily current parasitaemia since these tests detect

\(^5\) RDTs are immuno-chromatographic tests that detect parasite-specific antigens in a finger-prick blood sample. Some tests detect only one species (\textit{P. falciparum}), others detect one or more of the other three species of human malaria parasites (\textit{P. vivax}, \textit{P. malariae} and \textit{P. ovale}) (74–76).
antigens and not parasites. Compared with expert microscopy, they are able to achieve adequate sensitivities > 90% in the detection of *P. falciparum* at densities above 100 parasites per µl, but such performances decrease markedly with lower densities, with non-falciparum species and in case of inadequate quality control, storage and transportation (74).

### 3.2.5.4 Confirmed severe malaria

Confirmation of a suspected severe malaria case requires a microscope diagnosis, the measurement of parasitaemia and further clinical examination. The current WHO definition (48) is less restrictive than the previous one (77). Severe malaria is now defined as the presence of *P. falciparum* on thick smear and at least one of the following clinical or biological criteria: coma or impaired consciousness (Blantyre coma scale < 5), repeated convulsions (≥ 2/24 hours), prostration, respiratory distress, jaundice, metabolic acidosis (bicarbonates < 15 mmol/l), severe normocytic anaemia (Hb < 5 g/dl or Ht < 15%), hypoglycaemia, hyperparasitaemia (parasitaemia > 4% in non-immune patients), macroscopic haemoglobinuria, renal failure, collapse (TAS < 60 mm Hg before 5 years of age), abnormal bleeding or pulmonary oedema (X-ray criterion) (78). In practice, the majority of health-care facilities do not have the capacity to document properly many of these indicators of severe malaria, particularly acidosis, renal failure based on creatinine and pulmonary oedema.

However, diagnosis of severe malaria without the confirmation of the presence of parasites or the consideration of the malaria-specific clinical criteria⁶ is common, resulting in both overdiagnosis and unnecessary treatment. This is illustrated by a research study conducted at 10 well-organized hospitals in the UR Tanzania which showed that only 46% of children and adults admitted and treated for severe malaria subsequently had a positive slide for malaria. With the exception of children under the age of 5 years living in areas of high malaria transmission, most children and adults had no evidence of parasites on carefully examined research slides, and the chances of an episode treated as malaria actually being malaria decreased systematically with decreasing intensity of transmission (56). In another study, only 52% of 256 children aged under 5 years admitted as severe malaria cases to a hospital in Niger had a positive blood smear, and only 114 (44%) met the recommended criteria for severe malaria (79).

Similarly to uncomplicated malaria, a laboratory confirmation of the presence of malaria parasites in the peripheral circulation increases the likelihood that severe symptoms are attributable to malaria, but this is not always the case. Malaria parasites may exist asymptomatically in patients suffering from severe forms of other febrile diseases. Conversely but rarely, severe malaria may be manifest in patients with negative blood slides owing to parasite sequestration into the deep tissues⁷. Hence, it was found that mortality was higher in malaria slide-negative patients than in malaria slide-positive patients in all age groups hospitalized for suspected severe malaria in Ghana (80) and the UR Tanzania (56).

---

⁶ Vomiting children are often admitted for quinine infusions without proper consideration of other complications.

⁷ In such cases, good clinical practice (GCP) requires that parasitaemia is monitored daily in patients suspected of severe malaria.
3.2.6 Inconsistent registration and classification of cases

Each of the different functions of a surveillance system requires registration and classification of cases to be specifically tailored for the purpose of analysis and feedback to those who generated the data. This is a major challenge to the design of a surveillance system that both fulfils programme needs and can still be effectively operated at the periphery with limited and overworked staff. This goal is not being met, with the result that the formatting of routine surveillance data does not meet the needs for the early detection of malaria epidemics.

Early detection of malaria epidemics based on trend analyses does not require accurate measurements of malaria morbidity at any moment in time. However, it is important to ensure that the collected indicators are comparable over time and not distorted by external factors such as changes in attendance, the workload in the clinic and laboratory, drug availability or diagnostic practice. This comparability of data requires that standard operating procedures for registration and classification of cases, as well as for all day-to-day procedures in both the clinic and laboratory, are agreed upon nationally, available in all health facilities and adhered to by all responsible staff.

3.2.6.1 Registration of cases

Multiple registration of cases is common. Uncomplicated and severe malaria categories are intended to be mutually exclusive, and recorded and reported separately. However, it is common practice that the same patient may be registered twice or even three times for the same infection. This occurs firstly when the patient is diagnosed with uncomplicated malaria, secondly if this diagnosis is confirmed by the laboratory, and thirdly if the patient develops signs and symptoms of severe malaria. This situation arises because data are generally extracted from three separate record books maintained in the outpatient, inpatient and laboratory-services departments. The best procedure is to record cases within well-defined categories on discharge, taking into account a consolidated diagnosis.

3.2.6.2 Classification of cases

Malaria cases should be classified and reported according to the following categories for a malaria EDS:

- probable uncomplicated case;
- probable severe case;
- confirmed uncomplicated case; and
- confirmed severe case.

The absence of such standardized procedures for the classification of cases means that the most common indicator to be monitored for EDS, i.e. “probable uncomplicated malaria” (alternatively called “clinical malaria”), is particularly subject to different interpretations. It is usually interpreted as “suspicion of malaria treated without laboratory test”; but it may also include those
treated with antimalarial drugs in spite of a negative laboratory test. This is a common practice in many areas where clinical staff do not have confidence in the laboratory results. Additionally, it might in practice include all suspected malaria cases that were tested in the laboratory or simply only those with positive blood slides.

Classification of malaria cases into outpatient (probable uncomplicated malaria) and inpatient cases (i.e. those admitted to hospital with probable severe malaria) is also common in routine surveillance. While this classification is operationally useful to analyse the utilisation of health services and plan resource allocation, it is unsuitable for an EDS since its breakdown does not always correspond to the categories of uncomplicated and severe malaria.

The 20th Expert Committee on Malaria recommended that, where possible, malaria case-data should be reported by age groups and parasite species (17). Indicators based on such data have potential for routine surveillance, e.g. to evaluate malaria prevention and control in young children and pregnant women, and malaria EDS to determine an emerging epidemic. Reporting of laboratory-tested cases needs special attention and guidance since mixed infections of *P. falciparum* with other species is common. The monitoring of these indicators for EDS requires further evaluation (see section 4).

Figure 1 shows 12 different categories of malaria cases that should be used for reporting by surveillance systems. Some of them clearly correspond with others and are mutually exclusive, but most only overlap to a partial degree that varies depending on the interpretation of diagnosis and case-management protocols (see section 3.2.5).

### 3.2.7 Inappropriate guidelines

A close examination of the generic version of IDSR technical guidelines (81) and other modules (82) has identified a number of specific problems in using data produced by IDSR for the early detection of malaria epidemics. They are detailed below.

#### 3.2.7.1 Periodicity of reporting

The current guidelines and other modules of the WHO African Region classify malaria as a disease of public health importance to be monitored only on a monthly basis. This is in contrast to other WHO recommendations that malaria should be classified as an epidemic-prone disease with weekly monitoring (14, 19) established in recognized epidemic-prone districts. However, malaria has been reclassified as an epidemic-prone disease by certain countries, e.g. Ethiopia (83), and the national IDSR guidelines modified accordingly, but this is not frequent. By 2004, according to country reports 15 African countries had reclassified malaria to be reported weekly by IDSR, with 10 of the remaining 25 epidemic-prone countries continuing to strictly apply the regional guidelines with monthly notification.
An analysis of current practices and future priorities

Ethiopia, Madagascar and South Africa continue to use their pre-existing surveillance systems for malaria surveillance, including EDS.

Figure 1. Variable overlapping of classes of malaria cases according to the capacity of confirmation and interpretation of case-management guidelines

<table>
<thead>
<tr>
<th>RECENT FEVER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnosis according to IMCI Guidelines for children aged 2 months–5 years in areas with low malaria risk</strong></td>
</tr>
<tr>
<td><strong>UNLIKELY</strong> (excluding other causes): <strong>UNCOMPLICATED</strong> (possibly combined with pneumonia): <strong>SEVERE FEBRILE DISEASE</strong> (with danger signs)</td>
</tr>
</tbody>
</table>

Common classifications depending on interpretation of standard country-specific case definitions

- PROBABLE or SUSPECTED or CLINICAL
- PROBABLE UNCOMPLICATED
- PROBABLE SEVERE

Classification depending on interpretation of case-management guidelines

- OUTPATIENT
- INPATIENT

Classification depending on capacity and criteria for testing

TESTED

Classification depending on quality of testing and definition of confirmed severe malaria

<table>
<thead>
<tr>
<th>NEG</th>
<th>O</th>
<th>M</th>
<th>V</th>
<th>Mix</th>
<th>P</th>
<th>O</th>
<th>M</th>
<th>V</th>
<th>Mix</th>
<th>P</th>
<th>NEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONFIRMED

- UNCOMPLICATED
- SEVERE

NEG = negative; O = *P. ovale*; M = *P. malariae*; V = *P. vivax*; Mix = mixed species, *P. falciparum*.

3.2.7.2 Case definition of severe malaria

Severe malaria in the IDSR guidelines is defined as “any person hospitalized with a primary diagnosis of malaria and confirmed by a positive blood smear or other diagnostic test for malaria”. Such a definition ignores the essential clinical and biological criteria for severe malaria. This may be the result of a typographical error, so that the definition should have read “any person hospitalized with a primary diagnosis of severe malaria and confirmed by a positive *P. falciparum* blood smear or other diagnostic test for malaria”. This lack of clarity might lead to misinterpretation and consequently to significant bias in the longitudinal analysis of useful EDS indicators (see section 4).
3.2.7.3 Reporting format for malaria cases

The malaria reporting form proposed by the IDSR guidelines is reproduced in Table 7. It is indicated that data are entered into the “white” cells but not in the shaded “grey” cells of the form.

There are several points concerning this form that might affect the accuracy of the data reported and result in inappropriate use of the various indicators required for the detection of epidemics. These are:

- lack of instructions on how to complete the form;
- inconsistency in format design; and
- lack of data on the total number of laboratory-tested cases.

Table 7. Integrated disease surveillance: monthly surveillance summary report form for outpatient cases, and inpatient cases and deaths

<table>
<thead>
<tr>
<th></th>
<th>Outpatient</th>
<th>Inpatient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases</td>
<td>Cases</td>
</tr>
<tr>
<td>Malaria &lt; 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uncomplicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria &gt; 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uncomplicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient malaria with severe anaemia (&lt; 5 years old)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomplicated malaria &lt; 5 years old, laboratory-confirmed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomplicated malaria &lt; 5 years old, laboratory-confirmed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* from the district to the next level (49)

(i) Lack of instructions on how to complete the form

Guidance is not given on how to complete the form. As a consequence, it is unclear:

- whether the different categories of uncomplicated malaria (confirmed or not) are inclusive or mutually exclusive;
- how to register and report clinically-diagnosed cases of uncomplicated malaria that were negative in the laboratory test;
- whether inpatient malaria with severe anaemia (< 5 years) is a subgroup of severe malaria or should be registered and reported separately; and
- how to record a patient who presents as an inpatient with uncomplicated malaria but is later hospitalized with severe malaria.

(ii) Inconsistency in format design

The four cells of “uncomplicated malaria” (below and above 5 years) in the inpatient column (cases and deaths), and the two cells for severe malaria in the outpatient column, are not shaded in grey and therefore require data entry. This appears to be in contradiction with the case definition of uncomplicated
and severe malaria given in the guidelines. One may assume that the cases of uncomplicated malaria to be entered in the inpatient column are those that are hospitalized either without being previously diagnosed as severe malaria or who were later shown to be uncomplicated and not severe cases.

(iii) Lack of data on the total number of laboratory-tested cases

The slide positivity rate (SPR) among outpatients is considered to be one of the most reliable indicators for the detection of malaria epidemics (see section 4.2.3). Unfortunately, it appears that this valuable indicator cannot be derived from IDSR data since it is not foreseen in the guidelines to report the total number of cases that are laboratory-tested (i.e. the total of those tested positive and those shown to be negative by blood-smear examination or RDTs). This figure is the essential denominator required to calculate the SPR.

3.2.8 Organizational limitations and inappropriate structures

Although decentralization and the integration of disease surveillance and prevention and control activities in Africa are still in the initial stages of implementation, this has had important implications for the implementation of malaria EDS since:

- The capacity of systematic laboratory-confirmation of fever cases suspected to be malaria has been reduced and even lost in some areas, with the closure of malaria treatment posts owing to a lack of understanding of the importance of laboratory diagnosis for malaria surveillance and case-management in Africa south of the Sahara.
- The technical and supervisory capabilities for malaria control have been reduced.
- The integration of existing disease-surveillance systems is still incomplete so that parallel surveillance programmes may exist. For example in Ethiopia, there are three systems, i.e. the national malaria control programme surveillance system (MCPSS), the national integrated disease surveillance and response programme (IDSR) and a health management information system (HMIS) recently initiated in SNNP (Southern Nations, Nationalities, and Peoples Region) by the nongovernmental organization John Snow Inc. These systems cover different geographical areas, use different case definitions, report over different time periods and rely on the same multipurpose peripheral health and district staff who are increasingly being requested to provide additional information such as data on disease risk factors, the incidence of drug resistance, and for programme monitoring and evaluation. This duplication of effort, poor coordination among the various systems and a heavier workload are demoralizing for peripheral staff and often result in their failure to transmit the correct information to allow an appropriate response. Ideally, a single countrywide integrated system would enable each disease-specific system to meet its data collection needs while avoiding duplication of effort. This goal appears to be far from being achieved.
Administrative structures do not permit rapid communication. While the ministry of health still has overall responsibility for both malaria surveillance and control activities in countries where integrated surveillance and decentralized disease-control programmes are being initiated, different departments at the provincial and regional levels may be involved in surveillance, prevention and control. This raises major challenges for ensuring the rapid communication, effective coordination and commonality of technical standards and guidelines at all administrative levels of the health services. This is particularly important in epidemic-prone areas where early detection and rapid response are the key to success. Unfortunately, these challenges have still to be overcome in most African counties, including Ethiopia, Madagascar and Sudan.
4. Indicators for an early detection system

Indicators of malaria epidemic risk and vulnerability are required to determine what kind of EDS is needed, and where and how it should be implemented. Ideally these indicators should be derived from a systematic evidence-based ongoing and either population-based or representative analysis of the local situation. However, given the paucity of epidemiological data, it is inevitable that some indicators will initially be hypothesis-driven rather than evidence-based (14). This section discusses the applicability of potential indicators for determining epidemic-prone areas and the emergence of a malaria epidemic, and concludes that there is no perfect indicator applicable to all situations.

4.1 Indicators for determining epidemic-prone areas and where to set up an EDS

4.1.1 Climate-based models

4.1.1.1 MARA/ARMA

During the past decade, the availability of geographical information systems (GIS) software and large continental sets of climatic and population data in digital format have led to the development of a model using climatic data and age-related prevalence rates to map malaria risk on the African continent. This model has been developed as part of the MARA/ARMA project.

Rationale. As epidemiological and entomological data to determine different malaria situations in Africa are not available for most of the continent, the project has developed a fuzzy logic model of malaria risk based on the effect of rainfall and temperature on malaria transmission parameters (86). Long-term climate data have been used to define the probability of malaria transmission, in terms of a “climate suitability index”, ranging from 0 (unsuitable) to 1 (very suitable). Each country has been mapped into areas defined by the following four classes of suitability:

Class 1 Unsuitable

Class 2 Where populations are exposed to a marginal risk of malaria transmission that is uncommon in an average year (suitability greater than zero but < 0.25)

Class 3 With suitability > 0.25 and < 0.75 corresponding to usually short seasonal transmission with a tendency to epidemics

Class 4 With stable, perennial malaria transmission (suitability > 0.75)

MARA/ARMA = Mapping Malaria Risk in Africa/Atlas du risque de malaria (85).

Fuzzy logic is an extension of Boolean logic that deals with the extent that a statement is true, measured as values between 0–1. Any 0–1 curve is considered suitable to the subject.
Continental and country-specific malaria risk maps are available for downloading from the MARA web site. The country maps show three categories of transmission:

- **Class 1**: Unsuitable
- **Classes 2–3**: Marginal or epidemic
- **Class 4**: Endemic

The duration of transmission, traditionally negatively associated with epidemic risk, has also been mapped using four categories (none in average year; 1–3 months; 4–6 months; and 7–12 months).

**Conclusion.** While these maps provide a rough overview of malaria endemicity, the model has several limitations to being used for identifying and delimiting epidemic-prone areas within a country. For example:

- The model uses long-term mean climatic data from 1920–1980 that do not reflect the interannual variations in rainfall and temperature needed to identify epidemic risk in many epidemic-prone areas.
- While the model functions at the continental level, it does not take into consideration factors at the country level that affect malaria transmission such as rivers and flood plains in areas of low rainfall, and agricultural practices such as irrigation and development projects. Thus, it does not take into account hydrological processes that may provide active breeding sites for vectors even when rainfall is low.
- Validation of the model against parasite prevalence surveys in Kenya suggests that the model underestimates stable transmission and overestimates areas where there is no risk of malaria.

When MARA/ARMA model outputs were compared with both historic records of malaria epidemics and parasitological data from the epidemic-prone highland areas of eastern Africa, it was concluded that MARA maps in their present form cannot be used to define epidemic-prone areas because the effects of rainfall and temperatures are confounded significantly at the local level by non-climatic factors.

### 4.1.1.2 Satellite–based images

**Rationale.** Another approach to malaria-risk mapping has been developed by the MALSAT project. The model is based on a comparison of the seasonality of vegetation growth determined by satellite images as a proxy measure for climate change, with the frequency and seasonal distribution of clinical cases. The normalized difference vegetation index (NDVI), used as a proxy for humidity, has been shown to be correlated both with seasonal malaria transmission in Namibia and with malaria prevalence rates in children aged under 5 years in the Gambia.

---

10 [www.arma.org.za/](www.arma.org.za/)
11 MALSAT = Environmental Information Systems for Malaria Research Group, Liverpool School of Tropical Medicine, UK.
12 NDVI is derived from a manipulation of data from two satellite wave bands presented as a ratio \[NDVI = (\text{near infrared} - \text{red})/(\text{near infrared} + \text{red})\]. It is often used in routine monitoring of seasonal vegetation development in response to regional rainfall distribution.
This approach has been modified specifically for the mapping of semi-arid epidemic-prone areas by overlaying historical data of the annual variability of rainfall from 1951–1995 from desert-fringe areas with annual rainfalls of 200 mm–600 mm. Subsequently, a mathematical model of vectorial capacity, using temperature and rainfall data, was proposed to determine the dynamic monitoring of transmission potential (92).

**Conclusion.** The MALSAT model enables interactive malaria risk maps to be produced within a GIS allowing the analysis of malaria risk over time and at a spatial resolution of 5 km. It is not easily applicable for the stratification of epidemic risk. It may have potential for the mapping of epidemic risk in desert-fringe areas, but there is not sufficient evidence yet to support its operational use. However, it can be used for the continuous monitoring of rainfall anomalies as part of a malaria early warning system (MEWS) (93).

### 4.1.1.3 A vector stability model

**Rationale.** Another spatial model delimits areas of malaria transmission according to a stability index (94) based on factors that influence the vector capacity of regionally-dominant vector species and its interaction with climate factors (94).

**Conclusion.** While this model combines more comprehensively the interaction of climate with malaria parasites and their vectors on a global scale, the calculation of the stability index is relatively complex and the application of the method for mapping epidemic-prone areas is yet to be established. The authors plan to use this model to explore the impact of malaria risk on economic development.

### 4.1.2 Community-based surveys

#### 4.1.2.1 Infection prevalence among children

**Rationale.** Parasite rates (15) have become a widely used marker of malaria endemicity as they roughly correspond to the frequency and duration of parasite exposure. Endemicity has traditionally been classified into four categories of transmission intensity, defined by the prevalence at one point in time of parasitaemia in children aged 2–10 years: hypoendemic, denoting < 10% parasite rates (incidence) represent the occurrence of new cases of a disease within a defined population at risk (i.e. in January, 30 cases of malaria were detected in a village of 2600, the incidence rate was 30/2600 x 1000 or 12/1000 person x month). The parasite rate is the proportion of subjects within a defined age range with detectable parasitaemia (parasites of any plasmodium species). The term “rate” suggests a measure per unit of time and is often erroneously used instead of proportion (19).

Proportions are defined as the portion of the total number of events usually expressed as a percentage (i.e. of the 120 patients admitted last year, 80 were affected by malaria; the proportion of malaria was 80/120 x 100 or 66.7%). Ratios are the relative frequency of the occurrence of some event compared to some other event (i.e. the ratio of cases among adults to cases among children, or ratio of uncomplicated/severe cases).
prevalence; mesoendemic, 11%–50%; hyperendemic, 51%–75%; and holoendemic, a prevalence of over 75% throughout the year (95). In areas of stable malaria, transmission is generally high and not subject to annual fluctuations, and the resulting population immunity\(^{16}\) is high. In contrast in areas of unstable malaria, transmission is variable, being subject to marked seasonal and annual fluctuations so that the collective population immunity is low.

Field studies in a rural non-irrigated arid area of Sudan demonstrate a typical epidemiological pattern of low and unstable seasonal transmission, with parasite rates among children remaining relatively low (around 15%) even during the high transmission season (96). Individuals acquire the ability to control infections, but protection is far from solid and malaria occurs in all age groups.

**Conclusion.** Low parasite rates are likely to be the indicator of choice to document low population immunity during interepidemic periods. However, there are certain drawbacks to using them to measure malaria endemicity since:
- they are liable to vary significantly over time and space, particularly in areas of unstable transmission, and therefore measurements should be carried out throughout the annual transmission season;
- a single measure does not reflect the seasonality of transmission; and
- careful attention should be paid to sampling methodology and sample size to ensure representativeness and ease of interpretation.

### 4.1.2.2 Spleen rates in children

The proportion of enlarged spleens, determined by Hackett’s measurement, in children aged 2–10 years has also been used to describe the same four categories of endemicity used in the parasite rate model above (97).

**Rationale.** It has been shown that epidemics did not occur in areas where the spleen rate in children was consistently high (98).

**Conclusion.** This method has limitations. Spleen enlargement can be due to other causes (e.g. leishmaniasis, schistosomiasis) and has lost much of its value as an indicator of malaria endemicity, especially in areas where antimalarial treatment is readily accessible (99). In addition, differences in spleen rates between ethnic groups and people of differing nutritional status also limit its usefulness; they are therefore not a reliable indicator to be used in a malaria EDS.

### 4.1.2.3 Period-prevalence of malaria fever

**Rationale.** Community-based cross-sectional demographic and health surveys (DHS)\(^{17}\) have been used since 1984 to determine the period-prevalence of fever. Originally, DHS did not specifically include malaria-related questions,

---

\(^{16}\) Population immunity. If enough people in a community have partial immunity against malaria, then the spread of the disease among members of that community becomes more difficult (62).

\(^{17}\) DHS are nationally representative household surveys that focus on reproductive and child health and are a primary source of information on all-cause under-5 mortality rates. Typically, they consist of interviews with between 4000 and 12 000 women aged 15–49 years living in households that
but a malaria module that captures essential malaria indicators and prevalence of anaemia by haemoglobin measurement in children aged under 5 has been incorporated into DHS to be conducted in malaria-endemic countries.

DHS conducted in western, central and eastern Africa have shown that 30%–35% of children aged under 5 had a fever in the two weeks preceding the survey (4). Empirical estimates of period-prevalence of fever calculated from DHS data obtained from 33 countries with high transmission of malaria suggested a median “fever rate” of 9.1 per child per year (100). Reported period-prevalence of fever has consistently been found similar for all age groups in areas of stable transmission (101). This equity of fever prevalence among children and adults has also been recently documented in the highlands of Kenya, where it is suspected to be independent of the level of malaria transmission (102).

**Conclusion.** Period-prevalence of reported fever appears to be identical irrespective of the level of malaria transmission, and therefore cannot be used to classify malaria risk.

### 4.1.3 Data from inpatient departments

Although indicators such as the proportion of clinically-diagnosed malaria among outpatients might correlate with the level of transmission at the local level, they may not be sensitive to the level of transmission owing to the poor specificity of diagnosis. In contrast, cases classified as severe or those admitted to hospital are often confirmed by laboratory diagnosis so that the diagnosis of malaria is more specific and such patients are much less likely than those with uncomplicated malaria to seek treatment in the informal sector.

The following sections will explore the potential value of some inpatient department indicators to help in the classification of epidemic risk. However, their comparability over time and place might be limited because the numerator is highly sensitive to criteria used for hospitalization and for case definitions of severe malaria that are subject to variable interpretation.

#### 4.1.3.1 Proportion of malaria cases among hospital admissions

**Rationale.** Given the incompleteness of coverage and case-reporting from the health services, relative malaria morbidity among hospital admissions is a more informative indicator than absolute numbers of malaria cases.

**Conclusion.** Routine surveillance data from malaria-endemic countries in Africa south of the Sahara may vary significantly. For example, clinically diagnosed malaria accounts for 25%–35% of all outpatient visits, and between 20% and 45% of all hospital admissions are attributed to malaria (4). Therefore, although not properly documented and calibrated, the proportion of hospital admissions attributed to malaria should reflect the level of endemicity.

are sampled in a multiple-stage cluster design. DHS results are comparable between countries and over time because the questionnaires are standardized and change little between surveys. Mothers of children under 5 years are asked whether their child had a fever during the last two weeks.
4.1.3.2 Proportion of severe cases

**Rationale.** Although infants and young children are most likely to have severe illness in areas of high endemicity (103), evidence suggests that the highest rates of hospital admissions and mortality among children under 5 years with severe malaria may be in areas of low to moderate transmission (104). Areas of low transmission are also likely to record the highest rates of combined admissions for children and adults because the risk for severe disease in young children is greater and vulnerability extends to older children and adults (105).

**Conclusion.** A relatively high proportion of severe cases among a stable resident population (either adults or all ages combined) might be an indication of prevailing low transmission. However, the potential use of this indicator is likely to be limited by the following constraints: (i) it is very difficult to estimate the true number of uncomplicated confirmed cases because testing is rare and not representative; and (ii) it does not reflect the actual balance between uncomplicated and severe cases in the community because of different patterns of attendance between the two groups.

4.1.3.3 Age-related distribution of severe malaria complications

**Rationale.** Several studies have demonstrated a correlation between clinical presentation, age of patients, and malaria risk. Specifically, the age distribution of cerebral malaria and severe anaemia varies with the level of *P. falciparum* transmission (106, 107). In hyperendemic areas, severe anaemia peaks before the age of 1 year and cerebral malaria between 2 and 3 years (108). With decreasing intensity of transmission, older children and adults are affected (109, 110). These observations were confirmed in a recent study in a semi-arid area of Sudan which showed that the mean age for severe anaemia was around 5 years, while that for cerebral malaria was approximately 14 years. The median age of patients with either severe malaria or its subcategories of complications (severe anaemia or cerebral malaria) was higher than that reported from hyperendemic areas of Africa (96).

**Conclusion.** Data on the age-related distribution of complications due to severe malaria are likely to be the most accurate available information in many countries, as a greater effort will have been made to diagnose correctly cases serious enough to be hospitalized.

4.1.3.4 Adult-to-child ratios among inpatients

**Rationale.** Adult-to-child ratios (ACR) of patients admitted to hospital with severe malaria may be used as a proxy measure of transmission stability, so that an ACR approaching unity\(^\text{18}\) would suggest unstable transmission and a lack of population immunity acquired through repeated parasite exposure. For example, more adults than children were hospitalized with a resultant ACR of 1.96 in an

---

\(^{18}\) Assuming a typical age-structured population for a developing country with equivalent sizes of population below and above 15 years of age and no age-dependent biases in attendance rates.
arid area of north-eastern Kenya, where a major malaria epidemic occurred in 1998 (111). Over 90% of the ACR exceeded 1 in 50 hospitals located in other parts of Kenya where the MARA fuzzy-logic climate suitability was less than 0.2 (112, 113).

In contrast, more children than adults were admitted to hospital with a malaria diagnosis in the highland areas of western Kenya where clinical malaria has an acutely seasonal distribution. Mean ACRs below 0.5 have been reported over a 20-year period in these areas where parasitological surveys indicated a malaria prevalence around 10% during transmission (114). The same study describes a substantial instability of ACRs over time with several rises above unity that are notably not concomitant with malaria epidemics.

**Conclusion.** Theoretically, the ACR might be a potential tool to rapidly assess the extent to which a community has sufficient parasite exposure to invoke some degree of clinical immunity. However, its accuracy is compromised by the following factors that would affect the incidence of severe malaria in both children and adults:

- use of personal protection (insecticide-treated net – ITN),
- professional exposure to vectors,
- recent migration,
- delay of care-seeking after first symptoms,
- criteria for hospitalization,
- definition of severe case,
- criteria for laboratory confirmation.

### 4.2 Indicators to detect epidemic development

#### 4.2.1 Absolute case-counts from health facilities

**Rationale.** Probable cases of uncomplicated malaria, defined by clinical signs and symptoms, are the most widely available data at the periphery of the health services. These data are likely to be the only available indicator in many situations for detecting the occurrence of a malaria epidemic. Compared with other indicators, its widespread availability allows the analysis of malaria prevalence over time.

**Conclusion.** Monitoring of unconfirmed malaria cases is notably subject to biases because of imprecise clinical case definitions and varying diagnostic practices. Attempts to produce more specific fever algorithms for malaria diagnosis have so far been unsuccessful.

---

19 These authors, therefore, argue that these data do not support the view that malaria transmission in this region is unstable and epidemic-prone, rather it is best described as seasonal and mesoendemic.
The major pitfall of using data based on clinical signs and symptoms is the potential for confusion between genuine increases in malaria incidence and seasonal peaks of other febrile illnesses, such as influenza and acute respiratory infections. This problem is particularly acute in areas of low malaria transmission where the proportion of malaria fever cases is low in relation to the total number of fever cases.

Despite these important drawbacks, the number of probable, i.e. unconfirmed, cases of uncomplicated malaria is the most suitable indicator to monitor in settings where access to a reliable laboratory is rare.

4.2.1.2 Confirmed malaria cases

**Rationale.** Parasite confirmation of suspected malaria fever is essential to diagnose the cause of an epidemic of febrile illness and to confirm the end of an epidemic.

**Conclusion.** The use of this indicator is restricted since laboratory services are generally unavailable or of poor quality in most peripheral health facilities and even in some district-level hospitals. For example, only 12% of the presumed malaria cases were confirmed by microscopy in the district hospitals of Madagascar in 2002, and this proportion was even lower in smaller health facilities (2). It is also notably unreliable since the small proportion of cases that are laboratory-tested are generally unrepresentative owing to selection criteria that may differ over time and place. The effects of unregulated diagnostic practices on morbidity are illustrated by a study of the use of microscopy in the highlands of the UR Tanzania (115). This study showed that 10% of hospital consultations were treated presumptively for malaria and 17% sent for laboratory confirmation of the presence of malaria parasites. Among the latter, only 6% were reported as slide-positive, but 48% of the slide-negative patients were nevertheless treated with antimalarial drugs. In addition, adults were four times more likely than children to be laboratory-tested.

4.2.1.3 Admitted cases and deaths

**Rationale.** The number of cases admitted to hospital with malaria and the number of malaria-related deaths are potentially very sensitive indicators for the early detection of epidemics, since evidence suggests that:

- the highest rates of hospital admissions and mortality among children under 5 years with severe malaria occur in areas of low to moderate transmission (104);
- these indicators should also be relatively more reliable than outpatient data owing to lower competition from informal care providers for treating severe conditions; and
- data from paediatric admissions/deaths are more likely to give an accurate picture of local malaria transmission than those from adults in areas where there are significant seasonal migrations of workers, since children are less likely to have functional immunity or to have acquired the disease elsewhere (114).
Conclusion. The use of these indicators is compromised by poor diagnostic practices that ignore recommended standard case definitions and treatment guidelines. Hence, diagnosis of severe malaria without the confirmation of the presence of parasites or the consideration of the malaria-specific clinical criteria is common. This results in the widespread overdiagnosis of malaria in patients presenting with severe febrile illness, particularly in areas with low to moderate transmission and in adults.

Similar limitations apply to the monitoring of deaths attributable to malaria that are difficult to assess without recourse to autopsy.

4.2.1.4 Drug consumption and blood transfusions as proxy indicators

Rationale. In places where EDS do not exist, the monitoring of antimalarial drug use in private clinics, pharmacies and from alternative providers has been proposed as a proxy indicator of incipient epidemics (99). Monitoring of the number of blood transfusions has also been used as a proxy measure for the incidence of severe malaria in hospitals in Kenya and Uganda where health information systems are absent or ineffective (116).

Conclusion. These indicators are probably valuable to verify both the emergence and the extent of epidemics in remote communities that are poorly covered by health facilities. However, there is no evidence that they are more reliable than other indicators in areas where health-service coverage is widespread and of good quality. The collection and analysis of such data are likely to be demanding.

4.2.2 Common constraints in the use of absolute numbers as indicators

Currently recommended epidemic thresholds are derived from absolute case-counts over time without consideration of potential variations in patient attendance at health facilities, care-seeking practices of the population and diagnostic practices within the health services.

4.2.2.1 Trends in attendance

Absolute case-counts from the health services are biased by trends in attendance figures that may vary with time for various reasons unrelated to epidemic development. Trends in attendance are affected by many factors including:

- variations in the time that seasonal transmission starts each year;
- geographical distribution of health facilities, quality of health care and number of staff;
- changes in the use of the health-care system;
- cost, particularly of antimalarial drugs and laboratory diagnosis;
- natural population growth (it has been suggested that this might partly explain the apparent epidemics reported during 1997–1998 in the Kenyan highlands) (111); and
- population displacement.
These problems were identified as critical issues during both the early stages of the implementation of an EDS in the highlands of Madagascar (29) and the analysis of the epidemics in Ethiopia and Sudan (1, 3).

4.2.2.2 Care-seeking practices during epidemics

Documentation of changes in care-seeking patterns during epidemics is extremely limited. Although it was impossible to compare the results with a baseline pattern, a survey carried out in the western highlands of Uganda during the 1998 epidemics showed that more than 80% of both children and adults sought treatment at a medical facility, a large proportion within one day after the onset of symptoms (117). It is likely that this prompt care-seeking was favoured by the availability of information of increased risk of malaria disease and death publicized by national authorities and the media to strengthen public awareness.

Dramatic rises in malaria incidence reported by the formal health sector during epidemics might also be enhanced by the impact of the interruption of cost-sharing and improved drug procurement by the public sector. For example, the withdrawal of cost-sharing schemes in Uganda during 2001 resulted in a sudden surge in attendance at government health facilities (118). In addition, any abrupt loss of attraction of a specific clinic or the opening of new health facilities in the area is likely to affect attendances in existing ones.

4.2.3 Proportions or ratios derived from health-facility data

4.2.3.1 Proportion of outpatients with attributed malaria

Figure 2. Monthly outpatient department data*a El Obeid hospital, Sudan, 1994–2002

**Rationale.** The impact of trends in attendance figures is illustrated in figure 2. This figure shows that during the period 1994–2002, the proportion of malaria consultations at the El Obeid hospital in Sudan was relatively stable in non-epidemic years, varying 10%–20%, but increased to 25%–50% during the epidemic years of 1994, 1997, 1998 and 1999. During the whole 8-year period,
the total number of consultations did not exceed 5000 per month (calculated as the monthly average of the number of consultations each year). In contrast, there was a notable rise in attendance with average monthly consultations over 6500 in 1995 and 2001, with a concomitant increase in the number of malaria-attributable cases. However, the proportion of malaria consultations remained below 20%, indicating that the epidemic alerts of 1995 and 2001, based on absolute numbers of malaria cases, were “false” alerts.

This illustrates the major advantage of using the proportion of outpatients with attributed malaria as an indicator for malaria EDS since, unlike absolute numbers, proportions are not sensitive to variations of attendance and care-seeking behaviour. In the absence of community-based incidence data, proportional morbidity and mortality data from health facilities have often been used to estimate the relative malaria burden as an indicator for monitoring and evaluating national malaria control activities (60).

**Conclusion.** The proportion of outpatients with attributed malaria is a practical and widely available indicator that can be used to correct absolute counts biased by attendance variation.

**4.2.3.2 Laboratory-based data**

**a) Slide positivity rates (SPR)**

**Rationale.** Parasite prevalence among fever cases suspected of malaria is potentially an important indicator of endemicity if it is determined in a range of age groups (62). It has been consistently shown to have risen substantially in 35 affected sites in Ethiopia during the 2003 epidemic (1) and appears to have the potential to detect epidemics early in their development. For example, a retrospective analysis of laboratory data during the 1998 epidemics in Uganda demonstrated a rise in SPR in one location that preceded by one or two months a rise in patient attendance (119). Similar observations have been reported from Kenya and Zimbabwe (24, 120). The SPR has been proposed as a “universal” indicator for the early detection of malaria epidemics, with rates over 50% in adults indicating the possible onset of an epidemic (51).

**Conclusion.** SPR is potentially the most reliable indicator to detect increased malaria incidence and occurrence of epidemics, because it is a ratio based on a numerator of malaria-confirmed cases and a denominator of the total number of slides examined (positive plus negative slides). Unfortunately, its accuracy is often questionable because of the frequent poor quality of microscopy and the fact that the number of slides examined and the proportion of clinically-suspected cases tested vary significantly over time.

This is a common problem illustrated by a case study in Sudan (3). Figure 3 shows laboratory data for the period 1997–2002 from El Soki health centre in central Sudan. During this 5-year period, both the SPR (line, top graph) and the proportion of suspected cases that were laboratory-tested (dotted line, bottom
graph) varied greatly every month. In late 2001, the area was affected by an epidemic with the monthly numbers of clinically-diagnosed cases exceeding 1500 in October (grey bars, top graph). It should be noted that the SPR had already started to rise from about 50% to 75% between July and August, reaching a peak of 90% in September, and decreasing to below 75% in October when the peak of clinical cases was reported. During the same period, absolute numbers of confirmed cases did not increase markedly (bottom graph). The explanation of this poor correlation between confirmed and suspected malaria is that laboratory capacity was limited (to about 800 slides per month) and the criteria for testing became more restrictive as attendances grew. This consequently affected the accuracy of the SPR.

b) Proportion of \( P. falciparum \)/\( P. vivax \)

**Rationale.** In some epidemic-prone countries of Africa such as Ethiopia, \( P. falciparum \) and \( P. vivax \) coexist in proportions that are likely to vary considerably depending on the local situation. As a consequence, most epidemics in areas such as the Ethiopian highlands are caused by the two species superimposed on each other. These mixed epidemics can be theoretically separated since:

- \( P. vivax \) epidemics are bimodal with one peak of cases early in the year resulting from long-term relapses from the previous year’s infections, and a later second peak when conditions are favourable for transmission; and
- there is only one peak of cases in \( P. falciparum \) epidemics since relapses do not occur. This single peak occurs when conditions are suitable for transmission, which is somewhat later than the second vivax peak since \( P. vivax \) requires a lower temperature for vector development and has a shorter incubation period than \( P. falciparum \).
These theoretical curves of malaria incidence illustrate the dynamics of true epidemics originating from a very small number of cases with no constraints to their dissemination in a susceptible population. In reality, most epidemics occur in areas of low endemicity or as a result of the mixing of infected and susceptible individuals and thus originate from a rather larger reservoir in a population that is not fully susceptible (99). Thus, an apparent single epidemic may actually be a number of overlapping local epidemics in different phases. In the context of epidemics due to exaggerated seasonal transmission, the peak of *P. falciparum* would coincide with optimal climatic conditions for transmission and therefore be more marked.

During the epidemic months in 2003, a substantial increase of both the SPR and the proportion of *P. falciparum* among positive slides, with peaks of at least 50% and 70% respectively, was observed in the Ethiopian highlands (1).

**Conclusion.** Although not properly documented, the predictive value of a sudden increase of the ratio *P. falciparum*/*P. vivax* above unity appears to be a potential indicator for EDS in areas where the two species coexist. This requires further evaluation.

**4.2.3.3 Inpatient data**

- **Proportion of hospital admissions and deaths attributed to malaria**

  **Rationale.** As for absolute counts, see section 4.2.1.3.

  **Conclusion.** This is a potentially valuable indicator. However, both the use of absolute numbers and of proportions of malaria hospital admissions and deaths are confounded in many cases by the absence of standard case-management protocols, case definitions and admission criteria. In the case of proportions, these limitations apply to both the numerator (absolute number of severe malaria cases) and the denominator (total number of cases admitted to the hospital). It can be expected that denominators would generally be consistently overestimated, but this should not affect comparability over time if admission criteria are consistent. However, during a malaria epidemic when hospital services are overloaded, admission criteria are likely to be more restrictive resulting in a lack of sensitivity of these indicators.

- **Case-fatality rates (CFR)**

  **Rationale.** High CFRs usually characterize epidemic malaria for a variety of interrelated reasons. Serious clinical consequences and high CFR are common during outbreaks because of poor public awareness of the risk of serious malaria disease, delayed treatment, and often restricted access to treatment. Thus during epidemics, the probability of dying from an untreated case of malaria at community level is approximately 10 times higher than in areas of high stable transmission (31, 36, 121, 122). During the 1998 malaria epidemics in Uganda, the CFR increased from baseline levels of 5% to more than 20% (119).
**Conclusion.** CFRs can only be measured accurately if the denominator is defined as the number of “confirmed severe malaria cases”. This denominator is rarely used by surveillance systems to define the total number of admissions to inpatient departments. It is more common that a variety of other less specific denominators are used, ranging from “severe febrile disease” to “probable severe malaria”. Baseline estimates provided by such systems would affect the accuracy of CFRs. The reporting of CFRs is also confounded by local variations in admission criteria and capacities, workload and the response capacity of the health services during epidemics.

Significant rises in the CFR generally reflect the impact of an excessive load of severe cases on already deprived and understaffed health structures that can be mitigated by improving the response capacity of the health facility. They therefore lack the sensitivity needed for epidemic detection. However, they could be useful as a specific indicator to document the severity of an epidemic and for monitoring the effectiveness of epidemic interventions.

### 4.2.4 Incidence rates

**Rationale.** It is difficult to calculate malaria incidence rates accurately for individual health facilities, since information on the size of the population in the catchment area of each facility (the denominator) is generally unavailable. The simplest means of partitioning a population between a series of facilities is by Thiessen polygons, defined as the area that incorporates all points that are closer to a given facility than any other. However, this is based on the key assumptions that all patients choose to utilize the nearest facility regardless of its attractiveness, and that the utilization rate is constant throughout the area (123).

These assumptions appear unlikely to be valid since health-service utilization varies with accessibility and the quality of the available services. Utilization is also likely to change with time and be distorted during epidemics. Several studies have shown that the utilization of health facilities is inversely correlated with the distance patients have to travel to them (124, 125). In addition, it has been demonstrated that the perceived lower quality of service available from the peripheral health facilities means that these facilities are less likely to attract patients over longer distances than are higher-level facilities (126).

**Conclusion.** Reliable estimates of malaria incidence can only be provided by longitudinal community-based studies within the context of operational research.

### 4.2.5 Entomological indicators

**Rationale.** The entomological inoculation rate (EIR) has been proposed as a comprehensive indicator of epidemic risk on which to base forecasting (127). It is defined as the mean daily number of bites inflicted on an individual by mosquitoes infected with sporozoites.
Conclusion. This is potentially the best indicator of epidemic risk, but its routine use for monitoring within an EDS is unrealistic. However, a large number of sampling sites are needed to reflect the situation in communities and large sample sizes of mosquitoes are required for measuring sporozoite rates for a particular time period. This is both time-consuming and costly. Epidemic-prone countries in Africa do not have the financial or technical capability to carry out such studies.

Furthermore, epidemics may occur with very low sporozoite rates, particularly in areas where the vectors are only partially anthropophilic. These low rates would be undetectable by the routine activities of national entomological services (16). Even the less demanding measurements of indoor-resting density more recently proposed as a potential indicator for epidemic forecasting would require additional capacities (117).
5. Constraints to defining epidemic thresholds

The robustness of the current methodology to define epidemic thresholds is still uncertain and its development and evaluation incomplete. Pioneering countries, such as Madagascar (29, 128) and those in southern Africa (Botswana, Namibia, South Africa, Zambia and Zimbabwe) (20) are building on two decades of experience in progressively refining their methodology to enhance the reliability and effectiveness of their malaria EDS. Others such as Sudan have only just started to develop their EDS and to identify a standard method(s) to determine epidemic thresholds.

Epidemic thresholds depend on the development of methods that will distinguish “normal” from “abnormal” incidences of malaria in areas that have a history of epidemics. Theoretically, the determination of such thresholds is relatively easy in areas where: (i) there are functioning health information systems; (ii) there is consistent coverage and access to health care over a sufficient period of time; (iii) access to historical epidemiological data for several years is guaranteed; (iv) health-care management and staffing are stable over a sufficient period of time; and (v) the population has remained stable (14, 26). However, these conditions are rarely met since national disease surveillance systems are generally poor, comparable historical data rarely exist and health care coverage in many epidemic-prone areas is insufficient.

Three different methods, the mean number of malaria cases + 2 standard deviations (SD), percentiles over the median and the cumulative sum (C-SUM) method, have been currently proposed by WHO for field application in resource-constrained environments (14, 20, 26). The applicability of these thresholds has not been widely evaluated in different epidemiological situations.

There are several major issues related to the development of appropriate epidemic thresholds that have an impact on the response. These include the following:

- It is now widely accepted that weekly reporting is essential to construct an efficient EDS, but what are the implications of this recommendation when most historical surveillance data are based on monthly reporting?
- Epidemic thresholds proposed by WHO are derived from a preceding reference or “baseline” period, but modifications in the level and seasonality of transmission during this period might affect significantly the accuracy of estimates of expected normal incidence.
- While it is acknowledged that the currently recommended methods lack the required accuracy and still need substantial refinement before they can be considered as operationally robust (20), what are their comparative sensitivities and specificities?
• Strictly speaking, the “normal” incidence of malaria cases can only be determined for a particular population in a specific area and at a specific period of time. Consequently, current thresholds should be developed for particular localities, as their sensitivity and specificity are likely to vary according to local epidemiological factors. Can alternative epidemic thresholds be developed in the absence of reasonably accurate and consistent historical data?
• Could unique thresholds be applicable throughout the year?

These issues and priority research to address them are discussed in detail below.

5.1 Deriving weekly thresholds from monthly historical data

Historical data, where they exist, are mainly based on monthly reporting. Only a very limited number of countries have accumulated five years or more of historical incidence data reported on a weekly basis. This constraint has not been properly addressed in a recent technical guidelines which propose to confront monthly thresholds with the sum of figures from 4 successive weeks (129). It does not tell how to deal with the last 4 weeks of the year. Alternatively, two attempts have been made to generate weekly historical data when only monthly data were available.

The first and only accurate method is to recompile the data on a weekly basis from the original record books in selected peripheral health facilities (24). However it is tedious, costly and unpopular with health staff. In addition, it is dependant on the records being available for at least a 5-year and preferably a 10-year period.

A second option is to transform more accessible monthly aggregates extracted from reports into weekly data. This is obviously difficult since monthly and weekly partitions of a year do not correspond. In the UR Tanzania, monthly incidence figures for each month are divided by 4.3 (130). This second option is imprecise and does not adequately address the problem since not indicating the weeks to which each month’s related fraction should be allocated.

5.2 The baseline period – measuring normal incidence

As long as the level of endemicity remains stable, the length of the reference period from which historical data are used to construct an epidemic threshold is not a major issue. In contrast, great care should be taken in the choice of both the timing and length of the baseline period in areas where there is a consistent variation in the level and seasonality of transmission.
5.2.1 The effect of changes in endemicity

The impact of changes in endemicity during the baseline period on the calculation of threshold values is shown by an analysis of data from a site in Madagascar (Fig. 4) where recent threshold values have been calculated with reference to baseline data from 1993–1997, a period when generalized indoor residual spraying had been resumed and malaria incidence and transmission were at their lowest levels (29). As a result, these thresholds are no longer valid as the use of indoor residual spraying has been progressively restricted since 1997, with the result that there has been an increase in malaria endemicity with higher levels of “normal” malaria incidence. Consequently, a very high number of “false” alerts have been reported by the EDS owing to the application of too sensitive thresholds that were no longer relevant to the current malaria situation (2).

Figure 4. Monthly thresholds for 2002 using four different baseline periods and confirmed outpatient malaria cases, Analarao health centre, Antananarivo Province, Madagascar

* Ref. (2).
5.2.2 Changes in seasonality of transmission

Epidemic risk is traditionally negatively associated with the length of the period favourable for transmission. In Sudan, the main transmission season from September to November is mainly rainfall-dependant and subject to epidemics. The level of transmission during the remaining months mainly depends on additional environmental factors such as the recent creation of large irrigation schemes that sustain suitable breeding sites during the driest and cooler season and result in an additional minor peak of transmission in May (3). Such changes in the seasonal pattern of transmission are likely to distort significantly the calculation of appropriate thresholds.

5.3 Methods for the calculation of thresholds

The challenge when calculating epidemic thresholds is to define the level above which malaria incidence is no longer considered as “normal” or “expected”. The calculation should take into account interannual variability and the seasonality of malaria incidence in a particular area, and be simple enough to be applicable to resource-constrained settings with a limited amount of historical data (usually 5–10 years).

5.3.1 Mean number of malaria cases + 2 standard deviations (SD)

This method was first applied in northern Thailand in the early 1980s using historical monthly data from the preceding eight years from which the epidemic years were excluded. The epidemic threshold was defined as the mean number of malaria cases plus 1.96 SD (131), This is based on the statistical principle that 1.96 SD around the arithmetic mean would capture 95% of the data in any normally distributed series. Corrections are needed to this calculation if both small numbers of data are used and there are variations from the normal pattern of distribution (132). This method is limited by the lack of objective criteria to define past epidemic periods.

This method was later adopted for surveillance in the Madagascar highlands (29) and promoted by WHO in Africa (19, 45) with the following modifications:
- rounding up of the SD from 1.96 to 2;
- use of only a minimum of 5 years of historical data; and
- exclusion of epidemic years.

5.3.2 Percentiles over the median

For some time WHO has used the expression “normal epidemic channel” to describe the normal seasonal pattern of malaria in an area (120). The recommended method for obtaining the upper limit of the normal channel is
to calculate the monthly/weekly third quartile from a consecutive 5–10-year series of monthly/weekly data. Months in which cases exceed the third quartile are declared routinely as epidemic months (16, 19, 25). The methodology was probably inspired by repeated observations of cyclic patterns of climate-driven epidemics (every 4–7 years). Hence, the choice of the third quartile or 75th percentile as a cut-off value means that abnormally high incidence is expected to occur every five years.

This method is simple since it requires only five years of historical data, does not exclude known or unknown epidemic years, and the epidemic threshold is the second-highest value of the five observations. It does not therefore require sophisticated computing facilities. It has been implemented in peripheral health units of Ethiopia (133) and is currently recommended by IDSIR technical guidelines (81).

5.3.3 The cumulative sum (C-SUM) method

The third proposed method uses cumulative sums (C-SUM) to determine the expected number of cases using the average for three months (including the previous and following month) during the previous five years (19, 26, 134). An epidemic threshold can then be defined as the upper limit of a 95% confidence interval for the expected cases.

5.4 Comparison of the different methods

Any attempt to compare the respective performance of methods is difficult. A strict comparison is impossible as there is no “gold standard” to determine true epidemic periods retrospectively.

However, it has been observed that:

- The distribution of monthly/weekly cumulated incidences of malaria case-counts are positively skewed but can be normalized by log transformation (3, 114).
- Values of third quartiles were consistently and substantially lower than corresponding means + 2 SDs in different settings (1, 3, 118, 135).

Figure 5 shows a comparison of eight different thresholds calculated for October, the month with the highest malaria incidence of probable malaria cases attending the outpatient department of the El Obeid hospital in Sudan. These thresholds were based on monthly reports and are either derived from medians, means or C-SUMs over variable baseline periods. There were significant differences in the threshold values calculated according to the different methods, ranging from 900 to 2800. Unsurprisingly, the mean + 2 SD method gave the highest

---

20 For example, to calculate the C-SUM for January add the values for each December, January and February during the 5-year period and divide the total by 15.
threshold when “epidemic” years were included and a substantially lower one when epidemic years were discarded.

The following sections demonstrate that there is increasing evidence to suggest that for the detection of an emerging malaria epidemic:

- the mean and C-SUM + 2 SD are not sufficiently sensitive; and
- the third quartile or 75th percentile is not sufficiently specific.

**Figure 5. Epidemic thresholds for October 2003 using eight different methods, North Kordofan, Sudan**

* Based on monthly unconfirmed malaria case-counts at the outpatient department of El Obeid hospital.

5.4.1 Lack of sensitivity of mean or C-SUM + 2 SD

Initially, epidemic thresholds were defined with only a single SD over the mean when calculated without excluding epidemic years (16). Later, a review of different epidemic thresholds used by countries of the Southern African Malaria Control Programme (SAMC) (20) suggested that the third quartile was too sensitive and the mean +2 SD was too specific, concluding that the best choice was the mean +1.5 SD.
In another study in Sudan, the validity of the mean +2 SD and third quartile methods was determined over five years in seven sites (3). Although not fully specific, the third quartile method performed slightly better than the mean +2 SD method for the detection of 17 probable epidemics. Only three alerts were not followed by a consistent abnormality of the threshold based on the third quartile, while that based on the mean +2 SD was exceeded one month later in four cases, which would potentially have resulted in a delayed response.

The C-SUM +2 SD is simply a “smoothed” derivative of the mean +2 SD method. It has been found to be less sensitive than the latter (114). This might be explained by the fact that the smoothing technique is likely to reduce the sensitivity of the method when applied to the months in which epidemics are expected to develop.

5.4.2 Lack of specificity of the third quartile or 75th percentile

The thresholds obtained by the different methods have also been compared using 20 years of paediatric admission data in three hospitals in Kenya (114). The effects of the normalization of the skewed series and use of alternative calculation of standard deviations for small sample sizes were also studied. This study concluded that the mean +2 SD method appeared to be more specific than the third quartile method, since it was better in capturing selectively the two years with the highest case-loads.

The public health value of different methods was also assessed by estimating the respective ability of various algorithms to potentially prevent cases using weekly data of confirmed cases from Ethiopia (136). This study showed that thresholds calculated on the basis of percentiles performed better than those derived from the mean + SDs and that the most effective level seemed to be between the 85th and 90th percentiles.

5.5 Research priorities

5.5.1 Further evaluation of existing methods

The further validation of the methods described in section 5.4 is of highest priority to determine the best method(s) to be used in the various epidemic situations. However appropriate and robust, the applicability of this method(s) would still be severely limited by the requirement for at least five years of historical data, and a relative stability both in transmission and health-service utilization. Hence there is a need for alternative methods for use in locations where historical malaria data are not available.

The simplest system is the one currently used in Botswana where a single and universal threshold of the absolute number of confirmed cases per district has
been defined for the whole country. In this system 400 cases per week in a
district indicates an alert to be acted upon at the district level, 800 cases
per week indicates that the national authorities should be informed, and 1200
cases per week indicates a national emergency (25). It was only possible to
apply this method because, in Botswana, there is a systematic confirmation of
cases, a good coverage of quality health services that are very attractive to the
population, and a similarity of population size in each district. The timing of
the onset of epidemics, which are restricted to the initial period of the high-
transmission season, is also well established (26). Such conditions are rarely
met in other African countries.

The following sections explore the possibility of developing innovative and
simplified methods for use in contexts where conditions such as those in
Botswana do not exist.

5.5.2 Methods to be used in the absence of historical data

The development of a method that could be applied in the absence of historical
data would have great operational importance. Such a method would require
other indicators and cut-off values from those currently in use. Such indicators
would need to be either universally applicable irrespective of the epidemiological
context, or defined according to parameters that can be easily and rapidly
assessed.

5.5.2.1 Variation of incidence

In analogy with algorithms adopted for meningococcal meningitis, epidemic
thresholds could theoretically be either an absolute value of weekly incidence
or the speed of its relative change over a short period of time. Unfortunately, it
is doubtful that reliable incidence of the disease at the community level could
be estimated from routine health-facility data (see section 4.2.3). However, a
doubling of the incidence within two weeks and a 1.5-fold increase of weekly
case-counts over the average calculated over the previous three weeks have been
proposed by WHO to be applied in emergency settings (137). The widespread
application of such thresholds still requires validation. The performance of
thresholds based on the slope of the increase in malaria incidence has been
evaluated with data from Ethiopia and shown to be relatively disappointing as
compared to the conventional methods discussed above (136).

5.5.2.2 Slide positivity ratio (SPR)

The SPR has been proposed as a “universal” indicator for the early detection
of malaria epidemics in emergency situations, with rates over 50% in children
aged over 10 years and adults indicating the possible onset of an epidemic (51).
The choice of this indicator is likely to be appropriate because of its acceptable
sensitivity (see section 4.2.3.2.a) and increased specificity when restricted to
adults. However, the cut-off value for non-emergency situations is significantly
lower in Ethiopia, with national EDS guidelines defining probable epidemics by
an SPR > 30% in all age groups (133). The optimal choice of a universal cut-off value needs to be further in accordance with local epidemiological situations.

5.5.2.3 Verification of epidemics at community level

(i) Period-prevalence of fever

The percentage of the population with a fever during the preceding week in a systematic sampling of 20 households is used in Ethiopia as a proxy measure of the level of transmission. A 30% threshold is used to guide the decision to implement vector control measures rapidly (133).

(ii) Parasite prevalence among children

In Madagascar, surveys of parasite prevalence in children aged 2–9 years were carried out in several affected villages during the major epidemic in 1986–1988. The follow-up of a representative sample of children revealed important seasonal variations of parasite rates, ranging from about 30% in October to more than 60% in May 1989 (37). Other studies during the same period indicated that malaria had become hyperendemic, with parasite rates >50% among healthy schoolchildren (138) and the general population, although these decreased with age (139).

Despite a potential bias that many children may have been ill with malaria and absent from school during the study, the measure of parasite prevalence among schoolchildren aged between 5 and 14 years has been proposed to monitor malaria endemicity in Madagascar (140).

Conventional parasite-prevalence studies have been used successfully to delimit areas of malaria transmission following five years of vector control with indoor residual spraying, but such studies are too complex, costly and time-consuming to be used for the routine confirmation of malaria epidemics (141). In contrast, lot quality assurance sampling (LQAS) is potentially an affordable alternative. LQAS based on a random sample of only 36 pupils has been shown to produce similar results in the same area, with a sensitivity of 100% and specificity of 94%. It was also shown to be able to rapidly classify areas according to predetermined prevalence levels, with a threshold of 15% prevalence being determined as a valuable operational signal to confirm emerging epidemics (142).

5.5.3 Can a unique threshold be used throughout the year?

The definition of a single epidemic threshold for the whole year is attractive because it could potentially simplify the analysis. The option of using thresholds specific for the season with highest incidence as a unique weekly threshold valid for the whole year is currently being assessed in the highlands of the UR Tanzania (130). However, the benefit might be questionable in areas where seasonality is bimodal, such as in the highlands of eastern Africa. Empirical evidence from these areas suggests that exaggerated incidence occurring during
a minor transmission season would never reach the level of the main season and never cause a major overload of the health services. In addition, a close examination of past epidemics in Ethiopia has revealed that some of the major episodes have been preceded by periods of exaggerated incidence during the earlier minor transmission season (35). In such situations, the detection of the latter would require season-specific thresholds.
6. Planning and implementation of early detection systems – future priorities

An EDS should be simple to operate and sufficiently flexible to take account of the changing epidemiological situation. It should balance sensitivity and positive predictive value and be closely linked to a rapid and effective response. This can only be achieved if:

- there is an appropriate strategy targeted to the context of the local situation;
- case registration, data collection, reporting and analysis are reliable; and
- the organizational structure is conducive to rapid communication and response from all levels.

6.1 Priority epidemic-prone areas for targeting an EDS

In the context of an EDS, malaria epidemics should be defined operationally, i.e. an epidemic occurs when the malaria case-load has or will exceed the capacity of the existing health services to handle it (26). This situation occurs during all epidemics and would similarly need to be detected and responded to promptly, irrespective of the type, as described in section 2.

In most circumstances, the implementation of EDS should be based on an evaluation of the outbreak risk, the value of early response, and the availability of resources for investigation. A very sensitive system can result in unnecessary resource-intensive investigations, whereas a very specific detection methodology might unnecessarily delay both detection and rapid response. Similarly, the spatial resolution and coverage of the network of sentinel sites should be adapted to the geographical and epidemiological context as there could be differences in establishing and operating cost-effective systems to detect different types of epidemics.

However, epidemics characterized by an upward trend in malaria endemicity are particular. They may affect all areas where the intensity of malaria transmission is low to moderate. Their detection does not require an EDS since a simple comparison of annual aggregated routine surveillance data would be sufficient to document such an event. Malaria epidemics are also predictable when control programmes are brutally or progressively disrupted so that an increase in transmission can be anticipated.
6.1.1 Towards a qualitative classification of risk

The goal is not only to delimit epidemic-prone areas but also to determine which types of epidemics may be expected to occur in these areas, according to the temporal and spatial distribution of risk factors. These risk factors, which are influenced by complex interactions between the population, diverse environmental factors and the characteristics of local vectors, may vary both within and between epidemic-prone areas.

Epidemic-prone areas in Africa have been classified into eight different settings, according to their respective transmission determinants, to guide the development of malaria early warning systems (MEWS) (19). These epidemic-prone areas have been consolidated into four categories (see Table 8), according to the nature and determinants of epidemic risk. This table also tentatively proposes strategies for the early detection of malaria epidemics that are adapted to each of the four situations. The rationale for these strategies is discussed in detail below.

Table 8. Classification of ecological settings according to determinants and the nature of epidemic risk

<table>
<thead>
<tr>
<th></th>
<th>Irrigation and river systems in semi-arid lowlands</th>
<th>Desert fringes in lowlands</th>
<th>Highland fringes</th>
<th>Highlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-annual variation</td>
<td>Seasonal</td>
<td>Usually absent or short season</td>
<td>Seasonal or bimodal</td>
<td>Usually absent or short season</td>
</tr>
<tr>
<td>Immunity</td>
<td>Moderate to high</td>
<td>Low</td>
<td>Low to moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Influence of climatic factors</td>
<td>Floods Rainfall Humidity</td>
<td>Rainfall</td>
<td>Rainfall Temperature</td>
<td>Rainfall Temperature</td>
</tr>
<tr>
<td>Influence of non-climatic factors</td>
<td>Significant</td>
<td>Low</td>
<td>Significant</td>
<td>Low</td>
</tr>
<tr>
<td>Predictability by early warning systems</td>
<td>Poor</td>
<td>High</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Type of epidemic</td>
<td>Exaggerated seasonal transmission</td>
<td>True</td>
<td>Exaggerated seasonal transmission</td>
<td>True</td>
</tr>
<tr>
<td>Periodicity</td>
<td>2–7 years</td>
<td>15–30 years</td>
<td>2–7 years</td>
<td>10–15 years</td>
</tr>
<tr>
<td>Population density</td>
<td>High</td>
<td>Zero or low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Active control programmes</td>
<td>Frequent</td>
<td>No</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Urbanization</td>
<td>High</td>
<td>No</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>Type of EDS required</td>
<td>Continuous Main cities</td>
<td>Monitoring if high rainfalls</td>
<td>Continuous Full and dense coverage</td>
<td>Monitoring if fringes affected</td>
</tr>
</tbody>
</table>
6.1.1.1 Irrigation and river systems in semi-arid lowlands

The potential effect of epidemics affecting urban populations in large cities surrounded by irrigated agricultural areas or crossed by rivers is of concern, e.g. in areas around Khartoum in Sudan. The presence of central authorities and the usual low level of transmission in these areas should not exclude the necessity of a well-functioning EDS in such settings.

6.1.1.2 Desert fringes in lowlands

These are affected by “true epidemics”. The continuous monitoring of malaria cases is likely to be impossible in such sparsely-populated areas that are mostly inhabited by nomadic groups. However the risk can be documented from records at health facilities in small towns and oases. Nonetheless, such risk in these areas is so infrequent and predictable that it is certainly more cost-effective to initiate a system of weekly case-monitoring once exceptional rainfall and resultant floods occur. In such situations, it is important that the national malaria programme, jointly with other relevant services, develops and implements a MEWS.

6.1.1.3 Highland fringes with seasonal transmission

These areas may be periodically affected by either widespread periodic waves of exaggerated seasonal transmission or small localized outbreaks. Such epidemics cannot be accurately predicted by currently available MEWS because of the complex interaction of many risks factors. A continuous weekly reporting system, based on a dense network of sentinel sites, would probably be cost-effective in these areas.

6.1.1.4 Highlands with unusual transmission

“True” malaria epidemics have been reported from the elevated highlands in Ethiopia and Madagascar where transmission is normally absent. These have been particularly severe because the health services were unprepared and the affected populations non-immune. Nevertheless, such episodes are likely to be infrequent and to affect small and sparse communities. Furthermore, cumulated evidence suggests that these epidemics result from unusual geographical expansions in climatic suitability for transmission in the highlands, in combination with increased transmission at lower altitudes which results in the highlands becoming temporarily suitable for vectors to transmit the disease. Such conditions rarely occur so that an EDS based on sentinel sites would not be cost-effective in these areas. However, it is imperative that the EDS should investigate the expansion of epidemics in such marginal areas as soon as an unusual seasonal fluctuation is detected.
6.2 Defining epidemic-prone districts in practice

Since the district is the principal operational level of the EDS (see section 6.4. for details), a list of those with epidemic potential should be established, based on the stratification of malaria endemicity and local expert opinion of risk.

6.2.1 Existing stratification maps

Stratification maps, based either on historical data and local expert opinion or climate models, are available in most countries. Maps such as those produced by MARA can be downloaded from the Internet\(^2\) and easily be interpreted to roughly delimit epidemic-prone areas.\(^2\) For example, a cut-off between stable and unstable transmission has been defined for outside southern Africa as a MARA suitability index of 0.75 \((100)\). However, it must be borne in mind that these maps might be either outdated or have insufficient resolution and accuracy to select epidemic-prone districts precisely (see section 4.1.1).

6.2.2 Location of past epidemics and maps of the Highland Malaria Project (HIMAL)

Studying the history of epidemics in a country is the most pragmatic approach to defining epidemic-prone areas since malaria epidemics are usually recurrent in the same areas. The HIMAL project used this approach first to evaluate accuracy of the MARA model in the eastern African highlands and then to map, with a 5 km x 5 km resolution, the epidemic risk in seven eastern African countries, by classifying epidemic-prone areas based on similarities of annual climatic profiles with those of known epidemic-prone localities \((89)\). Although apparently more accurate than MARA maps, when the locations of epidemics documented in 2003 from Ethiopia were included, the precision of the published HIMAL maps was not sufficient \((1)\). As a result, field investigations and analysis of data at and below the district level are necessary to define precisely the history of epidemics and the pattern of transmission in the locations suspected of being prone to epidemics (see section 6.3.2.1).

6.3 A sentinel-site approach

6.3.1 Rationale

Where quality data are too costly to collect universally, strategically-located sentinel health facilities within epidemic-prone districts can be highly cost-

\(^2\) www arma org za .

\(^2\) Epidemic-prone areas are generally in areas of unstable malaria. A cut-off between stable and unstable transmission has been defined for countries outside southern Africa as a MARA suitability index of 0.75 \((100)\).
effective. Malaria sentinel sites now exist in many African countries such as Angola, Botswana, Kenya, Uganda, Malawi, Mozambique, Namibia, South Africa, Swaziland, UR Tanzania, Zambia and Zimbabwe. These sites are being used for monitoring a variety of indicators such as antimalarial drug resistance, the burden of disease and poverty indicators. A weekly notification system based on sentinel-site monitoring is routine in some countries such as Botswana and Zimbabwe (14). This experience has led to the proposal that EDS in African countries should rely solely on sentinel-site monitoring, with a universal data collection system being restricted to routine surveillance. However, the WHO informal consultation on malaria epidemics held in 2003 recommended that complete reliance should not be placed on sentinel-site monitoring, since epidemics may often occur outside their catchment areas. This can be overcome by the establishment of mobile teams as already suggested for areas inhabited by nomads (14).

6.3.2 Selecting sentinel sites

The proper selection of sentinel sites is a crucial but difficult step. A broad outline of the criteria for their selection was developed by WHO in 2003 (14). These criteria included:

- evidence of unstable transmission and low immunity;
- “large” and “stable” attendance rates;
- high quality of health delivery with motivated and well-trained staff;
- capacity for laboratory diagnosis of malaria;
- adequate registration and storage of data; and
- “representativeness”.

The above criteria are essentially subjective. Some clarifications and practical orientations are proposed in the following sections for more objective guidance.

6.3.2.1 How to obtain evidence of unstable transmission and low immunity

a) Analysis of historical data

The analysis of historical data, expert and community opinion collected from a potential sentinel site is often neglected or restricted to the calculation of thresholds. Historical data are also a valuable source of information to determine the instability of transmission in the area. A rough analysis of malaria incidence overtime can be used to detect interannual abnormalities and eventually document the existence and periodicity of epidemics. Other simple and straightforward calculations of these data may determine intra-annual variability and seasonal patterns of transmission by plotting on simple charts the incidence of malaria, preferably as median or mean numbers of cases grouped by month. The shape of such a graph may define the seasonality of transmission, e.g. either uni- or bimodal. The variability in transmission may be calculated from the ratio of the highest and lowest month/week of incidence.
Although often biased by variations in patient care-seeking behaviour and case definitions by health staff, other indicators (see section 4.1.3) may theoretically be used to determine the relative intensity of transmission. These include:

- the proportion of suspected malaria cases among outpatients or inpatients, relatively low values within the range 20%-30% being indicative of low unstable transmission; and
- age-related incidences of severe malaria since these are related to the age-dependant effect of acquired immunity, with higher incidences in older children and adults being indicative of low unstable transmission, including:
  - the proportion of the severe form of the disease when all ages are combined;
  - the age of severe cases or those suffering main complications (i.e. severe anaemia and cerebral malaria);
  - adult-to-child ratios among inpatients.

b) Childhood prevalence

From an operational perspective, there appears to be consensus that malaria endemicity should be classified into only two groups, i.e. stable and unstable transmission. This classification has been recently adopted by WHO to estimate the malaria burden and risk, and to guide strategies for malaria prevention and control (51). The cut-off between stable and unstable intensity of transmission has been defined for countries outside southern Africa as a parasite prevalence of 25% in children aged 2–9 years or a MARA suitability index of 0.75 (100).

Availability of recent estimates of childhood prevalence in the catchment area of sentinel sites should be assessed by a comprehensive review of published and unpublished literature. In some cases these data may be obtained from systematic reviews that are accessible from several different databases. These include:

- the MARA database which is currently the most comprehensive source providing details of malarriometric surveys in Africa, with over 10 000 data points (85);
- the HIMAL project that provides data from 370 epidemic–prone locations and 956 prevalence surveys carried out in around nine countries with highlands (143); and
- a recent study in Kenya (88) that also provides good-quality data from surveys carried out on 217 sites and proposes that to ensure comparability of childhood prevalence data should be:
  - relatively recent;
  - restricted to children 0–15 years;
  - community-based;
  - randomly sampled with a minimum sample size of 50; and
  - importantly, performed during or just after the peak transmission season.

As shown in Table 9, a baseline prevalence below 25% would be indicative of epidemic potential and a valuable reference, allowing robust confirmation of
epidemics by subsequent comparative surveys (see section 6.8). Values below 10% characterize hypoendemic areas that are likely to be only affected by “true” epidemics and do not need to be covered by an EDS based on sentinel sites (see section 6.1). Hence the selection of sentinel sites would be preferably in locations where malaria prevalence in children is between 10% and 25%.

In the absence of childhood prevalence data, the possibility of carrying out prevalence surveys in the surrounding area should be assessed. Precise guidance and details of the relevant methods can be found elsewhere (51). Limited resources should not justify any concessions on the quality of protocol, the sampling methods and timing of the study. However, the strict random sampling of at least 100 pupils in a large primary school might be an affordable and acceptable alternative. Preschool children aged under 5 years may be recruited among those attending postnatal clinics to obtain data within the standard age range of 0–15 years old (144).

<table>
<thead>
<tr>
<th>Hypoendemic</th>
<th>Mesoendemic</th>
<th>Hyperendemic</th>
<th>Holoendemic</th>
<th>Malaria prevalence in children aged 2–9 years; Snow et al., 2003 (100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>Unstable</td>
<td>Stable</td>
<td></td>
<td></td>
<td>Snow et al., 2003 (100); WHO, 2005 (51)</td>
</tr>
<tr>
<td>0.25</td>
<td>0.75</td>
<td></td>
<td></td>
<td>MARA model values of “suitability index”</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
<td>MARA classes</td>
</tr>
<tr>
<td>Uncommon</td>
<td>Seasonal</td>
<td>Stable</td>
<td></td>
<td>Snow et al., 2003 (100); MARA</td>
</tr>
<tr>
<td>“True” “Exaggerated” seasonal transmission</td>
<td></td>
<td></td>
<td></td>
<td>Types of epidemics: WHO, 2002(^a) (20)</td>
</tr>
</tbody>
</table>

\(^a\) MARA = Mapping Malaria Risk in Africa.

6.3.2.2 Representativeness

This is the most important criterion, since the case-load at each sentinel site should reflect accurately the distribution of cases by time, place and population in the areas served by the site. In addition, the resolution of the sentinel-site network should be balanced according to the risk of localized epidemics, and the system be receptive to informal signals from the communities.
a) Consistent attractiveness over time

The selected health facility should be consistently attractive to the local population with a large and stable level of attendance. It is estimated that an average attendance rate of at least 0.3 consultations per person per year over the previous five years should be sufficient. This can be roughly calculated using historical attendance data and demographic consensus data to estimate the population living within a 10 km radius of the health facility. If this is not possible, a stable attendance > 600 consultations per month\(^{23}\) would be a good alternative. The stability of attendance is difficult to determine, but it can be estimated in the absence of recent population migrations and foreseeable significant changes in the density and quality of health services in the surrounding areas.

b) Sufficient density of sentinel network

Analyses of historical data from several countries have shown that malaria epidemics may be small and highly localized\(^{24}\) or vast and spread over several districts or even provinces. The geographical coverage of sentinel sites within each epidemic-prone district should take into account this potential for spatial expansion of malaria epidemics. The Highland Malaria Project (HIMAL) has implemented a monitoring system based on a network of five sentinel sites in each of four districts in Kenya and Uganda (145). While the number of sentinel sites will depend on the size of the each district, its population distribution and available human and financial resources, it might be cost-effective to start with 2–3 sentinel sites in each epidemic-prone district.

c) Appropriate health centres

Large hospitals are often preferred as sentinel sites for convenience since they are easily accessible, have higher case-loads and are more likely to have historical records available for a longer period of time. However, an EDS that relies solely on data from large reference hospitals is unlikely to detect localized epidemics in peripheral rural areas. Data from peripheral health facilities are more likely to be sensitive to rapid changes in malaria incidence in the surrounding population. A substantial proportion of the population seeks health care from the private sector, faith-based organizations and NGOs in many countries. In this context, the inclusion in the EDS of nongovernmental health facilities is essential to cover the most comprehensive portion of the population at risk.

All health centres selected as sentinel sites should already have well-functioning facilities to diagnose and treat uncomplicated malaria effectively in an outpatient section, and severe malaria cases in a permanently operative inpatient section. These sections require a sufficient number of well-trained staff, and quality should be assured by effective management with regular monitoring and

\(^{23}\) For a conservative low attendance rate of 0.3 per person-year, the indicative minimum figure for a health centre serving around 25 000 people would be around 600 consultations per month.

\(^{24}\) For example, exceptional case-loads may be very different between health centres separated by no more than 10 km in the Kenyan highlands (111).
evaluation. The quality of medical care can be assessed by rapid surveys, using available standardized methods to measure process and outcome indicators of malaria case-management (Box 1). However, the fulfilment of the specific tasks related to the implementation of an EDS would almost certainly require both a substantial upgrading of the capacity of the laboratory and a reorganization of the outpatient department and of data collection (section 6.5). This would not be achievable without substantial training and recruitment of new staff. The site would also require an efficient infrastructure and support network to ensure a continued and sufficient supply of quality equipment, supplies and drugs for the day-to-day operations of the facility.

Box 1. Criteria of suitability for potential sentinel sites

Inferred from on-site functional assessment:
- historical reports of epidemics
- childhood prevalence < 25%
- adequately equipped structure
- permanently operated inpatient department and laboratory
- availability of complete monthly reports for the previous five years
- absence of recent large population migrations
- absence of recent or planned changes in health services coverage.

Derived from data analysis of previous five years:
- obvious interannual variability (probable epidemic peaks)
- relatively stable and sufficient attendance (> 0.3 ppy or 600 consultations per month)
- substantial seasonality of incidence
- relatively low median proportional malaria morbidity
- relatively high median age of severe cases.

6.4 Operational structure of a malaria EDS

6.4.1 Basic operational organization

There is consensus that the simplest and most effective structure should be based on the following hierarchical organization:
• The community level should be properly involved to increase sensitivity of the system, particularly in rural areas. Implementation of an EDS should include building awareness of communities about their vulnerability to malaria and simple messages to identify the initial impact of emerging epidemics. Their leaders should be informed of the necessity and modalities to report abnormal events quickly, such as an increase in deaths or severe diseases, to the closest officials including those in charge of health.

• The peripheral health service is generally the first point of contact of an ill person with the health services. In addition to the diagnosis and management of malaria cases, the responsibility of staff at this level is also to compile data and submit weekly reports in a timely way to the district management level. They should be encouraged and have the opportunity to carry out a preliminary analysis by tabulating their own data and highlighting any apparent abnormalities. This will not only aid further detailed analysis at the district level but will increase the sense of ownership and responsibility of peripheral health workers.

• The district or intermediate level is an essential element of the early detection and response system since the district management team has responsibility for carrying out the critical tasks of data analysis, reporting back to those generating data and ensuring coordination of the development of preparedness plans of action, timely investigation and quick response.

• The central or provincial level plays a key role in determining policy and for the planning, budgeting, implementation and monitoring of the national EDS. It is responsible for providing national guidelines and supports the district level by mobilizing financial and human resources and organizing training. It is also responsible for liaising with both national and international partners involved in developing and implementing the EDS. A critical task is also to ensure connection with sectors other than health, for example with meteorological or agricultural services, to set up and validate a comprehensive malaria early warning and detection system able to prevent outbreaks.

The corresponding standards and responsibilities at each level should have potential for the development of a career structure, an essential element in increasing staff commitment.

Figure 6 summarizes the structure of a malaria EDS, organized in parallel with the routine surveillance system, indicating the related flow of information and actions to be taken at each level.

6.4.2 Transfer of responsibility to the district

The above structure of a malaria EDS is based on the premise that decision-making and the capacity for a rapid response should be established and maintained where the problems are expected to occur to ensure timeliness of action. This
means that staff at the peripheral level should be able to recognize and respond to an unusual event by reporting it rapidly to the district level, and district-level staff should manage the response to this report. Thus, basic epidemiological information collected at the periphery should ideally be analysed at the district level, with quick feedback and technical guidance provided to field staff for rapid action. However in many countries, analysis of data, decision-making and response are still carried out at the provincial or central levels which results in delays. In order to ensure that this change in responsibilities is effective, it is proposed that an interim period should be defined during which the provincial/central level would remain in charge of data analysis, until sufficient capacity could be transferred/developed at the district level. The capacity of the district
level to analyse data, and to plan and implement effective responses, requires the appointment of experienced epidemiologists and the support, supervision and feedback of staff at the central/provincial levels.

6.4.3 National guidelines for malaria early detection systems

Each epidemic-prone country should develop epidemic guidelines that are adapted to its specific epidemiological situation. These should describe the organization of the system with clear objectives and responsibilities for each institutional level involved. The level at which the reporting, analysis and response should be performed should also be clearly defined. For this purpose, a prototype is provided in the technical guidelines for IDSR in the WHO African Region (49) that may be adapted to the structure and level of sophistication of the existing health services of each country. The guidelines should also include the sources of data to be used, the standard operating procedures for data collection, analysis and reporting, and the action to be taken to rapidly verify reported epidemic alerts and to prevent and control their spread. A synthesis of a national guideline for a malaria EDS is proposed in Table 10.

6.5 Towards reliable data collection

6.5.1 Confirming malaria as the cause of fever

At present, a “syndromic approach” must be used at the periphery of the health services because of the absence of effective laboratory services. As a consequence, malaria cases are reported as “probable”, case definitions have low specificity and many detection systems only identify outbreaks of unspecified febrile diseases. The early confirmation that malaria is responsible for abnormal increases in fever cases would have an important impact in improving the performance and reliability of malaria EDS (14). Furthermore, the importance of accurate laboratory diagnosis and the need to expand diagnostic services at the periphery have become acute not only for EDS but to ensure rapid and effective case-management in areas faced with antimalarial drug resistance, particularly multidrug-resistant P. falciparum. In epidemic-prone areas and areas of low endemicity, it is clear that the cost of laboratory testing would be worthwhile if it avoided the treatment with artemisinin-based combinations (ACTs) of a large majority of febrile patients who are not parasitaemic. As a consequence, WHO has recommended that all cases of suspected malaria should be confirmed by a laboratory test in all areas of low to moderate transmission where multidrug resistance occurs and ACT is essential (18, 146).

Ideally the systematic testing of every patient presenting with a recent fever by a reliable method is certainly the best option. However, there are numerous constraints to reliable confirmation of cases, even if a restricted number of
## Systems for the early detection of malaria epidemics in Africa

### Identify

- Community: Unusual number of deaths/severe febrile diseases, particularly among adults
- Sentinel sites: Uncomplicated cases and confirm severe cases using standard operating procedures. Values of defined EDS indicators on a weekly basis
- District: Rumours from communities. Alerts from sentinel sites. Operational support required by sentinel sites.
- Province: Best practices for EDS/response. Gaps in financial and human resources.

### Analyse

- Community: Define alert thresholds and draw a chart. Plot EDS indicators on a weekly basis.
- Sentinel sites: Define epidemic thresholds with computerized spreadsheet. Confront EDS indicators with thresholds on a weekly basis.
- District: Define epidemic thresholds with computerized spreadsheet.
- Province: Capacity of districts concerning preparedness; epidemic reports; action plan.

### Investigate

- Community: Most precise and quantitative information through leaders.
- Sentinel sites: When alert threshold exceeded: proportion of confirmed malaria among outpatients with fever (SPR); spatial clustering and distribution of cases; alternative cause.
- District: When epidemic or alert thresholds exceeded or rumours reported.
- Province: Coordination with multiple partners for preparedness and MEWS.

### Report

- Community: Abnormal health-related event to closest health authority.
- Sentinel sites: On a weekly basis: incidence using standard case classification; values of EDS indicators. When alert threshold exceeded or rumour reported.
- District: Findings of rapid investigation team: confirmation; cause is malaria; expansion; planned response; required resources; support needs.
- Province: Programme monitoring, national level/donors: consolidated action plans/proposals; activity reports.

### Feedback

- Community: Engaged communities: IEC in communities; committed leaders; awareness of other sectors and partners.
- Sentinel sites: Regular information to community leaders about epidemic prevention and response.
- District: Field assessment.
- Province: Mobilization of: funds, supply staff, training. Technical guidance.

### Prerequisites

- Community: Engaged communities: IEC in communities; committed leaders; awareness of other sectors and partners.
- Sentinel sites: Well-operative platform: adequate and sustained level of equipment, supply and staff; performing organization and standard operating procedures.
- District: Strengthened capacity: adequate equipment/resources/operational funds/staffing for district health management team; efficient communications system; feedback procedures.
- Province: Enabling environment: adequate quality of management; sufficient national and external resources.

---

**Table 10. Definition of responsibilities for each level involved in EDS**
An analysis of current practices and future priorities

health facilities (i.e. sentinel sites) are used for malaria EDS and a limited but representative number of patients are tested to generate indicators such as SPRs. Thus it is commonly observed that, in locations where health facilities are already equipped with laboratory facilities, their limited capacity and quality combined with the lack of standardized diagnostic procedures often result in a questionable classification of cases (see section 3.2.5) which consequently alters the accuracy of potential EDS indicators (see section 4.2). In this context, economies of scale can be made by extending the responsibilities of sentinel sites established for evaluating the use of ACTs and the monitoring of drug resistance to include malaria EDS.

The improvement of the quality of microscopy at all levels of the health services has been identified as a high priority for malaria prevention and control. As a consequence, WHO has recently developed guidelines for the quality assurance of malaria light microscopy (57, 59, 147). In addition to such technical guidance, the deployment and maintenance of reliable microscopy also require substantial investments in both financial and human resources.

Evidence from Asia (148, 149) suggests that rapid diagnostic tests (RDTs) are likely to be a cost-effective alternative to light microscopy in situations where normal laboratory services are non-existent or overworked. However, their use should be supported by adequate quality assurance including temperature-stability testing, and they should not be relied upon as a sole basis for treatment (i.e. negative tests should not preclude treatment, particularly when severe malaria is suspected) (76, 150).

Establishing adequate laboratory services may take time, with the result that there may be an interim period when conditions are not yet available for the systematic testing of every patient suspected of malaria. In such circumstances, the following should be considered as minimum standards to ensure both adequate classification and case-management of febrile diseases (see section 3.2.5.4) and reliable estimates of the SPR among outpatients (see sections 4.2.1.2 and 4.2.3.2):

- Systematic testing of inpatients with a diagnosis of “severe febrile disease” or “probable severe malaria”.
- Routine testing using systematic sampling of outpatients (only those who are not admitted) with suspected malaria fever. The size of the sample and the frequency of sampling should be in accordance with the workload and capacity of the laboratory staff. However, accurate results may reasonably be expected from a minimum of 50 patients with suspected fever every first week of each month, or of 15 patients with suspected fever every Monday.

6.5.2 Centralized and sequential registration

The detrimental effects of multiple case-counts (see section 3.2.6.1) can be avoided by adopting adequate standard operational procedures for the registration of patients.
Patient flow should be strictly controlled with centralized registration, with every person being first examined in the outpatient department. Immediately after the initial consultation, each case of “probable malaria” should be registered in the outpatient department prior to eventual laboratory testing or hospitalization. There should be a single centralized record book with a standard template compatible with the prevailing diagnostic and case-management guidelines. Subsequent results of eventual testing and/or outcome of hospitalization would be recorded later on discharge.

The record book should contain the necessary personal details for patient identification and should record sequentially all actions taken and results of such action as the patient passes through various stages of case-management. A proposed template for registration of patients is given in Table 11. Each column should be completed according to the standardized list of instructions given beneath the table. The first six columns should be filled on initial registration, with the last three being completed later according to the laboratory results and outcomes of an eventual admission. This is the best way to ensure the rapid, easy and unambiguous compilation of case-counts required for completing the weekly report forms. The outcome of the admission could be entered by the officer in charge of surveillance/HMIS/EDS in an additional column when the patient is discharged. This outcome should be described according to the standard classification of malaria cases outlined in section 6.5.3 and in the reporting form (Table 12). This is the minimum information required for EDS, but it could be complemented by other columns (i.e. name of patient, new case/ follow-up, date of discharge, etc.).

**Table 11. Proposed comprehensive record template to include essential EDS information for centralized and sequential case registration**

|------------------|-----------|---------|-----------|-----------------|----------------|---------------|

1. Date of consultation
2. New case (Y) or follow-up consultation (N)
3. Patient name
4. Sex
5. Age: three age groups (< 5 years; 5–15 years and > 15 years); and pregnancy
6. Village of residence: name
7. Presence of signs of severe disease: none (N) or detailed
8. Hospitalization (Y) or not (N)
9. Result of microscopy/RDT testing: NO is not tested; NEG is negative; PF is *P. falciparum* or mixed; PV is *P. vivax*, *P. ovale* or *P. malariae*
10. Treatment: name of drug and dose
11. Discharge: (N) or death (Y)
12. Date of discharge or death
13. Case classification on discharge: same as column 9 if no sign of severity; CS is confirmed severe; OS is for other severe conditions
6.5.3 A mutually-exclusive case classification

Clear instructions concerning the steps to be taken to confirm a “probable malaria” case are essential to avoid confounding factors in health facilities that have functional laboratory services (see section 3.2.6). Figure 7 provides an algorithm for the sequential classification of malaria cases according to the different diagnostic steps to be taken. This algorithm allows all probable uncomplicated malaria cases to be classified into four mutually-exclusive categories: those “tested negative”, “confirmed falciparum or mixed cases”, “cases of vivax, malariae or ovale malaria” and “not-tested” if laboratory tests are not carried out systematically. It should be noted when using this algorithm that all cases with a negative blood slide are defined as probable malaria and should be counted as so. It is assumed that every hospitalized patient with signs of “probable severe malaria” will be laboratory-tested (see section 6.5.1) and that the presence of *P. falciparum* infection would be sufficient\(^25\) and necessary\(^26\) to define a case of confirmed severe malaria.

Compliance with these procedures should ensure that every case is counted only once, which should substantially improve the quality and ease of data analysis.

---

**Figure 7. Proposed flow-chart for the classification of probable malaria cases in five mutually-exclusive categories**

---

\(^{25}\) Even if other coincidental infections could not formally be excluded.

\(^{26}\) Exclusive infection by other species of plasmodia do not traditionally result in severe disease.
The corresponding standard case definitions, with an associated proposed template for reporting to be used in conjunction with the above flowchart, are given in Box 2 and Table 12. It is proposed that these definitions are adopted by both multidisease surveillance systems and the malaria EDS. This method of case classification combined with a sequential centralized registration as described in section 6.5.2 should avoid double-counting, each case recorded corresponding to a single patient.

**Box 2. Proposed mutually-exclusive malaria case definitions**

A probable case of malaria in areas with low/moderate level of transmission is a patient reporting a recent fever that cannot be attributed to other obvious causes than malaria after clinical examination.*

Five mutually-exclusive classes of malaria cases.

**Confirmed severe malaria is a probable case with:**

- one of the following signs: unconsciousness, severe anaemia, renal failure, respiratory distress, hypoglycaemia, shock, spontaneous bleeding, convulsions, haemoglobinuria; and
- the presence of *P. falciparum* identified by microscopy or RDT.

**Four classes of uncomplicated malaria:**

- not-tested: treated without being tested;
- tested negative;
- confirmed *P. falciparum or mixed*;
- confirmed *P. vivax, P. ovale or P. malariae*.

*In this case, malaria reporting is no longer based on whether the patient received treatment.*

Table 12 proposes that pregnant women are reported separately and children according to age, since pregnant women and children under 5 years are highly vulnerable to malaria in all situations, and are specifically targeted in health intervention programmes.

### 6.6 Improving the flow of data within the EDS

An EDS requires the data flow from each level to be very rapid and continuous in order to achieve its primary objective of detecting malaria epidemics within two weeks of their emergence. Hence, important changes are needed to improve the generally slow and incomplete reporting of current surveillance systems (see section 3.2). The following sections provide details of two simple ways of achieving this goal.

*27 This classification takes into account the current inability of rapid diagnostic tests to distinguish between species other than *P. falciparum*. 
6.6.1 Optimizing reporting formats

Reporting formats can be optimized to ease the tasks of peripheral health staff and reduce errors in data entry and interpretation if:

- a Monday-to-Sunday week is adopted;
- a yearly calendar with the weeks numbered 1–52 is available in all health facilities and is renewed in a timely fashion towards the end of the year;
- standard printed forms for weekly EDS reports are designed with clear indications of the location, dates, daily numbers and weekly totals, and with space to insert any relevant additional comments and information;
- reporting forms are self-copying for easy filing and transmission, with each copy clearly indicating where it should be sent or filed.

6.6.2 Data limited to minimal requirements

In order to increase the efficiency of the EDS, only the minimum essential data should be routinely transmitted between its different operational levels. More comprehensive information would then only be transmitted by ad hoc reports of alerts and rumours, along with the results of their related field investigation.

Table 12. Proposed template for standardized reporting of malaria cases

<table>
<thead>
<tr>
<th></th>
<th>Outpatients</th>
<th>Inpatients</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe malaria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not tested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. falciparum/mixed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. vivax/P. ovale/P. malariae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* PW = pregnant women. Other subcategories represent age groups irrespective of sex. The breakdown of severe cases according to age is needed in order to calculate adult-to-child ratios, a potentially useful indicator of epidemic risk.
6.6.2.1 From peripheral to district level

Data should be transmitted weekly from sentinel sites to the district level for analysis. This should be restricted to the minimum data required to derive the indicators being used for epidemic detection. For example, if epidemic thresholds are based on the proportion of outpatients attributable to probable malaria, only two figures would be required (i.e. the number of uncomplicated malaria cases and the total number of consultations). In peripheral rural areas where other forms of communication are difficult, these two figures could be easily transmitted weekly by radio or telephone, as soon as the compilation of record books is completed. The complete weekly report (as shown in Table 12) could then be dispatched by mail or courier with allowance for a short delay for the transmission of a paper-based copy.

6.6.2.2 From district to provincial/central level

As soon as conditions are met for the data analysis to be performed at the district level, the provincial/central levels need only be provided with a summary report informing them of any epidemic alerts, and the functional status of the sentinel sites for monitoring and evaluation. This could include the following information:

- number of informal or qualitative alerts;
- number of alerts detected by data analysis against thresholds;
- number of epidemic alerts confirmed by field investigations;
- number of sentinel sites reporting to the district level; and
- dates on which sentinel sites reported to the district level.

The principle of “zero reporting” should be strongly recommended, since this assures that systematic reporting is maintained, even in the absence of data on emerging epidemics.

6.7 Data analysis and interpretation

6.7.1 Minimum requirements for data management and analysis

The training and equipment provided should be sufficient to allow the focal persons based in districts to carry out their essential responsibilities of data management and analysis. Although it is crucial to ensure that the data collected are reliable, accurate, complete and timely, incorrect data entry and management can jeopardize their analysis and interpretation, leading to an inappropriate response. Thus it is essential that adequate hardware maintenance, system configuration and safe data storage and back-up are ensured. The database package should be adapted with convenient and stable functions for access, management and extraction of the data for analysis. Data analysis itself does not need either specialized epidemiological skills or a dedicated statistical
An analysis of current practices and future priorities

package. The calculation of predefined epidemic thresholds based on weekly data can easily be performed using simple spreadsheet software and suitably adapted charts.

6.7.2 Data to be used as indicators for EDS

Health-facility data may be used to develop indicators that have been shown to rise during the emergence of malaria epidemics. The challenge is to determine which of these indicators is sufficiently sensitive and specific in detecting the early stages of an epidemic, but does not result in repeated false alerts. This is a difficult choice since the sensitivity and/or specificity of each is affected by several factors (Table 13 and for more details see section 4.2). The following elements are particularly important:

- in contrast to proportions or ratios, absolute numbers are all biased by changes in population numbers and care-seeking patterns (see section 4.2.2); and
- laboratory and inpatient data can be severely distorted by inconsistent and uncontrolled case-classification and -management (see sections 3.2.5 and 3.2.6).

**Table 13. Indicators based on health-facility data sensitive to the early stages of epidemics, and related factors affecting their accuracy**

<table>
<thead>
<tr>
<th>Potential biases by changes in:</th>
<th>Population at risk</th>
<th>Care-seeking</th>
<th>Criteria for testing</th>
<th>Quality of laboratory</th>
<th>Criteria for admission</th>
<th>Definition of severe</th>
<th>Case-management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute case counts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable uncomplicated</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory-confirmed</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Severe</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Deaths</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Proportions or ratios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable / Outpatients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive / Tested</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Severe / Inpatients</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Deaths / Severe</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Although far from being ideal, it appears at present that the “proportion of outpatients with attributed malaria” is comparatively less likely than others to be affected by the above constraints (see section 3.2.6). However, it is critical when using this indicator to avoid the detrimental effects of double-counting that may result from the lack of standardized guidance for the compilation of uncomplicated malaria cases. This could be achieved if the numerator is defined as the number of “uncomplicated cases regardless of laboratory results” and compiled by the aggregation of the “not-tested”, “tested negative” and “confirmed” categories listed in Box 2. The denominator would then simply be the total number of consultations recorded in the outpatient department during the same period.

The implementation of the measures to standardize case definitions and registration outlined in section 6.5 should optimize the quality of the data collected and reduce the current distortion of indicators. This should allow the use of more specific indicators since they will be based on confirmed cases of malaria. Once changes are implemented, it should take another five years to gather the required minimum set of reliable baseline data needed to calibrate their related thresholds. It is only when this stage is reached that it will be possible to calculate epidemic thresholds with adequate precision, for which the following indicators appear to be the most appropriate:

- slide or RDT positivity rate in outpatients with uncomplicated malaria;\(^{28}\)
- proportion of hospitalized patients with severe malaria.\(^{29}\)

Operational research will be still needed to investigate their comparative accuracies.

### 6.7.3 Determining weekly epidemic thresholds

#### 6.7.3.1 Transformation of monthly into weekly data

The retrieval of raw daily data and their compilation in a weekly format should be encouraged in places where tally sheets or record books are still available, since this is the only accurate method of transforming monthly into weekly data. When such a tedious manipulation is impossible, the absence of weekly baseline data may be overcome by the transformation of monthly data. One method has been proposed, but does not seem to be appropriate (see section 5.1). A suitable alternative is to divide monthly figures by either 4 or 5. The choice of which month should be divided by 4 or 5 is imperfect and arbitrary, but the following might be considered for use as a standard (Table 14), the proposed rhythm being 544-544-544 throughout the year irrespective of month duration.

---

\(^{28}\) The proportion of tests positive for \textit{P. falciparum} would only be applicable where other species are common.

\(^{29}\) Case-fatality rates (CFR) are an indicator of the quality of case-management and not appropriate for EDS.
6.7.3.2 Baseline period to be used as a reference

Variations in attendance rates, environmental changes and the impact of control measures over time may distort the accuracy of epidemic thresholds. While the effect of variations in attendance rates may be reduced by using proportional morbidity as an indicator, it is difficult to control for other confounding factors.

This can only be achieved by “detrending” the data by time-series analytic methods such as auto regressive integrated moving average (ARIMA), but these methods are complex and not adapted to routine field use. A simpler method for time-series analysis is to stabilize means by removing secular and seasonal trends (151), but these transformations result in data that are unsuitable for obtaining epidemic thresholds.

The HIMAL project in Kenya and Uganda has adopted a complex method derived from the salmonella potential outbreak system (SPOT) (152). Data are successively log-transformed, twice “detrended” and then smoothed. The method produces two distinct thresholds combined in an algorithm to define epidemics (146). This method should be validated and refined before it can be more widely used with the assistance of computerized automated analysis.

Meanwhile the simplest alternative to minimize the effect of trends during the baseline reference period is to restrict its length to the minimum of the most recent five years, even if a longer set of data is available. As a consequence, thresholds would need to be updated every year by incorporating the most recent year and discarding the oldest.

6.7.3.3 Calculating epidemic thresholds

It has been proposed (26) that there should be two epidemic thresholds for malaria EDS. The first, an alert threshold, should be used to:

- provide an early warning and launch an investigation at the start of the epidemic;
- check epidemic preparedness; and
- prioritize areas for intensified control measures in the event of an epidemic.

The second threshold, the epidemic threshold, should be used to confirm the emergence of an epidemic so that control measures, such as case-management, can be intensified.

<table>
<thead>
<tr>
<th>Months</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of weeks</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

* These figures are based on the international convention of 52 weeks and 12 months in each year.
Both of these thresholds will need to be developed for each separate sentinel site, as dependant to local epidemiological factors.

**Alert thresholds**

The timeliness of malaria EDS could be enhanced by the introduction of “alert” thresholds which should be relatively more sensitive than the normal epidemic thresholds. Alerts triggered by sentinel sites would stimulate peripheral staff to verify any unusual increase in fevers by microscopy or RDTs, and allow more time for the district health services to organize a field visit to confirm the presence of an emerging epidemic and improve response preparedness. In such circumstances, it should be possible for an investigation team to be ready to perform investigations after two consecutive weeks of alert.

The third quartile or 75th percentile of the weekly figures of the previous five years is the alert threshold of choice, since it is simply the second-highest of the five daily values during the week (this assumes a week consists of five working days). This method provides both optimal sensitivity and simplicity, since its calculation does not require either a computer or a calculator (see section 5.3.2). Its use has been common practice in Ethiopia since 1998, with thresholds displayed on wall posters for easy reference.

**Epidemic thresholds**

The recommendation of a unique method for the calculation of weekly epidemic thresholds for malaria EDS is highly desirable. Although limited in number, observations and common sense suggest that methods based on percentiles are more robust than those based on means and standard deviations. They are more adapted to log-normal distributions and less sensitive to extreme values. Although the fine calibration of the optimal level of percentile would require further validation and probably need to be adapted to the local context of each country, the 85th seems a good tentative value to be adopted as a standard for an experimental period of five years.

**6.7.4 Operational definition of epidemic signals**

Box 3 summarizes the conclusion of the three preceding sections, and provides clear operational definitions of alert and epidemic indicators and their thresholds. The adoption of more specific indicators based on confirmed malaria cases (see section 6.7.2) would necessitate the compilation of five years of baseline data with sufficient quality once the standardized collection of data has started (see section 6.5). Until this is possible, alert and epidemic thresholds should be based on the proportion of outpatients with uncomplicated malaria attending the health facility.
Box 3. Operational definition of epidemic signals

A. Now, without standard classification and registration

• **Indicator:** weekly proportions of outpatients attributed to “uncomplicated cases regardless of laboratory results”.

• **Alert threshold:** week-specific third quartile of previous five years.

• **Epidemic threshold:** week-specific 85th percentile of previous five years.

B. In five years conditional on the adoption of standard classification and registration

• **Indicator:** weekly proportions of either:
  – slide/RDT positivity among outpatients; or
  – inpatients with attributed severe malaria.

• **Alert threshold:** week-specific third quartile of previous five years.

• **Epidemic threshold:** week-specific 85th percentile of previous five years.

6.8 Confirming an epidemic by field investigations

Malaria epidemics are often reported by the non-health sector, or they may be suspected from the analysis of EDS data by a statistical deviation of indicators from a normal baseline level. Increases in malaria incidence detected by both the alert and epidemic thresholds should trigger an immediate investigation by the district health services.

6.8.1 Investigation and response teams

The recruitment and training of mobile investigation and response teams based at the district level has been proposed both for malaria EDS (26) and also for IDRS (49). Such teams are essential and should be available for rapid deployment to the affected area. They should be trained in the verification process and given adequate human and financial resources, including for transportation. The minimum staff requirements for such teams would be a medical officer, an epidemiologist and trained staff with adequate facilities to perform diagnoses. As part of an integrated scheme, they should be able to investigate all kinds of suspected epidemics and trigger a targeted response.

6.8.2 Verification of the cause of the alert

The first step to formally confirm a malaria epidemic situation is to analyse trends in clinical and laboratory data from successive detailed weekly reports
of the sentinel site. These data should not only include malaria data but also those related to other potential causes of fever epidemics, e.g. relapsing fever, typhoid, haemorrhagic fevers, dysentery.

In such circumstances, the use of quality microscopy or RDTs to measure slide or RDT positivity rate in carefully sampled suspected malaria cases is critical to ascertain whether *P. falciparum* is the main cause of the epidemic. However, interpretation might be difficult in the absence of reference baseline data, and such investigations might be inconclusive because a universal cut-off value applicable to all localities has not yet been properly validated (see section 5.5.1). These demanding and time-consuming investigations are not required if systematic or at least representative testing of suspected malaria cases is carried out regularly at all the sentinel sites (see section 6.5.1).

### 6.8.3 Determining the geographical extent of the epidemic

Once an epidemic has been confirmed at the sentinel site, all epidemic-prone areas of the specific district should be presumptively considered affected until further investigations have proved otherwise. Investigations should include all surrounding peripheral health facilities as well as remote communities until the affected areas have been completely demarcated. Particular attention is required in highland areas where the more elevated marginal areas have the potential for “true” epidemics in their most severe form (see section 6.1.1). As explained below, the rapid verification of rumours and the characterization of epidemics at community level are often difficult for malaria.

#### 6.8.3.1 Verification of rumours

Rumours of malaria epidemics originating in isolated communities are often qualitative, being based on unusual occurrences of severe feverish illness that have caused death, especially in otherwise healthy adults or older children. This may not be immediately attributed to malaria, especially when “true epidemics” occur in areas where the disease is usually absent. Field investigations can often collect more precise information and qualitative data from leaders or community health workers. In some small and well-organized communities, relatively accurate retrospective weekly incidence and mortality rates may be available from community records. During complex emergencies or the initial phase of large population displacements, the proper assessment of the situation requires surveys to measure:

- period-prevalence (1–2 weeks) of fevers;
- prevalence of parasitaemia and splenomegaly; and
- retrospective mortality, eventually including verbal autopsies (51, 74).

#### 6.8.3.2 Rapid prevalence surveys

Methods and interpretation of the measures of childhood prevalence of infection in epidemic-prone areas have been discussed in section 6.3.2, but historical reference values are usually not available, particularly in remote areas. In
this case, special field studies may need to be carried out. Rapid parasite or fever prevalence surveys have been proposed for the confirmation of excessive transmission at the community level, but their interpretation in the absence of reference values is difficult and would require further operational research to be properly validated (for details see section 5.5.2). However, it is likely that an epidemic is probable when parasitaemia is detected among more than 30%–40% of a sufficiently large and properly-sampled fraction of a population living permanently in an area previously affected by epidemics.
7. Providing an enabling environment

7.1 Defining appropriate country-specific goals and objectives

National malaria control programmes operate in different environments with different priorities and resources. A single set of best practices cannot be applied throughout Africa. Instead, objectives and strategies should be adapted to each specific country. The African Summit on Roll Back Malaria held in 2000 defined the primary objective of an EDS, i.e. detecting epidemics within two weeks to permit timely response (48). This should be the goal of all countries in Africa prone to malaria epidemics. Some countries may be able to set more ambitious objectives such as providing estimates of the impact of malaria epidemics, the assessment of the impact of prevention and control measures, and identification of associated risk factors. In this context, partnerships are required with domestic and international research institutions.

7.2 Advocacy

Despite many declarations and pledges of support by global partners, country-level implementation of sustainable malaria prevention and control has been limited, particularly in the resource-poor countries of Africa. Although the situation has improved since 2002 with the influx of funds from GFATM which has led to several country initiatives with defined goals and targets, there is still complacency over the public-health importance of prevention and control of malaria epidemics. Particularly, the impact of malaria epidemics is greatly underestimated. This complacency can only be overcome if their importance is understood and there is commitment from all those involved in the early detection and control of malaria epidemics. These include senior administrators and decision-makers in international organizations, bilateral partners, NGOs and national programmes, as well as health workers at the periphery of the health services and in the community.

Decision-makers should be shown that there are substantial and real cost-savings as well as health and economic benefits to be gained by preventing and controlling malaria epidemics. Evidence-based cost-analyses should be carried out to demonstrate such gains. In addition to demonstrating the benefits of such programmes, managers should demonstrate to decision-makers that they are able to deliver a cost-effective programme by developing realistic budgets commensurate with the activities to be carried out within a feasible timeframe.
7.3 Cost-effectiveness of EDS

It is estimated that 124 million people live in epidemic-prone areas of Africa south of the Sahara (7). Figures from community surveys suggest that at least 2% of the affected population would die during an epidemic lasting four months. This corresponds to the crude mortality rate (CMR) usually recorded during severe complex emergencies (>2 per 10 000 per day) which is more than four times higher than baseline mortality levels. This rate might be twice as high among isolated and vulnerable communities (153).

EDSs have the potential for cost-effectiveness by improving the timeliness and targeting of control interventions and reducing the impact of malaria epidemics, but there is no direct evidence to support this hypothesis. Economic benefits have so far only been evaluated for early warning systems using a modelling approach, which showed that the cost per case prevented by residual spraying could be reduced by over 50% with early spraying triggered by an effective MEWS (154). Research efforts to measure the cost-effectiveness of EDS are of high priority.

7.4 Commitment

Commitment of health-service staff to the early detection of and rapid response to malaria epidemics is crucial. This can vary over time as the threat level, the perceived value of early detection, support for the methods of surveillance, communication between the various levels and resources fluctuate. Lack of commitment can manifest itself by the poor participation of health units in the EDS system, incomplete and late submission of data, poor analysis and reporting of data, poor communication and inadequate response. It can be overcome by:

• training and career development;
• recognition and encouragement;
• feedback and better communication;
• sense of ownership and responsibility; and
• the wise use of monitoring and evaluation, including corrective action when required.

EDS should be demand-driven with particular attention to the dialogue with peripheral staff in order to identify and overcome constraints leading to the late recognition of epidemics.
7.5 Adequate resource mobilization

Implementation of an effective EDS is a long-term activity that depends on strengthening the already overworked peripheral and district health services. While integrated disease surveillance may offer economies in the long term, the initiation of EDS for malaria will require an increase in both financial and human resources that are well in excess of the current budgets available for disease surveillance. This is unavoidable in view of the current status of disease surveillance in most African countries. When drafting budgets for EDS implementation, specific requirements for personnel, training, materials, data analysis, communications, and monitoring and evaluation should be included. Priority areas include the training of peripheral health workers to record and interpret disease data on a weekly basis, especially during the epidemic season, and reinforcing the capacity of district and national teams to provide appropriate technical support to outlying areas.

While the human and financial requirement for implementing a malaria EDS varies depending on the specific requirements and capabilities of each country, 5%–10% of the national programme budget for disease prevention and control might be considered appropriate.

7.6 Integration of malaria into communicable disease surveillance systems

7.6.1 Organizational issues

In the long term, malaria EDS should not be implemented as an independent programme. However, integrated disease surveillance systems (IDRS) that are currently implemented at the country level were designed primarily to carry out routine disease surveillance to aid the planning, management, monitoring and evaluation of routine prevention and control activities. The nature, flow and formatting of data for this purpose are incompatible with the needs of epidemic control where early detection and rapid response are essential.

As a consequence, WHO has recently recommended (14, 18) that, although the integration of malaria EDS into more general disease surveillance systems should be encouraged as it is likely to be beneficial in terms of improving the quality of data and the efficiency of the system, integration should be contingent on:

- appropriate training being provided at the peripheral level;
- surveillance approaches being consistent with malaria control needs; and
- surveillance systems being able to collect, analyse and report all the required indicators in a timely way.
The development of a coordinated policy for the incorporation of malaria into larger integrated disease surveillance systems is a major challenge that should not be underestimated. In view of the difference in the objectives and requirements of routine surveillance of malaria and a malaria EDS, consideration might be given to the separation of these systems among different administrative structures, with routine malaria surveillance being integrated into IDRS and EDS being part of a parallel structure for epidemic-disease warning and response.

Whichever model for integration is chosen, integration requires effective collaboration within the departments responsible for surveillance and for malaria prevention and control at all levels of the health services.

### 7.6.2 New International Health Regulations – EWAR surveillance

The final revision of the new International Health Regulations (IHR) has now been endorsed by the Member States of WHO (World Health Assembly resolution WHA58.3, 2005). As part of these new regulations, countries are expected to maintain a minimum capacity for the early warning of threats to the health of their populations. WHO is committed to support countries in the establishment of early warning and response (EWAR) functions. Although these regulations are targeted to public health emergencies of international concern (PHEIC), this initiative could also be of benefit for the control of epidemics of national public health importance, such as malaria.

Implementation of the new regulations should start in each country with a communicable disease threat assessment to establish a list of priority diseases and events to be included and reported by EWAR. These lists should be based on criteria that take into account the severity of the disease, the availability of control measures, its potential impact on the local population, its potential to spread to other countries, and national and international health regulations.

Although EWAR priorities at present only cover new emerging health threats, there is a very strong argument that re-emerging epidemic-prone diseases of public health importance, such as malaria, should be included in EWAR. This can only be achieved if senior decision-makers are convinced that this would lead to health and economic benefits. It also requires coordination between national communicable disease and national malaria control programmes, to ensure that national priorities for the detection, prevention and control of malaria epidemics are addressed adequately at the country level.

### 7.6.3 Communication of information on epidemic risk

The impact of malaria epidemics is increased by the failure of patients to seek medical care promptly, particularly during the early stages of epidemic development. There is therefore an urgent need to use local communications networks to make populations in epidemic-prone areas aware of both the risk of malaria epidemics and the need to seek medical care promptly if they become ill.
Internationally, a system should be established for the systematic and timely publication of information on malaria epidemics that occur globally. The inclusion of malaria within the existing web-based database of Disease outbreak news published by WHO might be an option.
References


92. Connor SJ. Improved knowledge on the climatic and environmental determinants of malaria distribution in sub-Saharan Africa. Malaria Knowledge programme at the London School of Hygiene and Tropical Medicine, technical report. New York, International Research Institute for Climate Prediction (IRI), 2003.


