

SECOND EDITION

Epidemiological approach for malaria control

GUIDE FOR PARTICIPANTS



TRAINING MODULE ON **MALARIA CONTROL**



Epidemiological approach for malaria control



GUIDE FOR **PARTICIPANTS**

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Contents

Foreword.....	v
Abbreviations	vi
Acknowledgements	vii
Development of the module	ix
Introduction	1
Part 1: Introduction to basic epidemiology and statistics	
Learning Unit 1: Introduction to epidemiology	5
Learning Unit 2: Ratios, proportions and rates	13
Learning Unit 3: Data presentation: tables, graphs and charts.....	21
Learning Unit 4: Measures of central tendency.....	35
Learning Unit 5: Measures of variability and normal distribution.....	43
Learning Unit 6: Assessing the accuracy of a test	51
Part 2: Applied malaria epidemiology	
Learning Unit 7: Understanding malaria at regional and global levels	57
Learning Unit 8: Determinants of malaria distribution	61
Learning Unit 9: The life-cycle of the malaria parasite	65
Learning Unit 10: The life-cycle of the vector	69
Learning Unit 11: Natural history of malaria in the human host	73
Learning Unit 12: Intensity of malaria transmission	79
Part 3: Malaria surveillance, monitoring and evaluation	
Learning Unit 13: Overview of malaria programmes phases	89
Learning Unit 14: Surveillance system.....	93
Learning Unit 15: Indicators for monitoring and evaluation of malaria control programmes	103
Learning Unit 16: Data collection methods.....	111
Learning Unit 17: Burden of malaria	123
Part 4: Prevention and control of malaria epidemics	
Learning Unit 18: Introduction to malaria epidemics	131
Learning Unit 19: Early warning, early detection, notification and verification of a malaria epidemic	135
Learning Unit 20: Prevention and early response to confirmed malaria epidemics	141
Learning Unit 21: Post-epidemic assessment and preparedness plan of action.....	149

Annex 1. Core surveillance indicators for malaria control	153
Annex 2. Suggested register for community health workers, health posts and outpatient departments of health centres and hospitals.....	159
Annex 3. Sheet for tallying outpatient attendance at health centres and hospitals.....	160
Annex 4. Daily and weekly records of outpatient attendance at health centres and hospitals.....	161
Annex 5. Discharge register for inpatient departments of health centres and hospitals	162
Annex 6. Reports from health posts and community health workers to health facilities.....	163
Annex 7. Reports from health facilities to the district level	164
Annex 8. Line lists of inpatient malaria cases and deaths to be reported to district level in low-transmission settings.....	166
Annex 9. Line lists of all confirmed malaria cases to be reported at district level in low-transmission settings	167
Annex 10. Example of supervisory checklist for malaria surveillance for countries with high to moderate transmission	168
Annex 11. Example of questionnaire for malaria post-epidemic assessment.....	169

Foreword

Malaria is a major global public health problem and a leading cause of morbidity and mortality in many countries. Malaria caused an estimated 219 (range 154–289) million cases and 660 000 (range 490 000–836 000) deaths in 2010. Approximately 80% of the cases and 90% of the deaths occur in Africa while the remaining cases and deaths occur mainly in the South-East Asia and Eastern Mediterranean Regions.¹

The World Health Assembly and Roll Back Malaria (RBM) targets for malaria control and elimination are to achieve at least a 75% reduction in malaria incidence and deaths by 2015.

Elimination of malaria is defined as the reduction to zero of the incidence of locally acquired infection by human malaria parasites in a defined geographical area as a result of deliberate efforts. Elimination programmes require more technical malaria expertise than standard malaria control programmes, and require by national expertise in malaria epidemiology and entomology.

To achieve the objectives of malaria control and elimination programmes, appropriately planned and targeted delivery of essential malaria interventions is critical, including: diagnostic testing of all suspected malaria cases and prompt treatment of confirmed infections with effective artemisinin-based combination therapy (ACT); chemoprevention of malaria in pregnant women (Intermittent preventive treatment during pregnancy – IPTp), infants (Intermittent preventive treatment in infants – IPTi) and children (Seasonal malaria chemoprevention – SMC), where appropriate; and application of appropriate vector control interventions, particularly the use of insecticide-treated nets (ITNs/LLINs) and indoor residual spraying (IRS).

This training module on the epidemiological approach for malaria control has been developed to support the staff involved in the planning and management and in the monitoring and evaluation of malaria control and elimination programmes.

¹ WHO (2012). *World malaria report*. Geneva, World Health Organization. http://www.who.int/malaria/publications/world_malaria_report_2012/en/index.html

Abbreviations

ABER	Annual blood examination rate
ACT	Artemisinin-based combination therapy
ANC	Antenatal clinic
API	Annual parasite index
CFR	Case fatality rate
CSP	Circumsporozoite protein
DALY	Disability-adjusted life year
DHS	Demographic and health survey
EIR	Entomological inoculation rate
ELISA	Enzyme-linked immunosorbent assay
GIS	Geographical information system
HBI	Human blood index
IEC	Information, education and communication
IPT	Intermittent preventive treatment
IRS	Indoor residual spraying
ITN	Insecticide-treated mosquito nets
IVC	Integrated vector control
KAP	Knowledge, attitudes and practices
LLIN	Long-lasting insecticidal nets
MDA	Mass-drug administration
MICS	Multiple indicator cluster survey
MIS	Malaria indicator survey
NGO	nongovernmental organization
NMCP	National malaria control programme
PCR	Polymerase chain reaction
POPs	Persistent organic pollutants
PPOA	Preparedness plan of action
RBM	Roll Back Malaria
RCT	Randomized clinical trial
RDT	Rapid diagnostic test
SPR	Slide positivity rate
SMPH	Summary measures of population health
TPR	Test positivity rate
WHO	World Health Organization

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The revision of the module was made possible through the Russian Federation grant for malaria capacity development in Africa.

Development of the module

The content of the module is based on the current WHO guidelines and other evidence-based technical documents.

This training module are arranged in four parts. The main framework of each part was developed at different times, and has been evaluated and reviewed in various separate education programmes. The decision to combine these four parts into a training module was made through technical expert meetings held in 2008 and 2009.

The training module was updated under the guidance of technical experts representing malaria training and academic institutions, malaria researchers, country programme managers, and WHO regional offices, who guided the process of reviewing and updating the module. The process included the following steps:

- ▶ Three consultations of technical experts (7–9 April 2008; 14–16 October 2008 and 15–17 April 2009) were held to review the existing WHO training materials on the epidemiological approach for malaria control and elimination, and to identify areas for update in view of the development of new tools, technologies and strategies for malaria control and the changing disease epidemiology.
- ▶ Technical experts were commissioned to incorporate the recommended updates in the module.
- ▶ The revised module was then reviewed for content and completeness by the technical experts, the WHO technical staff and additional external experts in malaria epidemiology.
- ▶ The updated module was field-tested in several national and international courses.
- ▶ Based on feedback from field tests, and in consultation with technical experts, the text was finalized for publication.

Introduction

The planning and implementation of a malaria control programme must be based on epidemiological analysis and application of interventions suitable to specific local malaria situations. Health workers and all stakeholders involved need to have a sound knowledge of malaria epidemiology and prevention and control methods at national, district and peripheral levels. The aim of this training module is to improve participants' capacity in critical analysis and synthesis of key determinants of malaria epidemiology, and their interactions, as the basis for the selection of appropriate prevention and control interventions.

The module can be used for in-service training or as part of a basic course on malaria control. For the latter purpose, it is recommended to deliver this module after the case management and vector control modules have been covered. Prior knowledge of malaria control, including case management and vector control options, would be beneficial.

The module is in two parts, the *Guide for Participants* and the *Guide for Tutors*. The *Guide for Participants* covers basic concepts and information, and includes a series of exercises to be carried out by the participants. The *Guide for Tutors* outlines the main points to be learnt, and provides answers for the exercises which may be indicative in order to stimulate active learning.

The intended users of this training module

The module is designed for health professionals involved in the planning, implementing, and monitoring of malaria control and elimination programmes. They include medical officers, medical assistants, public health officers, environmental health officers, parasitologists and entomologists involved in malaria control and working either with a national programme or with an NGO.

Objectives

At the end of the training programme based on this module, participants should have acquired the skills and competence necessary to:

- ▶ Describe the significance of malaria as a public health problem;
- ▶ Examine, analyse and interpret malaria data from routine health information systems, surveillance and surveys;
- ▶ Explain the methods of acquiring evidence for a malaria control programme;
- ▶ Distinguish different stages of a malaria control programme, and the main strategies and indicators for each stage;
- ▶ Analyse the malaria situation in a designated geographic area utilizing available information from various data sources;
- ▶ Identify the appropriate control measures for specific epidemiological situations;
- ▶ Describe how to use early warning and detection systems, and to notify and verify malaria epidemics;

- ▶ Identify the most cost-effective malaria epidemic preventive and control options;
- ▶ Develop a preparedness plan of action for malaria epidemics.

The training approach used in this module emphasizes active involvement of participants through a series of group exercises and discussions to stimulate active learning instead of passive attendance at lectures given by a single person. The reasoning and deduction required in the epidemiological approach makes the subject highly suitable for this training method, but the success of the module will depend on active participation in the training activities proposed. The module requires some basic knowledge of malaria case management, parasitology, entomology, and vector control. However, the contents of the module are flexible enough to allow the emphasis to be adjusted according to the specific training needs.

Use of the *Guide for Participants*

This *Guide for Participants* consists of instructional materials and exercises designed to enable the participants to achieve the learning objectives of this module. The guide is divided into 21 Learning Units grouped in five parts: Part 1 – Introduction to basic epidemiology and statistics; Part 2 – Applied malaria epidemiology; Part 3 – Malaria surveillance, monitoring and evaluation; Part 4 – Prevention and control of malaria epidemics.

Each Learning Unit includes a series of exercises (and hints and partial solutions to some of them) to be completed either individually or as a group, as stipulated by the tutor. The discussions during small group work and during plenary sessions with the participation of facilitators and tutors will assist the learning process. The exercises to be carried out in small groups aim to stimulate discussions and exchange of experience between the participants (who will come from different countries/areas with different experiences), the facilitators and the tutor. Ideally participants need to acquire the skills and knowledge contained in each unit before progressing to the next learning unit.

During the course, the *Guide for Tutors* will be available only to the tutor and facilitators. Upon completion of the course/module, all participants should receive a copy of the *Guide for Tutors* so that they can use it for further training and reference.

The module aims at developing an approach rather than to convey a body of facts (though many facts may be conveyed in the process). Most factual information and details are referred to relevant guidelines and other resource materials.

A single document cannot fully cover such a wide and dynamic subject as malaria epidemiology. Prevention and control methods evolve over time. The module will be successful if it helps the participants to understand the interactions between multiple factors influencing malaria epidemiology thus preparing them to understand how new developments contribute to better prevention and control approaches.

The *Guide for Participants* can also be used in conjunction with the *Guide for Tutors* for individual study, but this module is best learned in group training.

Evaluation

Judging whether or not the course was successful involves answering the following questions:

- ▶ *How well did the participants learn?*
- ▶ *How did the participants view the training?*

Evaluation of the participants

Progress and achievements are evaluated by the tutor, the facilitators, and by the participants themselves. As well as general assessment during the group activities, a number of quizzes and problems solve are used. The evaluation is intended to provide a helpful opportunity for participants to measure their progress, and as a contribution to the learning process.

Whether this module is used for group training or individual learning, assessment of progress made by the trainee in gaining skills and competence in the subject matter is essential. This can be accomplished by means of a pre-test and a post-test, using a multiple-choice questionnaire (MCQ). The pre-test will be given before the trainee reads the *Guide for Participants*. The post-test will be administered after all the Learning Units have been completed. In MCQ tests, each question is provided with a list of possible answers from which one must be selected (i.e. considered to be correct). At the end of these sessions the tutor will analyse the results to identify topics that were not fully understood. The tutor may also explain to individual participants where mistakes were made and areas where improvement is needed.

The evaluation of the participant's progress also includes assessment of classroom, practical and field activities, degree of group participation, etc. including how the group work was presented in plenary sessions, and the degree of clarity.

Evaluation of the training by the participants

The entire training activity, including the organization and content of the course, the suitability of the learning methods, the quality of the teaching and training materials, and the competence of the tutors and facilitators will be assessed by the participants. This will be done through administration of a questionnaire, and at a plenary session after the post-test questionnaires have been completed. This evaluation will take place at the end of the training period in order to provide as much feedback from the participants as possible. All participants are encouraged to make suggestions for improvement on the part of the tutor and facilitators as well as in the content of the course and the training facilities. The objective of the plenary session is to ascertain whether an issue(s) raised by one or more persons has the consensus of the whole group, and to judge the importance of the issue(s) raised. Feedback provided through this exercise allows the tutor to assess how well the training has been received and to propose modifications that seem necessary for improving future programmes.

LEARNING UNIT 1

Introduction to epidemiology

PART 1

Learning Objectives:

by the end, participants should be able to...

- Provide a definition of *epidemiology*
- Define descriptive studies and describe their purpose
- Describe the major types of descriptive studies and their primary uses
- Describe the major types of analytic studies
- Provide a definition of *random error, bias, confounding and validity*

Epidemiology may be defined as the study of the distribution and determinants of health-related states or events (including disease) in human populations, and the application of this study to the control of diseases and other health problems. The word epidemiology is derived from the Greek words (*epi*) = among, (*dem*) = people, and (*logos*) = doctrine.

Different methods are used in carrying out an epidemiological investigation: surveillance and descriptive studies are used to study distribution; analytic studies are used to study determinants (causes, risk factors).

1.1 Types of epidemiological studies

1.1.1 Descriptive studies

Descriptive studies may be defined as studies that describe the patterns of disease occurrence by time, place, and person.

Uses of descriptive studies

In health planning and administration, descriptive studies and the analysis of their results allow planners and administrators to allocate resources efficiently.

They are also used to generate hypotheses, often providing first important clues about etiology.

Types of descriptive studies

▶ **Case reports or case series**

- ▶ These describe socio-demographic, behavioural and/or medical characteristics for one or more persons with a similar diagnosis (example: characteristics of children admitted to a hospital with cerebral malaria during a one-year period).
- ▶ They provide an important link between clinical medicine and epidemiology.
- ▶ They are often useful for generating hypotheses and examining new diseases. However, conclusions about etiology or risk factors cannot be made without having undertaken analytic studies (see below) to examine the expected frequency of exposure to the etiological or risk factor in a group that does not have the illness under investigation.

▶ **Ecological studies**

- ▶ These may compare disease frequencies among different groups during the same period, or compare disease frequencies in the same population at different points in time as a function of a particular exposure. For instance Cambodia-Thailand, the increase over time in the number of persons working as gem miners along the Cambodia-Thailand border parallels the rise in *P. falciparum* malaria cases during the same time period (an outcome).
- ▶ Ecological studies are usually quick and easy to perform, and can be undertaken with already available information, but great care is needed to avoid reaching conclusions based on spurious associations.
- ▶ Ecological studies cannot link exposure to outcome in a given individual.
- ▶ Descriptive studies constitute one of the first steps in outbreak investigation; and should always be undertaken before initiating further analytic studies.

1.1.2 Analytic studies

Analytic studies may be defined as studies used to test hypotheses concerning the relationship between a suspected risk factor and an outcome, and to measure the magnitude of the association effect, and its statistical significance. An analytic study always implies a comparison among two or more groups.

There are two main types of analytic studies: observational and interventional.

Observational studies

- ▶ Most analytic studies fall in this category.
 - ▶ There is no human intervention involved in assigning study groups; one simply observes the relationship between exposure and disease.
 - ▶ Observational studies are subject to many potential biases. Careful design and analysis should help avoid many of these biases.
 - ▶ There are three basic categories of observational studies: (i) cross-sectional studies (ii) case-control studies and (iii) cohort studies.
- ▶ **Cross-sectional studies (surveys)**
- ▶ These examine the relationship between a disease, or other health-related characteristic, and other variables of interest as they exist in a population at a given time. The presence or absence (or the level) of a characteristic is examined in each member of the study population or in a representative sample. These studies are used to obtain information that is not routinely available from surveillance or case series.
 - ▶ Cross-sectional studies provide no information on the temporal sequence of cause and effect. In surveys examining the association between an exposure and an outcome, both are measured simultaneously and it is often difficult to determine whether the exposure preceded the outcome or vice versa.
 - ▶ Surveys may simply describe characteristics or behaviours within a study population (e.g. parasitaemia, use of insecticide-treated nets); or may be used to examine potential risk factors (e.g. how those who receive vaccination differ from those who do not).
 - ▶ In general, surveys measure the situation at a given moment, i.e. prevalence, rather than the occurrence of new events, i.e. incidence (see Learning Unit 2).
 - ▶ Surveys need very large sample sizes for the study of rare diseases or rare events. Surveys are not recommended for the study of diseases with short duration.
- ▶ **Case control studies**
- ▶ Case-control studies proceed conceptually from outcome to exposure. They start with groups affected with the outcome – in the case of a disease, the affected (“ill”) group and the groups not affected (“well”), and retrospectively determine the rates of exposure to a risk factor(s) for each group.
 - ▶ In case-control studies, both exposure and disease are normally considered to have occurred prior to enrolment in the study.

- ▶ As an example for case-control study, the rate of use of mosquito nets can be compared between cases of malaria and healthy controls.

▶ Cohort studies¹

Cohort studies proceed conceptually from exposure to outcome, starting with exposed and unexposed groups and following them to see if the rates of occurrence of the outcome in the two groups differ.

- ▶ Study groups are identified by exposure status prior to the occurrence of the outcome of interest; both exposed and unexposed groups are then followed prospectively in an identical manner until they develop the disease (outcome) under study, until the study ends, or the subjects die or are lost to follow-up. Both cohorts should have similar characteristics except for the exposure under investigation.
- ▶ Cohort studies differ from interventional studies in that the investigator does not determine exposure status. This is determined by genetics or biology (sex, presence or absence of genetic disease, etc.), subject's choice (e.g. smoking behaviour, use of contraceptives, sexual behaviours, food consumption) or other circumstances (e.g. rural versus urban, socio-economic status).
- ▶ In some studies, called *retrospective cohort studies*, exposure and outcome both lie in the past (before enrolment). The main conceptual element to remember is that the retrospective cohort proceeds from exposure to disease.

Exercise 1.1

Match the type of study with one of the descriptions given:

1. Descriptive study	a. Subjects are randomized into exposed and unexposed groups and followed over time to compare rates of disease development
2. Analytic study	b. Start with exposed and unexposed groups and determine if rates of occurrence of outcome in the two groups differ
3. Case series	c. Start with cases of disease and unaffected controls and determine rates of exposure to risk factors in each group
4. Ecological study	d. Examines the relationship between a disease and other variables of interest in a population at a particular point in time
5. Cross-sectional study	e. Compares disease frequencies in a population at different points in time as a function of a particular exposure
6. Case-control study	f. Describes characteristics of persons with a similar diagnosis
7. Cohort study	g. Test hypotheses concerning the relationship between suspected risk factor and an outcome
8. Interventional study	h. Describes patterns of disease occurrence by time, place, and person

Interventional studies

- ▶ The person conducting the study randomizes the subjects into exposed and unexposed groups and follows them over time to compare their rates of disease (outcome) development. Examples may include trials of the efficacy of a new drug compared with the efficacy of the drug currently in use; or assessment of the efficacy of insecticide-treated mosquito nets compared with non-treated nets.

¹ A cohort can be defined as a designated group of people who have had a common experience vis-a-vis exposure, and are then followed up or traced over a period of time.

- ▶ Randomization helps ensure comparability of the groups and avoids many of the biases inherent in non-interventional studies; for this reason interventional studies have been considered as a widely accepted “gold-standard”.
- ▶ Interventional studies are nevertheless expensive. They may take a long time to carry out, often present complex ethical problems,¹ or may simply not be feasible (e.g. randomized trials of the health benefits of breastfeeding). The results obtained may not be applicable to routine programme conditions.

1.2 The logical sequence of epidemiological studies

In epidemiological research, the current state of knowledge often determines the most logical study design. There is usually a progression from hypothesis-generating to hypothesis-testing studies. For example, hypotheses are often generated by methods such as surveillance, case reports, case series, or ecological studies. These hypotheses are then tested using data from experience, from previous cross-sectional studies, from case-control studies, or from retrospective cohort studies, which can be done relatively quickly and cheaply. If these studies lend support to the hypothesis, a prospective cohort study may be undertaken. Finally, in some situations, a randomized clinical trial may be appropriate.

The flowchart (Fig. 1.1) illustrates the application of the various types of primary studies. In all types of study, hypothesis-setting must precede analysis.

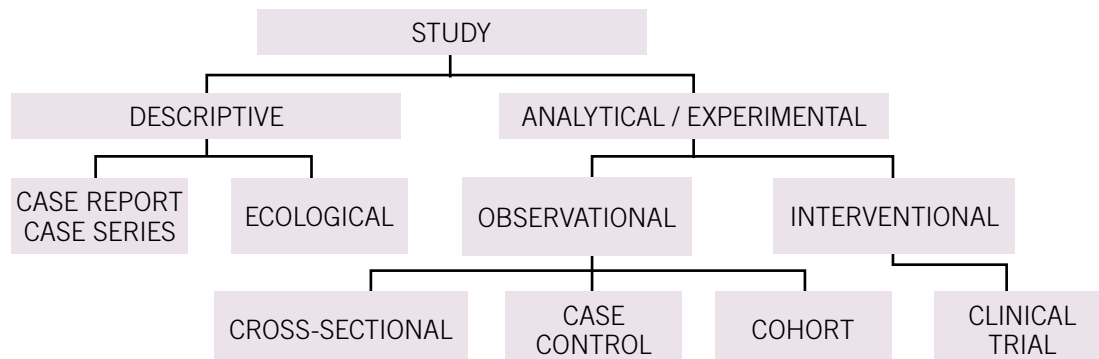


Figure 1.1 Types of primary epidemiological studies

1.2.1 Secondary research

In secondary research, the unit of study is the body of previous studies on the subject. If a secondary study has been conducted with (i) a systematic search, (ii) appraisal of the gathered studies and (iii) a systematic analysis, it is termed a ‘Systematic Review’. The statistical analysis of the systematic review would be a ‘Meta-Analysis’. The evidence gathered is graded to assess the strength of the evidence. Among all types of studies, including primary and secondary, the results obtained from Systematic Reviews, especially on randomized clinical trials, provide the highest level of evidence.

¹ The ethical problems relative to epidemiological studies are addressed in *International Ethical Guidelines for Epidemiological Studies* prepared by Council for International Organizations of Medical Sciences (CIOMS) in collaboration with the World Health Organization, Geneva, 2008.

1.3 Potential errors in epidemiological studies

1.3.1 Random error

Random error is the divergence, due to chance alone, of an observation on a sample¹ from the true population value, leading to lack of precision in the measurement of an association. There are three major sources of random error: individual/biological variation, sampling error, and measurement error.

Random error can be minimized but can never be completely eliminated since only a sample of the population can be studied; individual variation always occurs and no measurement is perfectly accurate. Random error can be reduced by careful measurement of exposure and outcome, appropriate selection of study participants and enrolling a sample of sufficient size.

1.3.2 Systematic error (bias)

Bias occurs when there is a tendency to produce results that differ in a systematic manner from the true values. A study with only small systematic bias is said to have high accuracy. Bias (or systematic error) may lead to over- or underestimation of the strength of an association.² The sources of bias in epidemiology are many and over 30 specific types of bias have been identified. The main biases are:

- ▶ Selection bias
- ▶ Information bias
- ▶ Bias due to confounding.

Selection bias

Selection bias occurs when there is a systematic difference between the characteristics of the people enrolled for a study and the characteristics of the source population.

Information bias (also called measurement bias)

Information bias occurs when there are quality (accuracy) problems in the collection, recording, coding or analysis of data among comparison groups. Interviewers might, for example, interview the cases with more diligence than the controls, or a person with a disease may recall previous exposures better than persons who are healthy (this type of bias is called *recall bias* which is a form of *information bias*).

From the practical point of view, often there is not enough information to correct for selection bias or information bias. It is best to think about possible sources of bias at the time of the study design so that they can be minimized or avoided.

Confounding

In a study of the association between exposure to a cause (or risk factor or protecting factor) and the occurrence of the disease, confounding can occur when another factor exists in the

¹ A sample is defined as a selected subset of a population. Sampling is the process of selecting a number of subjects from all the subjects of a population.

² Statistical dependence among two or more variables, which are said to be associated if they occur together more frequently than would be expected by chance. Statistical tests permit calculation of the association.

study population and is associated both with the disease and the initial factor being studied. A problem arises if this second extraneous factor is unequally distributed among the exposure subgroups. Confounding occurs when the effects of two protective or risk factors have not been separated and it is therefore incorrectly concluded that the effect is due to one variable rather than the other. For instance, in a study of the association between tobacco smoking and lung cancer, age would be a confounding factor if the average ages of the non-smoking and smoking groups in the study population were very different, since lung cancer incidence increases with age.

Another example of confounding is shown in Figure 1.2. A study of the relationship between income and malaria is illustrated by the top line of Figure 1.2. It is possible that income is associated with the risk of malaria. However it is known that income is also associated with the use of bednets to reduce the risk of malaria. The relationship between income and malaria is thus affected by the relationship between bednets and income. In other words, bednets confound the association between income and malaria.

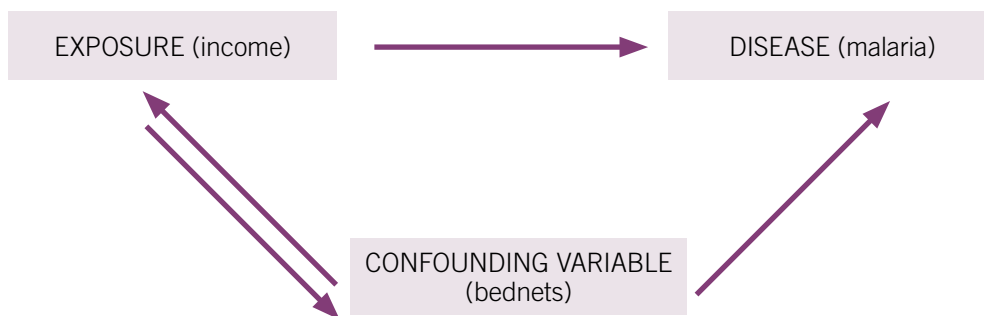


Figure 1.2 Confounding – bednets, income and malaria

A confounding factor is an alternative explanation for presence of the outcome, other than the exposure of interest, and this factor should not be an intermediate in the casual pathway from exposure to the outcome. Supposing that income reduces the risk of malaria through the use of bednets, the use of bednets is in the causal pathway of the effect of income on malaria, and consequently the use of bednets should not be considered as a confounding factor.

Confounding can be controlled for in the analysis if appropriate information has been collected during the study on potential confounding variables and if each factor is properly analysed and interpreted.

Exercise 1.2

Match the type of potential study error with one of the examples given.

Study errors	Examples
1. Random error	a. Studying the relationship between bednet use and occurrence of malaria if age is associated with both use of benets and susceptibility for symptomatic malaria infection
2. Selection bias	b. Collecting information regarding malaria treatment through a household survey conducted months after the treatment was received
3. Information bias	c. Assessing outcomes of uncomplicated malaria among patients admitted to a hospital
4. Confounding	d. Large divergence of a study result from the true value due to a small study sample size

1.4 Validity and reliability

Validity is an expression of the degree to which a test is capable of measuring what it is intended to measure. A study is valid if its results correspond to the truth; there should be no systematic error, and the random error should be as small as possible. Figure 1.3 illustrates the relationship between the true value and the measured values for low and high validity and reliability (or repeatability).

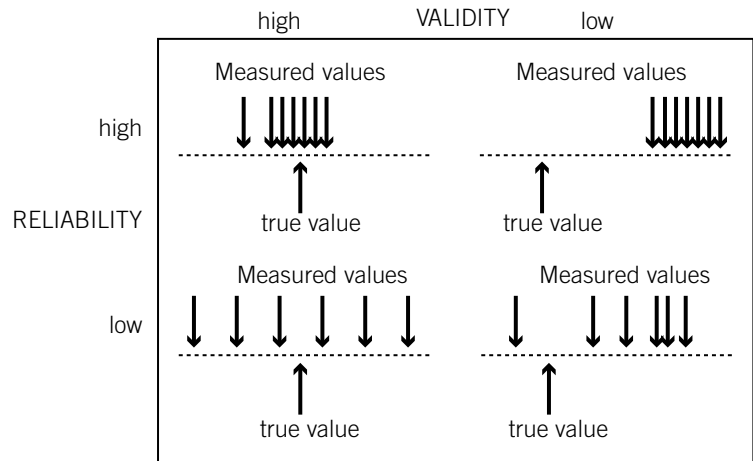


Figure 1.3 Validity and reliability

With low reliability but high validity the measured values are spread out, but the average of the measured values is close to the true value.

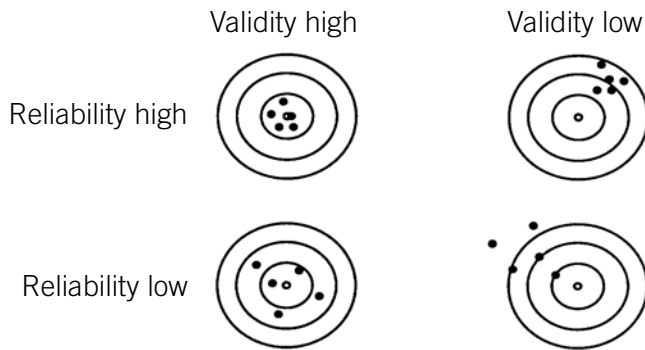


Figure 1.4 Validity and reliability

High reliability does not ensure validity since the measurements may all be far from the true value.

Figure 1.4 shows the same concept in a different graphical way: the centre of the target corresponds to the true population value; individual target shots are individually measured from 5 samples in each example.

Exercise 1.3

A well done study with a small systematic error (minimal bias or confounding) but a large random error could be described as having

- a) High validity and low reliability
- b) Low validity and high reliability

LEARNING UNIT 2

Ratios, proportions and rates

Learning Objectives:

by the end, participants should be able to...

- Define the terms ratio, proportion and rate
- Differentiate between incidence rate and prevalence rate, and give examples of their use
- Calculate rates, ratios, and proportions using appropriate numerators, denominators and constants
- Apply the concepts of relative risk and risk differences

Depending on who is using the data and for what purposes, the data may be presented as **raw data**, **proportion**, **rate**, and **ratio**.

2.1 Raw data

Raw data may be defined as the entire set of data collected in a study, before any rounding, editing or statistical organization. They are of use primarily in helping health planners and administrators determine health care needs. For example, a health planner may want to know the **number** of cases of malaria seen in the last year so that an estimate can be made of the quantity of antimalarial drugs to order for the next year. He/she may also want to know approximately **how many** births take place each year so as to staff the obstetrics services appropriately.

Any variable can be considered as one of two types: discrete or continuous.

Discrete variables have values that can fall into only a limited number of categories without intermediate levels (e.g. sex – M/F; survival – dead or alive; exposure status – Yes/No; race, marital status...). When the possible categories have a natural order of progression, the variables are called *ordinal* (e.g. improvement in mobility, or level of current cigarette smoking – none, light, moderate, heavy). Some quantitative data can also be discrete, e.g. parity (it is not possible to have a fraction of a live birth).

Continuous variables can assume all possible values along a continuum within a specified range (e.g. height, weight, blood pressure...). They are limited only by the accuracy and precision of measurement.

2.2 Proportion

Proportion is also a measure that is of use primarily to planners and administrators. It is defined as the number of events among all possible events, usually expressed as a percentage. The formula is $(x/y)k$, where x is the number of individuals or events in a category and y is the total number of events or individuals in the data set and k is a constant, in this case 100.

Example 1

Of the 120 cases of malaria admitted to hospital X last year, 80 were children. The proportion (percentage) of children among the cases is $(80 / 120) \times 100$ or 66.7%.

It may be useful for the hospital administrator to know that 67% (two-thirds) of malaria hospitalizations occur in the paediatric age group and 33% (one-third) occur in adults. The number of beds and staffing of various categories required to take care of malaria patients as well as commodities (diagnostic testing and medicines) can be planned.

2.3 Rate

For the public health practitioner interested in determining who is at risk and monitoring the success of prevention efforts, the most useful measure is a rate. Rates measure the relative frequency of cases in a population *during a specified period of time*. The general formula is the same as for proportions, i.e. $(x/y)k$, although here x , y , and k take on different meanings. Rates measure incidence (new cases) within a specified period.

An **incidence rate**¹ is the occurrence of new cases of a disease within a defined population at risk during a specified period of time. In this situation:

- ▶ x is the number of new cases in the defined population which had its onset during a specified period of time
- ▶ y is the person time at risk. Typically the mid-year population of a defined geographic area is used to determine person time at risk over a one-year period.
- ▶ k , a constant, depends on convention or is the value such that the smallest rate in the data set has at least one digit to the left of the decimal point.

An **attack rate** is a variant of an incidence rate where shorter periods at risk (e.g. weekly or monthly) are used as denominator; it is typically measured during an outbreak. In practice, the attack rate will only differ from the incidence rate if there is a large proportion of persons in the population who are not at risk (for instance, children who have been successfully vaccinated against measles may be considered not to be at risk for the disease).

In a **prevalence rate**, x is the number of existing cases, new and old, in a defined population during a specified period (period prevalence) or at a given point in time (point prevalence). In reality prevalence is a proportion because it does not have time dimension. However, it is also commonly called “prevalence rate”. Another form of prevalence is “period prevalence” which can estimate old and new cases during a specific period of time. Whenever the term “prevalence” is used without specification of “point” or “period”, point prevalence should be assumed.

Example 1

In July, 3 new cases of malaria were detected in a village. There were already 10 people in the village who had the disease, but two successfully completed a course of therapy during the month and were considered cured. The population of the village was 2600. In this case:

- The incidence rate is:
 $(3 / 2600) \times 1000$ or 1.2 per 1000 persons per month²
- The period prevalence rate is:
 $[(3 + 10) / 2600] \times 100 = 0.5\%$
- The point prevalence as of 31 July is:
 $[(3 + 10 - 2) / 2600] = 0.4\%$

¹ In more rigorous definition, the denominator of “incidence rate” is person-time (people in month, year, etc). Therefore, an incidence rate shows how many cases (nominator) had occurred during in a certain person-time (denominator). In the same literature, the incidence rate which is presented in this module is considered “cumulative incidence rate”. However, in the day by day use of the incidence rate such distinction is not serious.

² Strictly speaking, the attack rate is the number of cases occurring during July in the population at risk (excluding those already affected), i.e. $[3 / (2600 - 10) \times 1000] = 1.2$ per 1000 per month, equal to the incidence rate. The Incidence Rate = $[3 / (2600 \text{ total} - (10 \text{ affected} - 2 \text{ cured and therefore sensitive again}))]$ i.e. $3 / 2592$. In practice, these requirements are often neglected where they make little difference.

2.4 Ratio

A **ratio** is an expression of the relative frequency of the occurrence of some event compared to some other event, for example, the ratio of male to female cases. Here, the formula is also $(x/y)k$, where:

- ▶ x is the number of events or persons having a specified attribute
- ▶ y is the number of events or persons having an attribute different from those of the event or person in x
- ▶ k is 1

In this situation, the ratio is often expressed as $x:y$, with y usually equal to 1 (y can be made equal to 1 by dividing both x and y by y).

Example 1

If there are 15 male cases (x) and 5 female cases (y) of malaria, the male:female ratio can be calculated as 3:1 by dividing both values by 5 (y).

Ratios are often used when it is difficult to ascertain the population denominator for a disease or a condition correctly. One example is the abortion ratio, which is the number of abortions divided by the number of live births during the same time period. The formula remains $(x/y)k$ with k determined either by convention or by the value that gives at least one digit to the left of the decimal point.

2.5 Relative risk and risk difference

Rates for two or more groups (males/females, age categories, educational levels, presence or absence of some behaviour) are often compared by dividing one by the other or by subtracting one from the other.

If they are divided, the result is called a **rate ratio** or **relative risk**. The formula is simply: **rate a/rate b**, where a is the incidence in the group exposed to the factor under investigation and b the incidence rate in the group that is not exposed. The **rate ratio** or **relative risk** may be used to identify possible causal risk factors and identify markers that may be useful in targeting services. A ratio of 1 means that there is no difference in outcome between the exposed and the unexposed groups (if the outcome is an incidence rate, this will be the same for both exposed and unexposed groups). A ratio >1 suggests that the characteristic (exposure) is a risk factor; a ratio of <1 suggests a protective effect.

Example 1

People who go into the forest have a malaria incidence rate of 10 / 1000 per month, while people who do not go into the forest have a malaria incidence rate of 1 / 1000 per month. The risk ratio is $(10 / 1000) / (1 / 1000) = 10$. Thus, people who go into the forest are 10 times more likely to contract malaria than those who do not.

Example 2

People who use mosquito nets have a malaria incidence rate of 2/1000 per month; people who do not use nets have a rate of 8/1000 for the same period. The ratio of the risks is $(2/1000)/(8/1000) = 0.25$. Thus, those who use nets incur a lower rate of malaria incidence than those who do not (this is called the protective effect and is calculated as $1 - \text{the relative risk}$ or $1 - 0.25 = 0.75$). This is roughly equivalent to saying that those who use bednets in these circumstances will have 75% fewer episodes of malaria compared to those who do not use a bednet.

Example 3

People who are illiterate have a malaria incidence rate of 9/1000, while those who are literate have a rate of 3/1000 for the same period. The ratio of the risks is 3. Thus, those who are illiterate have three times more risk of malaria than those who are literate. Here, literacy is a marker rather than a causal risk factor. Illiteracy does not cause malaria, but those who are illiterate are at risk for other reasons, such as living conditions, occupation, etc.

Rates may also be compared by subtracting one from the other. The resulting value is known as the **(absolute) risk difference**. This is calculated as: **rate a** – **rate b**. This represents the absolute differences in risk between the exposed and the unexposed groups. If disease incidence is the same in the exposed and in the unexposed group, the value of the absolute risk difference will be zero. If there is a causal relationship between the characteristics being studied and the outcome, the risk difference provides information on the amount of disease that could be prevented if the characteristic could be eliminated.

Example 4

Those going into the forest have a malaria incidence rate of 10/1000 per month; those who do not go into the forest have a malaria incidence rate of 1/1000 per month. The risk difference is $(10/1000 - 1/1000 = 9/1000)$. The absolute difference between the groups is 9 per 1000. Because there is a presumably causal relationship, it could be concluded that if people stopped going into the forest, the malaria rate would be reduced by as much as 9/1000, to 1/1000.

Caution is required in drawing such conclusions since often people will have more than one characteristic (exposure) that puts them at risk for a disease; eliminating only one behaviour or characteristic usually does not fully solve the problem. Caution is required if the characteristic is a marker rather than a causative factor; changing a marker without changing the causal factors associated with it is unlikely to result in a lower disease rate.

A note on rounding

The procedure for finding the last digit of a measure is called “rounding”. There are three general rules for rounding:

Rule 1: if the digit *beyond the last digit* to be reported is less than 5, drop everything after the last digit to be reported. Rounding to one decimal place, the number 5.3467 becomes 5.3.

Rule 2: if the digit after the last digit to be reported is greater than 5, increase the last digit to be reported by one. The number 5.798 becomes 5.8 when rounding to one digit.

Rule 3: to prevent rounding bias, if the last significant digit is exactly 5, it is general practice to round to the integer preceding the 5, and rounding up if this is an odd integer. Thus the number 3.55 (rounded to one digit) would be 3.6 (rounding up) and the number 6.450 would round to 6.4 (rounding down when rounding to one decimal).

It is also possible to round by taking the nearest whole number: 66.7% may be rounded to 67%.

Exercise 2.1

The following table 2.1 presents malaria morbidity data for Province X in Africa, which has received a large number of immigrants in recent years:

Table 2.1 Number of malaria cases, Province X, 2001–2005

YEAR	CASES	POPULATION
2001	30 858	492 810
2002	36 602	585 540
2003	46 172	738 870
2004	56 439	891 280
2005	68 392	1 044 620

- Describe in words the trend in the number of cases.
- Calculate the incidence rate of malaria cases/100 population per year and describe the trend in words.
- Compare the trend in the number of cases and the trend in rates. How do you explain your observations?
- Which is the more appropriate measure to monitor changes over time in the area?

Exercise 2.2

The adjoining Province Z (population 169 250) had 15 233 cases of malaria in 2005.

- Which province had the higher incidence rate in 2005?
- In your opinion, which area should receive intensified control efforts and why?

Exercise 2.3

A survey among children aged < 5 years in Region A shows that 450 out of 950 children have malaria parasites in their blood.

- What is the parasite rate?
- Is this the incidence rate or the prevalence? Explain your answer.

Exercise 2.4

In 2001, 49 140 malaria cases occurred among males and the remaining 23 250 occurred among females.

- What is the ratio of male:female cases?
- What percentage of the total cases occurred in males? What percentage in females?

Exercise 2.5

At one of the health centres in Province X (Table 2.2), the age breakdown of malaria cases was as follows:

Table 2.2 Age breakdown of malaria cases, Province X, 2006

AGE	CASES	% OF ALL CASES	POPULATION AT RISK	INCIDENCE RATE/100/year
0–11 months	71	2.4	1980	3.6
1–4 years	645	21.9	7920	8.1
5–14 years	698	23.7	12 300	5.7
≥ 15 years	1528	51.9	27 300	5.6
TOTAL	2942	100.0	49 500	(5.1)

- Which age group accounts for the biggest percentage of all cases?
- Which age group is at greatest risk of contracting malaria?
- Why are the answers to questions a) and b) different?

Exercise 2.6

A study shows that the incidence rate of malaria is 10/1000 population per week among Thai villagers who work as gem miners and go into the forests, whereas this rate is 2/1000 population per week among farmers from the same villages.

- Calculate the relative risk of malaria among gem miners
- Interpret your findings in words
- Calculate the risk difference between the gem miners and the farmers
- Interpret your findings in words

LEARNING UNIT 3

Data presentation: tables, graphs and charts

Learning Objectives:

by the end, participants should be able to...

- List the features of good tables, graphs, and charts
- Plot and label a series of tables, graphs and charts correctly from raw data
- List the uses for semi-logarithmic presentation

3.1 Tables

A table may be defined as a set of data arranged in rows and columns designed to present the frequency with which some event occurs in different categories or subdivisions of a variable, as can be seen from Table 3.1.

3.1.1 Guidelines for developing tables

- ▶ Keep them simple: better 2 or 3 small tables than a single large table
- ▶ No more than 3 variables should be used in a table
- ▶ All tables should be self-explanatory
- ▶ Clear and concise title telling **what, where, and when**
- ▶ Rows and columns must be clearly labelled
- ▶ Units of measurement must be stated
- ▶ Codes, abbreviations, and symbols must be footnoted
- ▶ Totals must be shown
- ▶ If data are not original, their source must be footnoted

Rows and columns to be clearly labelled

Clear and concise title telling what, where and when

Table 3.1 Proportion of malaria cases in relation to total inpatients, State Z., 2001–2005

YEAR	All patients	Malaria patients	%
2001	136 289	16 946	12.4
2002	114 327	18 117	15.8
2003	101 050	13 821	13.7
2004	79 485	10 757	13.5
2005	76 403	11 533	15.1

Data collected from 24 district hospitals

Footnote to enhance clarity

3.2 Graphs

A graph may be defined as a method of showing quantitative data using a drawing on a coordinate system. The most common form is a rectangular coordinate, with two sets of lines at right angles to each other and divided into equal intervals. The x axis by convention is the horizontal axis, and the y axis is the vertical one.

Graphs are used for continuous variables such as time, parasite counts, etc. Charts rather than graphs are used for non-continuous variables such as sex or educational level.

The variable (age, year, etc.) is usually classified along the x axis; the y axis is the axis generally used for measures of frequency. See Figure 3.1.

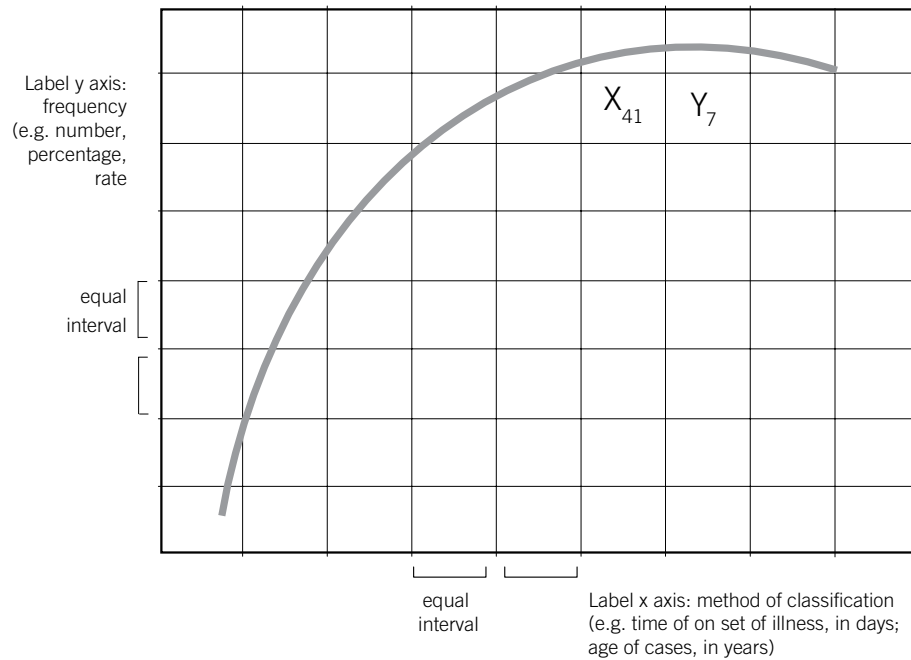


Figure 3.1 General graph with descriptive annotation

3.2.1 Guidelines for preparing graphs

- ▶ Keep them simple and do not try to put in too much information.
- ▶ Every graph should be self-explanatory.
- ▶ Avoid interrupting the axis (scale breaks) if at all possible.
- ▶ Title should be clear and concise.
- ▶ Axes clearly labelled.
- ▶ Units on the x and y axis clearly specified.
- ▶ Equal quantities must be represented by equal intervals on an axis; on the x axis, categories covering 10 years, for example, should be twice as long as categories covering 5 years.

3.2.2 Types of graphs

The graph must have enough information to be clear without further explanation.

Charts

The most common forms are bar charts, pie charts and geographic coordinate charts. Applications are given here for 620 patients, classified according to 4 age categories (<1, 1–5, 6–10 and 11–15 years). In the <1 group there were 250 patients; in the 1–5 group there were 325; in the 6–10 group there were 30; and in the 11–15 group 15 patients.

Pie charts

This is defined as a circular chart most frequently used to show percentage distributions, using wedge-shaped portions proportionate to the size of the category. The convention is to start at the 12:00 clock position and arrange “slices” anticlockwise in order of decreasing size. See Figure 3.2.

Example

The pie below shows the treatment profile of 100 paediatric malaria patients prior to admission to hospital A in Province Z.

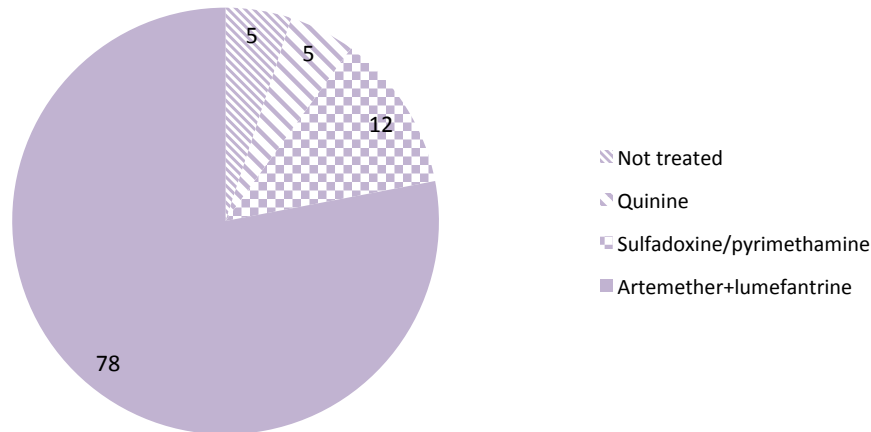


Figure 3.2 Treatment of paediatric malaria patients prior to hospitalization, Hospital A in Province Z, January–December 2001

Bar charts

Bar charts have cells, all of which have the same column width whatever the size of the category. The bars may be arranged vertically or horizontally. By convention, there is always a space between the bars. Bar charts are easier to use when categories are of unequal size; they *must* be used if categories are not continuous (i.e. sex, marital status, etc.), as is the case in Figure 3.3. Figure 3.4 is a bar chart of continuous data (age) with categories of unequal importance.

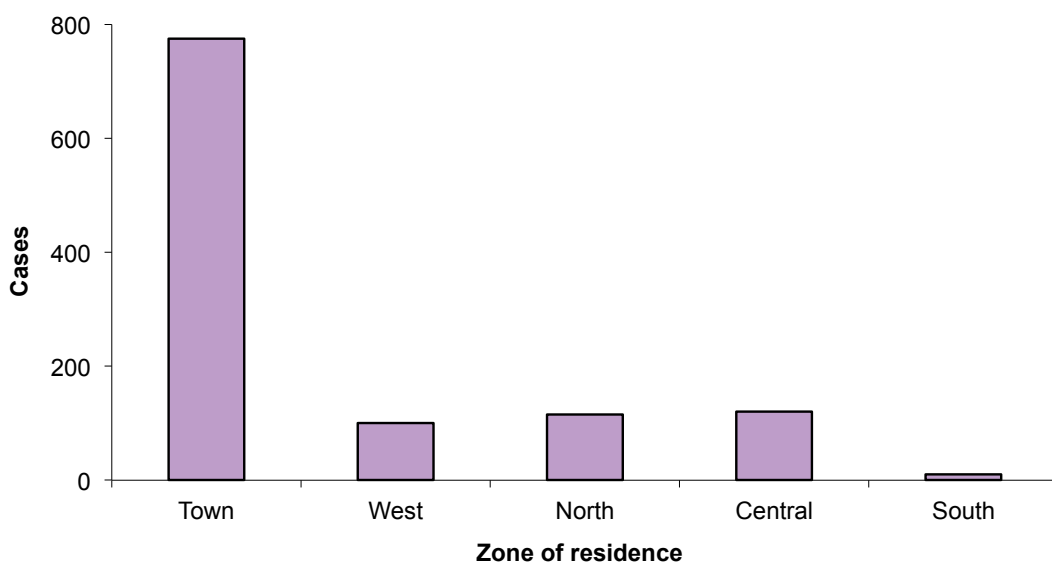


Figure 3.3 Cases of malaria in hospitalized paediatric patients in hospital A, town B, January–March 2001

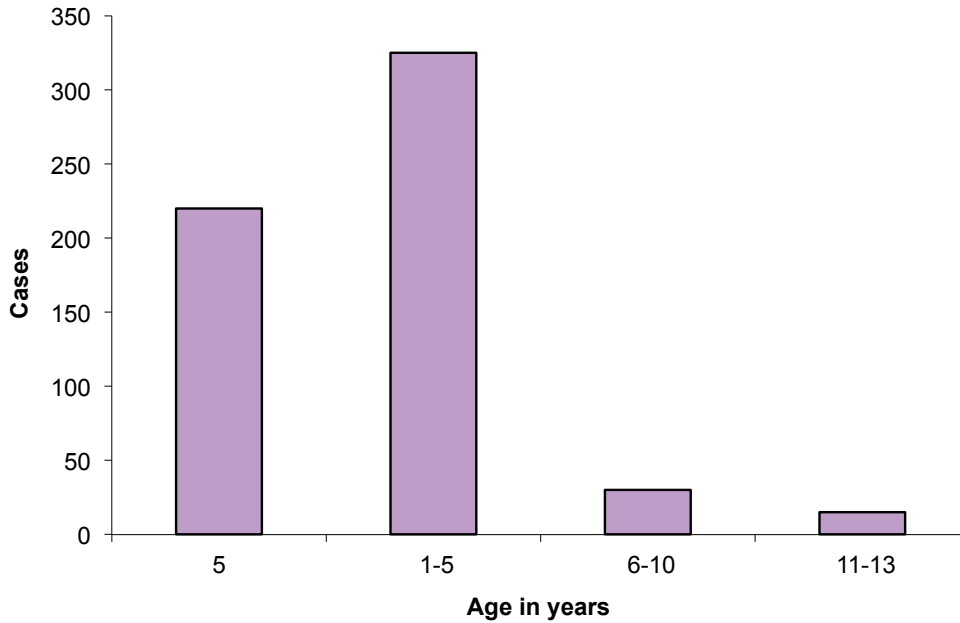


Figure 3.4 Age distribution of hospitalized paediatric patients in hospital A, town B, January–March 2001

Histogram

This may be defined as a bar graph of the frequency distribution of a **continuous** quantitative variable in which the width of the bar is proportional to the unit of value of the variable on the *x* axis and the height of the bar is proportional to the unit of value of frequency on the *y* axis. By convention, there is no space between the bars, and no scale breaks are allowed on the *y* axis (Fig. 3.5).

Histograms can be used to plot the number of cases or percentages on the *y* axis, but are generally not used to plot rates.

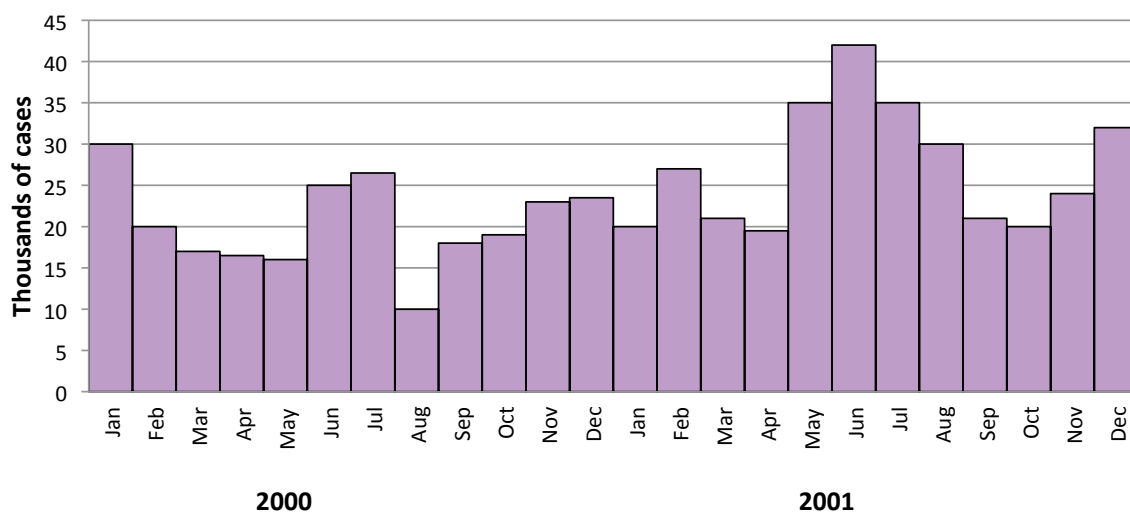


Figure 3.5 Monthly distribution of malaria cases reported by PHC units and health centres, State Z, 2000–2001

Line graphs

A line graph may be defined as a graph of the frequency distribution of a continuous variable created by plotting the frequency of a category on the y axis at the midpoint of the category on the x axis. Values for each category are connected by a continuous line.

If a graph is to contain the frequency distribution by category for more than one group (e.g. the frequency of cases over a 10-year period for males and females), it may be advisable to use line graphs.

Line graphs may be used to plot number of cases and percentages; they are the method of choice for plotting rates. See Figures 3.6 and 3.7.

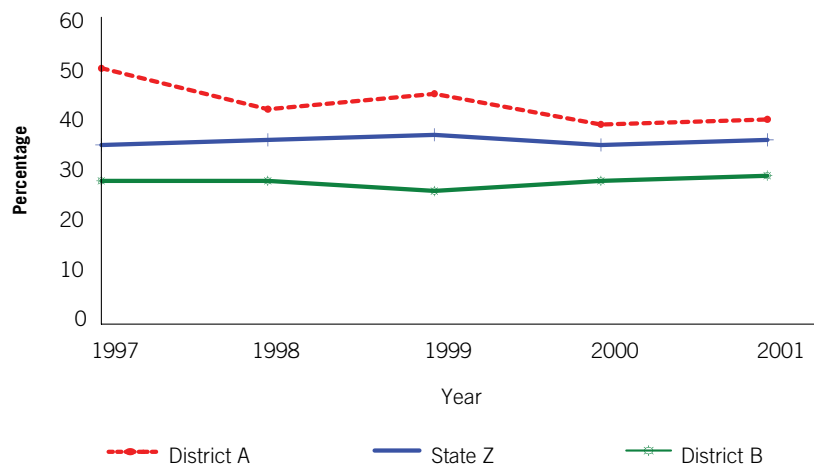


Figure 3.6 Rate of positivity for malaria blood films examined at hospitals level, State Z, 1997–2001

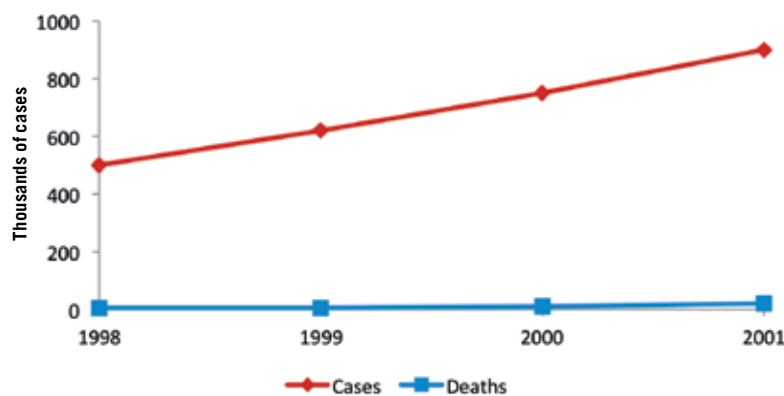


Figure 3.7 Malaria cases and deaths officially notified in health facilities run by physicians, Country Y, 1998–2001

In Figure 3.7, it is difficult to show the variations in deaths over time. This can be easily shown by using two vertical axes: the primary vertical axis for the malaria cases and the secondary vertical axis for the malaria deaths as shown in Figure 3.8.

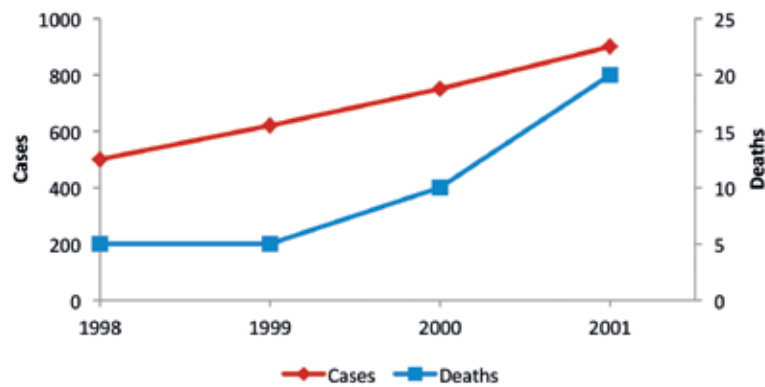


Figure 3.8 Malaria cases and deaths officially notified in health facilities run by physicians, Country Y, 1998–2001

Geographic coordinate chart

This is a map where areas are shaded geographically according to the incidence or prevalence rate of the disease considered. See Figures 3.9.

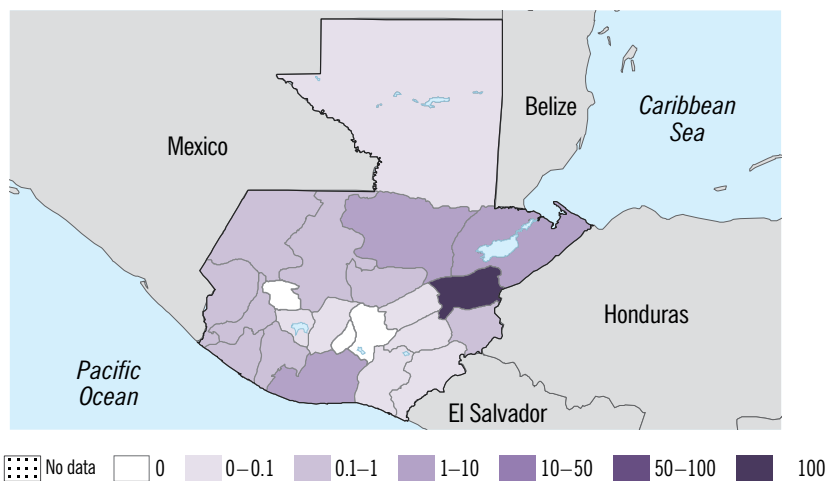


Figure 3.9 Distribution of confirmed malaria cases (per 1000 population), 2011 Guatemala

Semi-logarithmic graph

This may be defined as a graph in which the y axis is measured in logarithms of units and x axis is measured in arithmetic units. These graphs are generally used to:

- ▶ Plot data when the range is too great to present meaningfully on an arithmetic graph.
- ▶ Examine relative rather than absolute changes over time.

If a line plotted on a semi-logarithmic graph is straight, it indicates a constant rate of change, and the slope allows direct measurement of the rate of change. Two or more lines that follow parallel paths have equal rates of change. See Figure 3.10, which represents a logarithmic plot of the data shown in Figure 3.7 and shows more clearly the trends and relative rates of change for cases and deaths.

The reason to use a log-scale is normally to obtain the relative change over time. However, this is of course also the major limitation in the sense that a very steep increase in absolute counts does not look very steep using a log-scale. One can thus easily underestimate the increase, or decline.

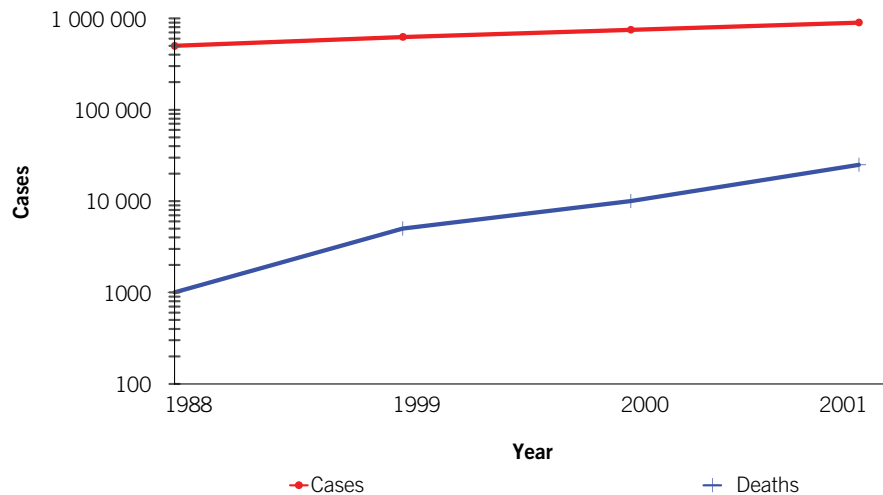


Figure 3.10 Malaria cases and deaths officially notified in health facilities run by physicians, in country Y, 1998–2001

Note: With the generalization of computer graphics software programmes, charts, maps, graphs etc are increasingly prepared on the computer; the use of semi-log paper is declining.

Box plot

In descriptive statistics, a box plot (also known as a box-and-whisker diagram or plot) is a convenient way of graphically showing data through their descriptive statistics: sample minimum, the lower quartile, the median, the upper quartile, and sample maximum. Note that the box plots can be drawn vertically or horizontally, depending on whether you display the descriptive statistics along a vertical or a horizontal axis.

Example: Admissions of malaria patients of Hospitals A and B are presented below). Prepare a box plot for the data.

Months	Hospital A	Hospital B
January	321	465
February	235	399
March	202	345
April	304	456
May	621	746
June	600	802
July	590	845
August	431	578
September	381	503
October	142	478
November	98	389
December	96	390

The calculated sample minimum, lower quartile (25% percentile), median, upper quartile (75% percentile), and sample maximum and box plot graph (Fig. 3.11) of malaria admissions in Hospitals A and B are presented below.

Parameters	Summary Range	
	Hospital A	Hospital B
Min	96	345
25th percentile	218.5	427.5
Median	321	478
75th Percentile	510.5	662
Max	621	845

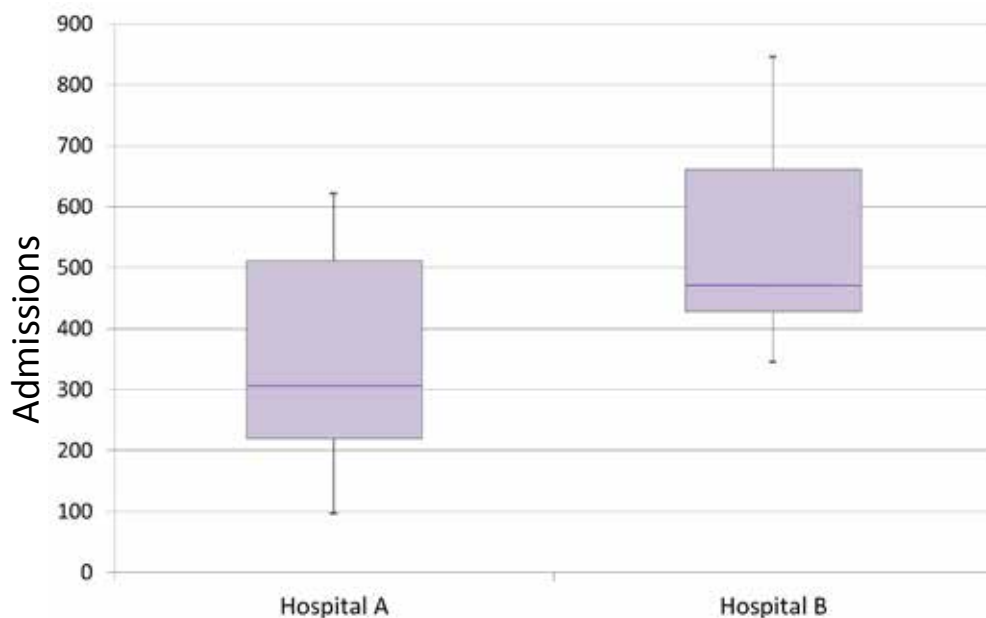


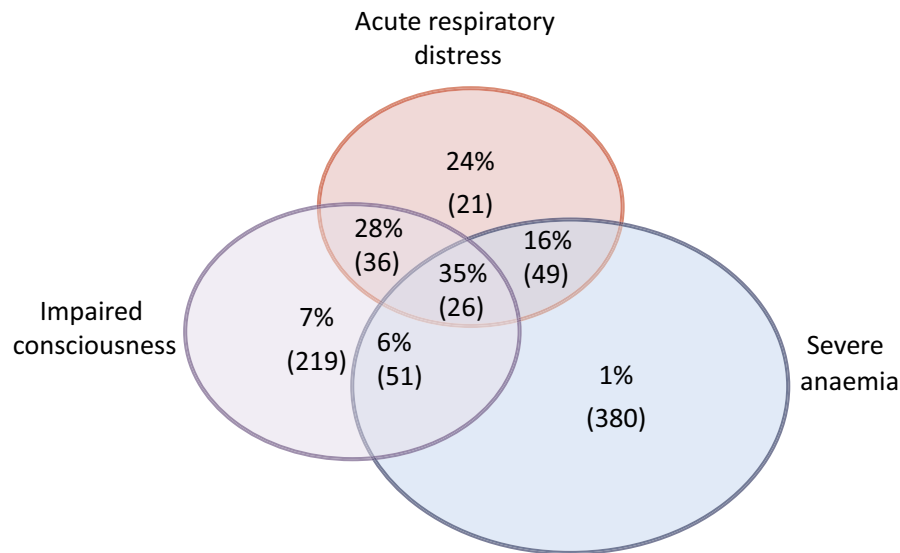
Figure 3.11 Malaria inpatients in Hospitals A and B for 12 months period.

Venn diagram

Venn Diagrams are pictorial ways of representing interactions among sets to display information that can be read easily. Each set of given information is designated a circle. Interactions between the sets are shown in the circles' intersections; items common to both sets are found in the intersection whereas other items are found outside the intersection. Figure 13.12 shows case fatality rates (with respective sample size) among children with different clinical presentations of severe malaria conditions admitted between 1989 to 1991 in Kilifi District hospital in Kenya. The figure clearly presents the case fatality rates among children with the following severe conditions:

- ▶ severe anaemia
- ▶ impaired consciousness
- ▶ acute respiratory distress

- ▶ severe anaemia and acute respiratory distress
- ▶ severe anaemia and impaired consciousness
- ▶ acute respiratory distress and impaired consciousness
- ▶ acute respiratory distress, severe anaemia and impaired consciousness



Source: Marsh et al., NEJM 332, 1399-1404, 1995

Figure 3.12 Case fatality rate (sample size) among Kenyan children with severe malaria admitted in 2005

Exercises

The government of a large Asian country started a national programme 5 years ago to reduce the morbidity and mortality from 3 major childhood diseases. Each District Medical Office (DMO) is now being asked to evaluate the effectiveness of this programme in their district and to learn as much as possible about who remains at risk for developing these diseases. The DMO of District W has decided that the best way to begin is to use the surveillance data from the past 5 years to examine the trends in the incidence of these three diseases over that period. The surveillance data provide the number of cases and deaths by month for each disease and are broken down by broad age categories, including one for children <5 years of age.

The following exercises should be carried out in small groups.

Exercise 3.1

- a. What are the advantages and disadvantages of using surveillance data to monitor trends for the 3 diseases?
- b. What other sources of data might the DMO consider to gather information on trends in the 3 diseases?

Exercise 3.2

- a. The DMO has the number of cases and deaths for children under 5 for each disease.
- b. What other number(s) does the DMO need in order to monitor disease trends over a several year period in an adequate manner? Where can the DMO obtain such numbers?

Exercise 3.3

The most recent national census was conducted in 2000, and no population estimates are available for the years 2001–2005. The population in 2000 in the <5 age group was 56 650. The rate of natural increase of the population is 3.3% per year. How can the DMO estimate the population aged <5 years in the district for each of the years 2001–2005?

Exercise 3.4

After estimating the mid-year population of children under 5 for each year between 2001 and 2005, the DMO develops a table containing data for the 3 diseases over the 5-year period (see Table 3.1 below).

Divide each group into 3 smaller subgroups. Each subgroup should do one of the following:

- a. Plot the trends for the incidence, mortality and case fatality for each of the 3 diseases.
- b. Plot the trends for the incidence of each of the 3 diseases on the same graph.
- c. Plot the trends for mortality from each of the 3 diseases on the same graph.
- d. Plot the trends for case fatality rates in each of the 3 diseases on the same graph.

Describe the trends you have graphed to the rest of your group.

Exercise 3.5

Each subgroup will do one of the following:

- a. For the disease assigned to your group, plot the age distribution from a hospital record review (Table 3.2).
- b. Plot the seasonal distribution based on 5 years of surveillance data for the disease assigned to your group (Table 3.3).

Exercise 3.6

Taking into account the graphs you have prepared, define the characteristics of the disease assigned to your group. Describe in words the trends for incidence, mortality and case-fatality as well as the age and seasonal distribution of the disease, and what types of actions or events may have been responsible for the temporal trends observed. Prepare a summary to present to the rest of the class. Presentations will be limited to 10 minutes per group.

Table 3.1 Incidence, Mortality, and Case-fatality rates for diseases A, B, and C, District W, 2001–2005**Disease A**

Year	Population aged <5 years	Cases in <5 years	Deaths in <5 years	Cases/1000	Deaths/1000	Case-fatality %
2001	58 520	10 241	205	175	3.5	2.0
2002	60 541	10 353	157	171	2.6	1.5
2003	62 446	10 616	131	170	2.1	1.2
2004	64 507	10 966	123	170	1.9	1.1
2005	66 635	11 261	113	169	1.7	1.0

Disease B

Year	Population aged <5 years	Cases in <5 year	Deaths in <5 year	Cases/1000	Deaths/1000	Case-fatality %
2001	58 520	3113	152	53.2	2.6	4.9
2002	60 541	1604	85	26.5	1.4	5.3
2003	62 446	4571	219	73.2	3.5	4.8
2004	64 507	1251	71	19.4	1.1	5.7
2005	66 635	2259	113	33.9	1.7	5.0

Disease C

Year	Population aged <5 years	Cases in <5 years	Deaths in <5 years	Cases/1000	Deaths/1000	Case-fatality %
2001	58 520	480	386	8.2	6.6	80.5
2002	60 541	454	394	7.5	6.5	86.7
2003	62 446	381	356	6.1	5.7	93.4
2004	64 507	348	329	5.4	5.1	94.4
2005	66 635	347	320	5.2	4.8	92.3

Table 3.2 Age distribution for diseases A, B and C – District W, Hospital 1 January–31 December 2005

Age group (in months)	Number of cases		
	Disease A	Disease B	Disease C
0–5	427	37	258
6–11	1063	296	
12–23	2312	411	
24–35	1239	223	
36–59	647	115	
Total	5688	1082	258

Table 3.3 Average monthly distribution for diseases A, B and C, 2001–2005

Month	Percentage of cases (%)		
	Disease A	Disease B	Disease C
January	3	13	8
February	7	10	7
March	15	9	6
April	18	7	8
May	13	5	9
June	41	4	7
July	7	4	8
August	5	5	9
September	3	7	12
October	6	9	9
November	7	12	8
December	5	15	9
Total	100	100	100

LEARNING UNIT 4

Measures of central tendency

Learning Objectives:

by the end, participants should be able to...

- Define the terms mean, median, and mode
- Describe the advantages and disadvantages of using the mean versus the median
- Calculate means, medians and modes from individual and from grouped data

With variables such as age, number of children, haemoglobin, and parasite counts, it is often useful to develop a single value that is representative of the individual values in the group. These single, representative values are known as measures of central tendency. These values not only facilitate the description of a population, but also facilitate the comparison of populations.

- ▶ The most common measures of central tendency are the **mean**, the **median**, and the **mode**. These measures can be calculated from individual data if the number of items in the data set is small; if there are many items, these measures are calculated from grouped data.

4.1 Mean

The mean is the **average** of the values in the data set. It is calculated by taking the sum of the individual values in the data set and dividing this sum by the number of values in the set. The mean is the most commonly used measure of central tendency, in part because it is used in other, more sophisticated statistical tests. Its major disadvantage is that it can be affected by the presence in the set of a few extreme values, large or small.

Mathematically, the formula can be expressed as follows:

$$\bar{X} = \sum x_i / n$$

where:

\bar{X} is the arithmetic mean

\sum is the sum of the individual values

x_i is each individual value in the set

n is the number of individual values in the set.

Example 1

Calculate the mean of a set of 5 values: 12, 15, 7, 13, 8

$$\bar{X} = \frac{12 + 15 + 7 + 13 + 8}{5} = \frac{55}{5} = 11$$

4.2 Median

The median is the value or point in a data set that divides the ranked values into 2 equal-sized groups, one consisting of values smaller than the median, and the other consisting of values greater than the median. If the data set is skewed (by one or more extreme values), the median is a more representative measure of central tendency than the mean, because it is less influenced by outliers. The median is calculated as follows:

- ▶ Order the values by rank (place the values in sequence, either in ascending or in descending order)
- ▶ Identify the mid-point of the sequence. If there is an **odd** number of values identify the middle number. If there is an **even** number of values identify the mid-point between the two numbers in the middle of the sequence.

The general formula to identify the middle value is:

$$\text{middle value} = \frac{\text{total number of values in sequence} + 1}{2}$$

- ▶ The number corresponding to this middle value is the median of the values in the data set.

Example 2

Determine the median of a data set containing an odd number of values (12, 15, 7, 11, 8).

- ▶ Rank values in ascending order: 7, 8, 11, 12, 15
- ▶ Determine the mid-point of the sequence $(5 \text{ values} + 1) / 2 = 3$
- ▶ The median is therefore the 3rd value in the sequence
- ▶ The 3rd value is 11, therefore the median is 11

Example 3

Determine the median of a data set with an even number of values where the middle numbers are different (12, 15, 18, 7, 13, 8).

- ▶ Rank values in ascending order: 7, 8, 12, 13, 15, 18
- ▶ Determine the midpoint of the sequence $(6 \text{ values} + 1) / 2 = 3.5$
- ▶ The median is the value that lies halfway between the 3rd and 4th values
- ▶ The 3rd and 4th values are 12 and 13. The median is: $(12+13) / 2 = 12.5$

Example 4

Determine the median of a data set with an even number of values where the middle numbers are the same (12, 15, 18, 7, 12, 8).

- ▶ Rank values in ascending order: 7, 8, 12, 12, 15, 18
- ▶ Determine the midpoint of the sequence $(6 \text{ values} + 1) / 2 = 3.5$
- ▶ The median is the value that lies halfway between the 3rd and 4th values
- ▶ The 3rd and 4th values are 12 and 12. The median is: $(12 + 12) / 2 = 12$

4.3 Mode

The mode is the value in a set of data which occurs most frequently. It is identified by counting the number of times a value occurs in the data set and determining which value occurs most often. Sometimes a data set may have more than one mode.

Example 5

Determine the mode of the values 12, 15, 18, 7, 12, 8, 3, 19, 2.

The mode is 12 because this number appears twice while the others appear only once.

Example 6

Determine the mode of values 12, 15, 12, 3, 18, 7, 12, 8, 3, 15, 19, 3, 2.

This sequence has two modes, 3 and 12, since both numbers appear 3 times while the others occur only once or twice.

Calculation of the mean, median and mode for grouped data

If there are many observations in a data set, or if the observations have been grouped together for other purposes, the mean, median, and mode can be calculated using the frequency distributions.

Example 7

Table 4.1 Haemoglobin levels in grams/100 ml among Amazonian Gold Miners, Brazil in 2000

Hb in grams	f_i Number of cases
8.0–9.9	6
10.0–11.9	23
12.0–13.9	9
14.0–15.9	1
16.0–17.9	2
TOTAL	41

Mean

In order to calculate the mean, the formula is:

$$\bar{x} = \sum f_i x_i / n$$

where:

- \bar{x} is the arithmetic mean
- \sum is the sum of the individual values
- f_i is the frequency of occurrence of an event (i.e. the numbers in column 2 in the above table 4.1)
- x_i is the measurement units or the midpoints of the intervals (see column 3 below)
- n is the number of individual values in the data set.

In order to determine the mean haemoglobin value, it is necessary to add a 3rd and 4th columns to the above table 4.1:

Table 4.2 Haemoglobin levels in grams/100 ml among Amazonian Gold Miners, Brazil, 2000

Class interval Hb in grams	f_i Number of cases	Cumulative number of cases	x_i Midpoint of interval shown	$f_i \times x_i$ – product of columns 2 & 4
8.0–9.9	6	6	8.95	53.70
10.0–11.9	23	29	10.95	251.85
12.0–13.9	9	38	12.95	116.55
14.0–15.9	1	39	14.95	14.95
16.0–17.9	2	41	16.95	33.90
TOTAL	41			470.95

Applying the formula,

$$\sum f_i x_i = 470.95 \text{ and } n = 41, \text{ hence}$$

$$\bar{X} = \sum f_i x_i / n = 470.5 \text{ g} / 41 = 11.5 \text{ g}$$

Median

The median will occur in an interval. The steps in calculating a median for grouped data is to determine the middle data value and then to find what interval this value occurs in. The median is the midpoint of that interval. The middle data value is $(\text{total number of cases} + 1) / 2$. Here, there are 41 cases and the middle case is the 21st (class interval 10.0–11.9). It is now necessary to find which haemoglobin value corresponds to the 21st observation. This is done by calculating the cumulative number of cases, starting with the lowest haemoglobin value:

The 21st case is included in the range 10.0–11.9 (cases 7–29). Next the following formula is applied to determine the exact median value:

$$\text{Median} = L + (JW / f)$$

where:

L is the true lower limit of the class interval containing the median point (in the present case, $L = 10$)

J is the number of cases in this interval below the midpoint case, calculated as the number of cases below the midpoint (here = 21) minus the cumulative number of cases up to (but not including) this interval (here = 6), which is 15

W is the width of the class interval = 2

f is the number of cases in this class interval (in this case = 23)

Applying the formula,

$$\text{Median} = L + (JW / f) = 10 + (15 \times 2 / 23) \text{ g/ml} = 11.30 \text{ g/ml}$$

Mode

The mode is the midpoint of the interval that occurs most frequently. Looking at the frequency column of Table 4.2, we can see that the “10.0 – 11.9” interval occurs most often. So, the mode is the midpoint of that interval, which is 10.95.

Exercise 4.1

Last month, 20 patients with malaria were admitted to hospital X. The age distribution is as follows (in years): 4, 3, 3, 1, 2, 26, 64, 3, 2, 5, 7, 4, 22, 3, 1, 1, 12, 2, 3, 6.

- What is the mode?
- What is the median?
- What is the mean?
- Why are there differences between the median and the mean?
- Which is a better measure of the age distribution in the population, and why?

Exercise 4.2

The duration of hospitalization for the 11 children admitted last month to hospital X with cerebral malaria was as follows:

Child 1	3 days
Child 2	7 days
Child 3	8 days
Child 4	5 days
Child 5	4 days
Child 6	11 days
Child 7	6 days
Child 8	10 days
Child 9	5 days
Child 10	1 day
Child 11	4 days

- What is the mode?
- What is the median?
- What is the mean?
- Why are the median and the mean closer than in Exercise 1?
- Which is a better measure of the distribution of length of stay of the children in this case? Why?

Exercise 4.3

The following data on parasite density were obtained for 200 consecutive patients seen in clinic X during the first quarter of 2004:

Density: parasites/1000 WBC	Frequency
1000–2999	20
3000–4999	70
5000–6999	80
7000–8999	25
9000–10999	5
Total	200

Calculate:

- The mean parasite density
- The median parasite density
- The modal parasite density

Exercise 4.4

The parasite densities (asexual parasites per μl) of 23 malaria patients admitted to hospital X last month were as follow:

Patient number	Parasite density (per μl)
1	1069
2	3941
3	4514
4	8048
5	8793
6	11654
7	12736
8	13680
9	17614
10	18630
11	21186
12	22099

Patient number	Parasite density (per μl)
13	22827
14	23585
15	29648
16	32265
17	32739
18	38000
19	40684
20	66211
21	67231
22	159091
23	196500

Calculate the mean and median parasite density and discuss the difference between the two values.

If you know how to calculate the geometric mean, please also calculate this and discuss the difference with the other participants and the tutor.

LEARNING UNIT 5

Measures of variability and normal distribution

Learning Objectives:

by the end, participants should be able to...

- Define the terms *range*, *standard deviation* and *normal distribution*
- Describe the advantages and disadvantages of using *range*, *standard deviation* and *normal distribution*
- Calculate a *range* and a *standard deviation*
- Calculate and interpret a chi-squared value

The measures of central tendency (mean, median and mode) are very useful for describing a frequency distribution, but they do not indicate the spread of values that may have the same central tendency. In making decisions for the management of tropical diseases, as in many other public health fields, it is important to establish what is “normal”. The “normal” value is a statistical concept and depends, to a great extent, on the distribution of the attribute in the population. The extent of variability can be summarized through two measures:

- ▶ the range,
- ▶ the standard deviation.

5.1 Range

The range indicates the distance between the highest and the lowest value in the distribution.

Example 1

The range of 11 values 3, 4, 4, 5, 6, 6, 6, 7, 7, 8, 10 is 3 to 10.

Range can also be expressed as $10 - 3 = 7$

The range is simple to calculate and easy to understand, but the range tells only about two values of a series of observations. An extremely high or low value may be due to a measurement error. The range does not take into account variability of observations between the two extreme values.

5.2 Standard deviation

The standard deviation is a measure that describes the scatter of observations around the mean. If all the observations had the same value, the standard deviation would be zero; the further apart from one another (and from the mean) the individual observations are, the greater is the standard deviation. If the standard deviation of a sample is very small, the sample average closely represents every individual value; a large standard deviation indicates that this is not so.

The steps in the calculation of the standard deviation are as follows:

- ▶ Calculate the difference between each observation and the mean ($x_i - \bar{x}$)
- ▶ Square each difference ($(x_i - \bar{x})^2$)
- ▶ Add the above squares and divide this sum of squares by the number of observation minus 1, i.e. $(n - 1)$
- ▶ Calculate the standard deviation by finding the square root of the number obtained in the above steps in application of the formula:

$$SD = \sqrt{\frac{\sum_i^n (x_i - \bar{x})^2}{n - 1}}$$

- where:
- x_i each value
 - \bar{x} the mean
 - $(x_i - \bar{x})^2$ the square of each difference
 - Σ the sum of
 - n number of observations

Note that the denominator is $n - 1$ rather than n . In practice, when n is reasonably large, it makes little difference. However, for theoretical reasons, $n - 1$ is preferred.

Example 2

Calculate the standard deviation (SD) of a set of 11 values: 3, 4, 4, 5, 6, 6, 6, 7, 7, 8, 10.

Following the above steps:

- ▶ Calculate the mean: $66 / 11 = 6$
- ▶ Calculate the difference between the value of each observation and the mean:

Mean	6										
Values x_i	3	4	4	5	6	6	6	7	7	8	10
Difference from mean $x_i - 6$	-3	-2	-2	-1	0	0	0	1	1	2	4
Squared difference from mean	9	4	4	1	0	0	0	1	1	4	16

- ▶ Add the squares of differences
sum of squares = $9 + 4 + 4 + 1 + 0 + 0 + 0 + 1 + 1 + 4 + 16 = 40$
- ▶ Divide by number of observations minus 1 ($n - 1$), where: $n = 11 = 40 / 10 = 4$
- ▶ Calculate the standard deviation by finding the square root of the result:

$$SD = \sqrt{4} = 2$$

A quicker calculation can be:

$$SD = \frac{\sum x^2 - (\sum x)^2 \div n}{n - 1}$$

- where:
- $\sum x^2$ take each observation, square it, then sum the squares
 - $(\sum x)^2$ sum the observations, then square the sum

Using the values of the previous example: 3, 4, 4, 5, 6, 6, 6, 7, 7, 8, 10 ($n = 11$)

- ▶ Square each observation and then sum the squares:
 $9 + 16 + 16 + 25 + 36 + 36 + 36 + 49 + 49 + 64 + 100 = 436$
- Thus $\sum x^2 = 436$



- Then sum the observations and square the sum:

$$(3 + 4 + 4 + 5 + 6 + 6 + 6 + 7 + 7 + 8 + 10)^2 = (66)^2 = 4356$$

$$\text{Thus } (\Sigma x^2) = 4356$$

$$\text{with } \frac{(\Sigma x)^2}{n} = \frac{4356}{11} = 396$$

$$\text{and } SD = \sqrt{\frac{(4356 - 396)}{10}} = \sqrt{4} = 2$$

The standard deviation is based on all observations; therefore it is better suited than the range for describing the distribution.

5.3 The normal distribution

The standard deviation is especially applicable when the underlying distribution is close to normal (Gaussian), i.e. symmetrically bell-shaped. This is often assumed to be the case for many biological characteristics, such as height, weight and blood pressure. The normal distribution has some useful characteristics and many statistical tests can be used if the observations follow a normal distribution. Approximately two-thirds of the values under a normal distribution curve fall within \pm one standard deviation of the mean, and approximately 95% fall within \pm two standard deviations of the mean (Fig. 5.1). However, many biological distributions in parasitology and epidemiology do not follow a Gaussian (normal) curve.

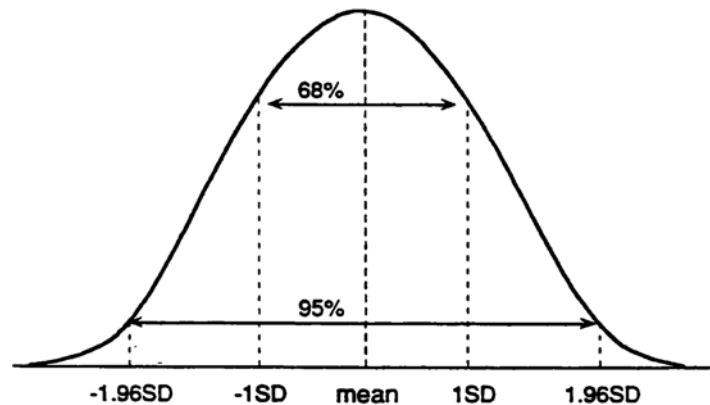


Figure 5.1 The normal distribution curve

Standard deviation of a percentage

If a sample (of at least 30 subjects) yields a percentage of $p\%$, it is possible to calculate the standard deviation of this percentage in the population as follows:

$$SD = \sqrt{\frac{p(100-p)}{n}}$$

Consider a sample of 100 persons of whom 80% are women and 20% are men. The standard deviation of the percentage of women in the population is:

$$SD = \sqrt{\frac{p(100-p)}{n}} \quad \text{with } p = 80, \quad 100 - p = 20, \quad n = 100$$

$$\text{here } SD = \sqrt{\frac{p(100-p)}{n}} = 4$$

It would be expected that there are less than 5 chances in 100 that the proportion of women in one sample is less than

$$\begin{aligned} &80\% \text{ minus } (1.96 \times 4) \quad \text{or} \quad 80\% - 7.84\% \quad \text{or} \quad 72.16\% \\ &\text{or more than} \\ &80\% \text{ plus } (1.96 \times 4) \quad \text{or} \quad 80\% + 7.84\% \quad \text{or} \quad 87.84\% \end{aligned}$$

If not using a calculator, 1.96 may be rounded up to 2 to simplify calculations.

Note: 95% of the observations fall within ± 2 times the standard deviation.

5.4 Test of association: the chi-square test

The chi-square (χ^2) is a results statistics test used to show if results are as expected or unusual. The test is commonly used to examine the null hypothesis.

The test is calculated as the sum of the squares of observed values minus expected values divided by the expected values. The table below shows the distribution of two variables A and B and how to calculate the chi-squared statistics to test for an association.

Note: the example is given for a 2×2 distribution with $(2-1)(2-1) = 1$ degree of freedom, for which the threshold values of chi-squared statistics is 3.84 at 5% probability. For degrees of freedom greater than 1, see Table 5.1.

Observed values

Variable B		Variable A		
		Present	Absent	Total
	Present	A	B	A+B
	Absent	C	D	C+D
	Total	A+C	B+D	A+B+C+D

- Establish the null hypothesis and calculate the expected frequencies (E) for each observed (O) cell under the null hypothesis of independent (no association).

If the null hypothesis were not rejected, the expected values would have been as follows:

Expected values

Variable B		Variable A		
		Present	Absent	Total
	Present	$(A+C)(A+B) / N$	$(B+D)(A+B) / N$	A+B
	Absent	$(A+C)(C+D) / N$	$(B+D)(C+D) / N$	C+D
	Total	A+C	B+D	N = A+B+C+D

- ▶ Determine the degree of freedom of the distribution (the freedom to choose frequencies in the cells under the constraint of fixed marginal totals): this is equal to (number of columns of data minus 1) × (number of rows of data minus 1).
- ▶ Calculate the chi-squared statistics

$$\text{Chi-square} = \chi^2 = \sum \frac{(O - E)^2}{E} \text{ with a degree of freedom (df) = (row - 1)(column - 1)}$$

- ▶ Compare the results with the theoretical distribution of chi-squared to determine significance. If the calculated chi-square is greater than the tabulated value the null hypothesis can be rejected at the corresponding level (5%, 10%) of significance. For 1 degree of freedom, the value of χ^2 corresponding to $p = 0.05$ is 3.84.

Examples 3

Association between recent forest exposure and malaria infection, State A

Disease		Exposure		
		Present	Absent	Total
	Present	50	11	61
	Absent	16	41	57
	Total	66	52	118

- ▶ Null hypothesis: absence of association between forest and malaria
- ▶ Expected values

The expected value for the first cell (exposure and disease both+) would be

Disease		Exposure		
		Present	Absent	Total
	Present	$66 \times 61 / 118 = 34.12$	$52 \times 61 / 118 = 26.88$	61
	Absent	$66 \times 57 / 118 = 31.88$	$52 \times 57 / 118 = 25.12$	57
	Total	66	52	118

- ▶ Number of degrees of freedom = 1

This table can be filled by difference:

Disease		Exposure		
		Present	Absent	Total
	Present	$50 - 34.12 = 15.88$	$11 - 26.88 = -15.88$	61
	Absent	$16 - 31.88 = -15.88$	$41 - 25.12 = 15.88$	57
	Total	66	52	118

The absolute value of the difference between expected and observed value is:

$$(50 - 34.12) = 15.88 \text{ for all cells: the square of this difference is } 252.17$$

Chi-squared is the sum of the squared differences between observed and expected values/observed value =

$$(252.17 / 34.12) + (252.17 / 26.88) + (252.17 / 31.88) + (252.17 / 25.12) = 34.73$$

This is greater than 3.84 and hence the null hypothesis is rejected and the association between forest exposure and malaria infection is accepted.

Note: In practice, it is often sufficient to calculate $(O - E)^2/E$ for the smallest value of O . If, as is the case here, the result is > 3.84 , the chi-square test is positive and the distributions are significantly different.

Exercises

Calculation of the mean, standard deviation, range, and chi-squared

Exercise 5.1

The duration of hospitalization for 24 children admitted last month to hospital X with pneumonia was as follows:

Child 1	6 days	Child 13	10 days
Child 2	7 days	Child 14	18 days
Child 3	10 days	Child 15	14 days
Child 4	8 days	Child 16	12 days
Child 5	11 days	Child 17	11 days
Child 6	8 days	Child 18	10 days
Child 7	4 days	Child 19	10 days
Child 8	17 days	Child 20	15 days
Child 9	15 days	Child 21	5 days
Child 10	14 days	Child 22	12 days
Child 11	8 days	Child 23	6 days
Child 12	11 days	Child 24	11 days

- What is the range of values?
- What is the mean duration of hospitalization?
- What is the standard deviation?
- Is range or standard deviation a better measure of the distribution in this case? Explain your answer.

Exercise 5.2

The following data on the pulse rate were taken on admission from 10 male patients hospitalized in one week:

Male 1	83 beats/minute	Male 6	59 beats/minute
Male 2	72 beats/minute	Male 7	72 beats/minute
Male 3	77 beats/minute	Male 8	58 beats/minute
Male 4	62 beats/minute	Male 9	65 beats/minute
Male 5	60 beats/minute	Male 10	77 beats/minute

- What is the range of pulse rate values?
- What is the mean?
- What is the standard deviation?

Exercise 5.3

A sample of 200 population surveyed shows the following:

- ▶ Of 94 people with a positive blood slide, 34 regularly use an insecticide-treated bednet.
- ▶ Of 106 people with a negative blood slide, 80 regularly use an insecticide-treated bednet.

a. Tabulate the information

b. Is the distribution of “positive blood slides” and that of “bednet users” significantly different ($p = 0.05$)?

Table 5.1 Threshold values for chi-squared, $p = 0.05$ and $p = 0.01$

Degrees of freedom	$p = 0.05$	$p = 0.01$
1	3.84	6.64
2	5.99	9.21
3	7.82	11.35
4	9.49	13.28
5	11.07	15.09
6	12.59	16.81
7	14.01	18.48
8	15.51	20.09
9	16.92	21.67
10	18.31	23.21
11	19.68	24.73
12	21.03	26.22
13	22.36	27.69
14	23.69	29.14
15	25.00	30.58
16	26.30	32.00
17	27.59	33.41
18	28.87	34.81
19	30.14	36.19
20	31.41	37.57
21	32.67	38.93
22	33.92	40.29
23	35.17	41.64
24	36.42	42.98
25	37.65	44.31
26	38.89	45.64
27	40.11	46.96
28	41.34	48.28
29	42.56	49.59
30	43.77	50.89

LEARNING UNIT 6

Assessing the accuracy of a test

Learning Objectives:

by the end, participants should be able to...

- Define the terms *sensitivity*, *specificity*, *positive predictive value*, *negative predictive value*, and describe their importance to health practitioners and patients
- Describe the trade-offs between sensitivity and specificity
- Describe the effect of prevalence and incidence on positive predictive value
- Calculate and interpret sensitivity, specificity, and positive predictive value from sample data

An ideal laboratory test would detect all people who have a disease and at the same time identify as normal all those who do not have the disease (Fig 6.1).

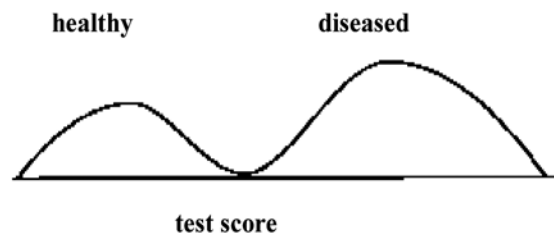


Figure 6.1 An ideal test should distinguish healthy and diseased

However, many biological parameters (such as haematocrit readings and blood glucose,) are based on continuous data and the values between people with and those without a disease may overlap (Fig 6.2).

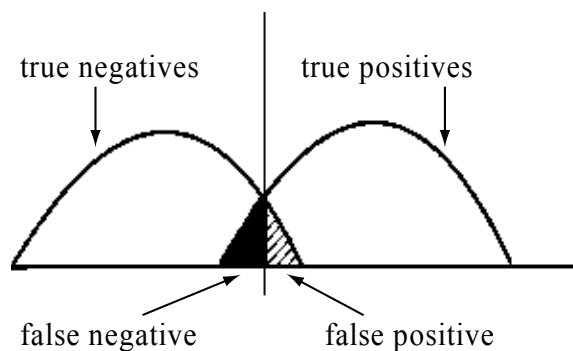


Figure 6.2 A schematic graph shows how cut-off point of a test can affect performance of a test

How well a laboratory test performs in the identification of individuals with or without the disease can be assessed from the values in the following 2 x 2 table:

	Disease present	Disease absent	
Test <i>positive</i>	True positives (TP) (a)	False positives (FP) (b)	TOTAL POSITIVE
Test <i>negative</i>	False negatives (FN) (c)	True negatives (TN) (d)	TOTAL NEGATIVE

From this table, it is possible to calculate the following values that summarize the performance of the test:

Prevalence	$\frac{\text{People with the disease}}{\text{Total population}}$	$\frac{TP + FN}{TN + TP + FN + FP}$	$\frac{(a + c)}{(a + b + c + d)}$
Sensitivity	$\frac{\text{People with the disease and a positive test}}{\text{All people with the disease}}$	$\frac{TP}{TP + FN}$	$\frac{(a)}{(a + c)}$
Specificity	$\frac{\text{People with a neg. test without the disease}}{\text{All people without the disease}}$	$\frac{TN}{FP + TN}$	$\frac{(d)}{(b + d)}$
Positive predictive value: % of positives with the disease	$\frac{\text{People with the disease and a positive test}}{\text{All people with a positive test}}$	$\frac{TP}{TP + FP}$	$\frac{(a)}{(a + b)}$
Negative predictive value: % of negative without the disease	$\frac{\text{People without the disease with a neg. test}}{\text{All people with a negative test}}$	$\frac{TN}{TN + FN}$	$\frac{(d)}{(c + d)}$

For most laboratory tests, the most critical items are:

- ▶ *Sensitivity* – does this test detect all or most persons with the disease?
- ▶ *Specificity* – does the test result exclude healthy individuals?
- ▶ *Positive predictive value* – among those testing positive, what is the probability that they are patients with the disease?

The cut-off point can be moved down for what constitutes an abnormal value in order to improve the sensitivity of a test, but by moving the cut-off point down, the rate of false positives is increased. Conversely, if the cut-off point is moved up in order to provide greater specificity, the sensitivity will decrease and the proportion of tests that are falsely negative will increase. Where the cut-off point is set determines the proportion of false positives and negatives.

- ▶ To reduce the chance of having *false negatives*, in the case of conditions where early action is important, the cut-off point should be set low (high *sensitivity*).
- ▶ In some cases, however, a positive test may entail other investigations or treatments that may involve risk for the patient. In such cases, the chance of *false positives* should be reduced by setting the cut-off point higher for higher *specificity*, even if this lowers the *sensitivity* of the test.

Sensitivity and specificity are *independent of prevalence* of a disease. However, positive predictive value is *dependent on prevalence*, as shown in Figure 6.3:

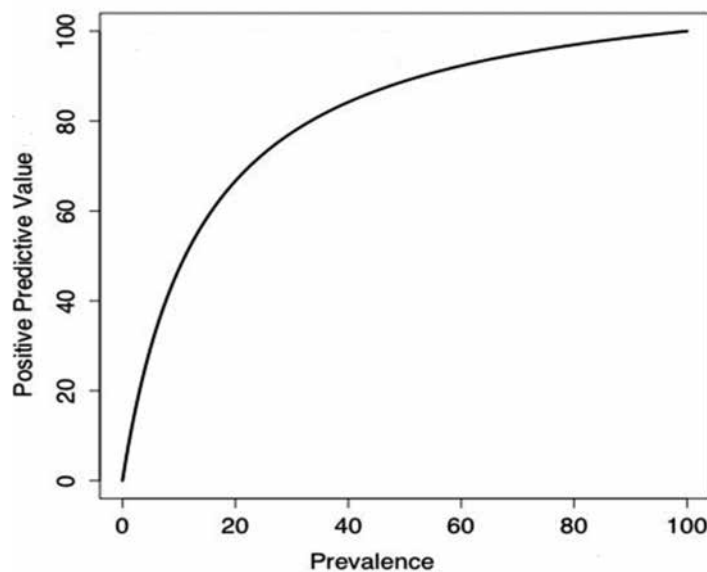


Figure 6.3 Change of positive predictive value according to prevalence

Example

A new diagnostic test to determine the presence of malaria parasites has been tested on all patients. The performance of the test has been assessed by comparison of the results with those obtained by microscopy (the 'Gold Standard').

The results obtained are shown in the following table:

		Microscopy results (Gold Standard)		TOTAL
		Malaria parasites present	Malaria parasites absent	
New diagnostic test	Positive	215	16	231
	Negative	15	114	129
TOTAL		230	130	360

Prevalence	TP + FN / Total	$(215 + 15) / 360 = 64\%$
Sensitivity	TP / (TP + FN)	$215 / (215 + 15) = 93\%$
Specificity	TN / (TN + FP)	$114 / (114 + 16) = 88\%$
Positive predictive value	TP / (TP + FP)	$215 / (215 + 16) = 93\%$
Negative predictive value	TN / (TN + FN)	$114 / (114 + 15) = 88\%$

There is an interesting relationship between the *prevalence* of a condition and the *positive predictive value* of the corresponding test. Consider what might have happened if everyone coming to the outpatient clinic had been screened. There would have been more negative slides, indicating that the latter population has less malaria than the previous one. This would give the following:

		Microscopy results (Gold Standard)		TOTAL
		Malaria parasites present	Malaria parasites absent	
New diagnostic test	Positive	215	248	463
	Negative	15	1822	1837
TOTAL		230	130	2070

Prevalence	TP + FN / Total	$(215 + 15) / 2300 = 64\%$
Sensitivity	TP / (TP + FN)	$215 / (215 + 15) = 93\%$
Specificity	TN / (TN + FP)	$1822 / (1822 + 248) = 88\%$
Positive predictive value	TP / (TP + FP)	$215 / (215 + 248) = 46\%$
Negative predictive value	TN / (TN + FN)	$1822 / (1822 + 15) = 99\%$

Sensitivity and *specificity* remained the same, but the *positive predictive value* and *negative predictive value* changed. Thus, the higher the prevalence results, the higher the positive predictive value. Conversely, the lower the prevalence results, the lower the positive predictive value.

Tests are sometimes used in sequence in order to maximize their sensitivity and specificity. For example, the ELISA for HIV has high sensitivity but low specificity. When a positive result is obtained, the ELISA must therefore be followed by a Western Blot test, which has higher specificity. Repeating the test on a higher prevalence population also improves the positive predictive value of the test.

Exercises: sensitivity and specificity

A study was conducted to investigate how well the clinical signs (fever + rigors) of malaria correlates with parasite positivity in a sample of adults from a high malaria endemic province (2% prevalence) and from a low malaria endemic province (0.2% prevalence). In both areas, 98% of those who have parasitaemia as diagnosed by a thick smear have fever and rigors, but 1% of those who have negative parasitaemia on thick smear also have fever and rigors.

Exercise 6.1

- Using the thick smears as the gold standard, what is the sensitivity of fever + rigors for detection of malaria?
- What is the specificity of these signs?

Exercise 6.2

For a hypothetical population of 100 000 adults in the **high** malaria endemic area as indicated above, calculate the following:

- The number of persons who would receive treatment each week, assuming that all those with fever and rigors would be treated
- The number who would be unnecessarily treated
- The positive predictive value
- The negative predictive value

Exercise 6.3

State in words the meaning of the positive predictive value and negative predictive value that you have calculated.

Exercise 6.4

Let us see what would happen in the areas of **low** prevalence.

For a hypothetical population of 100 000 adults in the low endemicity area, calculate the following:

- The number of persons who would receive treatment each week, assuming that all those with fever and rigors would be treated
- The number who would be unnecessarily treated
- The positive predictive value
- The negative predictive value

LEARNING UNIT 7

Understanding malaria at regional and global levels

PART 2

Learning Objectives:

by the end, participants should be able to...

- Describe the geographical distribution of malaria in the world

Introduction

The Learning Unit 7 of this Guide for Participants consists of a series of exercises to be completed either individually or in a group. The exercises aim to stimulate discussions and exchange of experience between participants (who will come from different countries/areas with different experience). The source materials and responses are in the Guide for Tutors which will be provided to the participants at the end of the course for future reference.



Figure 7.1 Countries or areas at risk of transmission, 2010

Exercise 7.1

a. Describe the burden of malaria in the world and explain its significance. See Figure 7.1.

Hint: what proportion of the world's population is at risk of malaria? Malaria transmission differs in intensity and regularity depending on local factors such as rainfall patterns, proximity of mosquito breeding sites and mosquito species.

b. What are the differences between endemic and epidemic malaria? Is the pattern of malaria infection different in the affected areas?

c. Discuss with group members the status of malaria in various parts of the world.

Exercise 7.2

List the factors which are different for malaria in Africa, South-East Asia and America. What are the characteristics of each of these factors in different continents?

Table 7.1 lists some of these factors; participants may complete them.

Table 7.1 Distribution of malaria characteristics

	AMERICAS	SOUTH-EAST ASIA	AFRICA
Parasitological species of malaria infections			
Principal malaria vectors			
Estimated proportion of population at malaria risk			
Estimated contribution to the global burden of clinical malaria cases			

Exercise 7.3

a. Do differences in the distribution of malaria in various parts of the world affect the objectives of national malaria programmes? Explain the programme objectives in different countries.

LEARNING UNIT 8

Determinants of malaria distribution

Learning Objectives:

by the end, participants should be able to...

- Categorize the determinants of malaria distribution
- Describe each of these determinants

Introduction

This Learning Unit consists of a series of exercises to be completed either individually or in a group. The exercises aim to stimulate discussions and exchange of experience between participants (who will come from different countries/areas with different experience). The source materials and responses are in the Guide for Tutors which will be provided to the participants at the end of the course for future reference.



8.1 Determinants of malaria distribution

Exercise 8.1

Which determinants influence the distribution of malaria in the world?

In general, the factors affecting malaria distribution can be classified into the following three groups:

1. Mosquito, parasite, human
2. Environmental factors
3. Global factors

8.2 Parasite

Exercise 8.2

How do the characteristics of the malaria parasite influence malaria distribution in the world?

8.3 Mosquito

Exercise 8.3

How do the characteristics of the Anopheles mosquito influence malaria distribution in the world?

8.4 Humans

Exercise 8.4

- a. How can human characteristics influence malaria distribution in the world?
- b. How do behavioural factors influence malaria distribution in different regions?

8.5 Environmental factors

Exercise 8.5

- a. *How can climate determine the distribution of malaria? Give examples of climate change that have led to a change in malaria transmission.*
- b. *In what conditions does malaria transmission not take place in tropical regions?*
- c. *Which species of malaria is most frequent in regions of cooler climate?*
- d. *How can climate and change in behavioural patterns alter the rate of malaria transmission?*

8.6 Global factors

Exercise 8.6

- a. *Is poverty a contributing cause of malaria, or is malaria a cause of poverty? How can poverty influence the distribution of malaria?*
- b. *In addition to those mentioned above, what other factors can influence malaria transmission in a region?*

LEARNING UNIT 9

The life-cycle of the malaria parasite and its relation to pathogenesis, immune responses, antimalarial drugs, and field measurements

Learning Objectives:

by the end, participants should be able to...

- Describe the life-cycle of human malaria parasites
- Describe important characteristics of infection with each of the 4 species of human malaria parasite
- Relate the parasite's life-cycle to pathogenesis, immune responses and potential vaccines
- Identify, in the parasite's life-cycle, the points of impact of the main antimalarial drugs
- Identify in the parasite's life-cycle what can be measured, using methods suitable for application in malaria control programmes.

Introduction

The Learning Unit 9 of this Guide for participants consists of a series of exercises to be completed either individually or in a group. The exercises aim to stimulate discussions and exchange of experience between participants (who will come from different countries/areas with different experience). The source materials and responses are in the Guide for Tutors which will be provided to the participants at the end of the course for future reference.

9.1 The life-cycle of the malaria parasite

Exercise 9.1

a. Working in small groups, discuss ways of preparing a schematic representation of the life-cycle of the malaria parasite. Consider the different viewpoints of your colleagues before preparing your own diagram (each individual participant).

Study the diagram of the life-cycle of the malaria parasite provided by the tutor (Fig. 9.1). Compare it with the one they have prepared and discuss any major differences with the facilitator.

b. Like all sexually reproducing organisms, the malaria parasite is diploid during part of its life-cycle and haploid during the rest of the cycle. Identify in what parts of the cycle the parasite is diploid and haploid, respectively. Discuss the biological significance of the haploid and diploid stages.

9.2 Characteristics of infection with each of the 4 species of human malaria parasites

Exercise 9.2

Working in small groups, list the different characteristics of an infection with each of the 4 species of human malaria parasites.

Prepare:

- ▶ A table of *time factors* (i.e. prepatency, duration of incubation period, time of appearance of gametocytes, and duration of asexual cycle in the blood) for each species
- ▶ A table of *multiplication factors* (number of sporozoites per oocyst, numbers of merozoites per hepatic schizont and per blood schizont) for each species
- ▶ A short list of other important differences among the species

Compare the results of the exercise with the tables and list presented by the tutor.

Discuss the differences.

9.3 The life-cycle of the parasite, pathogenesis, and immunity

Exercise 9.3

a. On a copy of the diagram of the parasite's life-cycle (Fig. 9.1), indicate the main ways in which the parasite can produce disease. List the main mechanisms of pathogenesis. Compare with the tutor's Figure 9.2. Discuss differences and implications.

- b. On a copy of Figure 9.2, indicate which stages of the malaria parasite provoke naturally-acquired immune responses (IRs) to the malaria parasite. For each category of IR, indicate by what parasite life stage(s) it is stimulated, and in what part of the life-cycle it exerts its impact. Compare to the tutor's Figure 9.3. Discuss the differences and implications.
- c. On a copy of Figure 9.3, indicate the expected points of impact of different types of potential malaria vaccines. Compare with the tutor's Figure 9.4. Discuss differences and implications.

9.4 The parasite's life-cycle and antimalarial drugs

Exercise 9.4

On a copy of the diagram of the parasite's life-cycle (Fig. 9.1), indicate the points of impact of the main antimalarial drugs. Compare with the tutor's Figure 9.5. Discuss differences and implications.

9.5 Epidemiological measurements

Exercise 9.5

- a. On another copy of the same diagram (Fig. 9.1) identify the possible epidemiological measurements. Indicate what can be measured technically and state by what methods. Compare with the tutor's Figure 9.6. Discuss differences and implications.
- b. What are the tools for diagnosis of human malaria cases at the field level?
- c. What are their diagnostic performances?

LEARNING UNIT 10

The life-cycle of the vector and factors that influence it in relation to malaria transmission

Learning Objectives:

by the end, participants should be able to...

- Describe the life-cycle of the malaria vectors
- Describe the factors affecting the vector's life-cycle in relation to malaria transmission (including vector control)
- Relate vector collection methods to the vector's life-cycle, and entomological data to their epidemiological interpretation

Introduction

This Learning Unit consists of a series of exercises to be completed either individually or in a group. The exercises aim to stimulate discussions and exchange of experience between participants (who will come from different countries/areas with different experience). The source materials and responses are in the Guide for Tutors which will be provided to the participants at the end of the course for future reference.

10.1 The vector's life-cycle

Exercise 10.1

Working in groups, discuss ways of preparing a diagram of the life-cycle of the malaria vector. Consider the different viewpoints of your colleagues before preparing your own diagram.

Study the diagram of the life-cycle of the malaria vector provided by the tutor (Fig. 10.1). Compare it with the diagram your group have prepared and discuss any important differences with the facilitator.

10.2 Factors affecting the vector's life-cycle in relation to malaria transmission

Exercise 10.2

Working as a small group, list the major factors that have a direct effect on the vector's life-cycle, and then organize these factors into appropriate groups.

The following groups may be considered:

1. Numerical factors, e.g. duration of life-stages
2. Vector behaviour
3. Vector-parasite interactions, perhaps including possible density-dependent regulation in the vector
4. Differences among vector species
5. Factors of the physical environment, perhaps subdivided according to type of effect on the vector's life-cycle, e.g. vector production, vector survival, human-vector contact, etc.

10.3 Vector control measures and their point of impact

Exercise 10.3

Group vector control methods according to their type, e.g. chemical, and to the stage of the vector's life-cycle to which they are applicable; also consider methods for reducing human-vector contact.

On a copy of the diagram of the life-cycle of the malaria vector (Fig. 10.1) indicate the points of impact of the different control measures. Compare this diagram with the one presented by the tutor (Fig.10.2).

10.4 Efficacy of vector control measures

Exercise 10.4

Working in groups, discuss the following:

Do all control measures have the same effect on the transmission of malaria? If not, how and why do they differ?

Consider the path followed by a vector in acquiring, incubating and transmitting the infection, and the number of times the same individual vector passes through the various stages represented on the diagram (Fig. 10.2).

Are conclusions about the expected efficacy of particular control methods affected by the assumption that all the mosquitoes in a given population may or may not behave in the same way?

For instance a given amount of exophilic behaviour (outdoor resting after a blood-meal) may be a function of the whole vector population or of only a part of that population (exophilic subpopulation). Would that affect the efficacy of indoor residual spraying?

Similarly a given amount of zoophilic behavior (proportion of bites on animals) could be a characteristic of the total population or concentrated only in a subpopulation; would that affect the impact of a control measure on transmission?

10.5 Measurement methods

Exercise 10.5

On another copy of the same diagram of the vector's life-cycle (Fig. 10.1), indicate the main *vector collection methods* that are technically feasible in a control programme.

A number of *variables* can be *measured* in the samples collected, e.g. sex, species, number, age-class of females, nulliparous or parous, infection rates, etc., and from these measurements various *indicators* can be *calculated*, e.g. human-biting rate, sporozoite rate, survival rate, etc. Information on the measurement of the variables and calculation of the indicators is provided in the module *Malaria Entomology and Vector Control*.

Compare the diagram with the one presented by the tutor (Fig. 10.3).

10.6 Interpretation of entomological data

Three problems of epidemiological interpretation of entomological data will be considered here.

10.6.1 Representativeness

Representativeness of entomological measurements: relationship between the actual measurement and the reality it is intended to measure.

The aim is to measure *vector density* and *vector behaviour*.

Exercise 10.6

- a. *Do the collection methods allow vector density and vector behaviour to be measured independently of each other?*
- b. *If the answer is no, do the methods measure the “true” density or only indicators of trend?*
- c. *Is this significant for measuring the impact of vector control, e.g. entomological impact of the introduction of insecticide-treated mosquito nets?*

10.6.2 Ratio between sample size and population size**Exercise 10.7**

- a. *Are entomological sampling fractions usually large, small, or very small?*
- b. *Consider the following example. In an isolated village, during one whole night, 20 female mosquitoes of species X are collected on two human baits. What other variables must be known to calculate the mosquito population of that night in that village?*
- c. *Attribute some plausible value to each of these variables, and calculate the mosquito population size and the sampling fraction.*
- d. *Is it common to find new cases of human infection without finding infected vectors? Can the sampling fraction of the two measurements be compared? Starting from the example just calculated, does the comparison explain the discrepancy?*

10.6.3 Calculating survival from age-composition**Exercise 10.8**

- a. *Name the two variables that determine age-composition of adult female vectors at a given point in time.*
- b. *What is being assumed if survival is calculated from age-composition at a given point in time?*
- c. *What is being assumed if survival is calculated from average age-composition over a period of time, e.g. a transmission season?*

LEARNING UNIT 11

Natural history of malaria in the human host and factors that affect it

Learning Objectives:

by the end, participants should be able to...

- Describe the natural history of malaria in the human host
- Describe the factors that have an effect on the natural history of malaria in the human host, including immunity and malaria control measures
- Describe the role of improved diagnostic testing and treatment services at intermediate and peripheral levels in reducing morbidity and mortality due to malaria

Introduction

This Learning Unit consists of a series of exercises to be completed either individually or in a group. The exercises aim to stimulate discussions and exchange of experience between participants (who will come from different countries/areas with different experience). The source materials and responses are in the Guide for Tutors which will be provided to the participants at the end of the course for future reference

11.1 Natural history of malaria in the human host

Exercise 11.1

Working in small groups, discuss ways of preparing a diagram of the natural history of malaria in the human host. Prepare a flowchart from inoculation to death, including intermediate states and reversible steps.

After considering the viewpoints of colleagues in the group, each participant should draw his/her own diagram of the natural history of malaria in the human host.

Study the flowchart (Fig. 11.1) presented by the tutor. Compare it with the one prepared by the group and discuss any important differences with the tutor or facilitator.

Exercise 11.2

Discuss the following three questions in the small group, draft answers, and compare them with the tutor's answers:

- a. *How rapidly do patients move from one state to another?*
- b. *What are the implications for case-management?*
- c. *Does the risk of disease and the risk of severe disease change in the course of time after inoculation?*

Exercise 11.3

Not every case proceeds all the way from inoculation to death and different cases stop at different intermediate states. Discuss in group *what factors might affect the outcome of an inoculation, and how to classify the factors in a meaningful table*. Each participant should prepare a table. Note that this section covers the *identification* and *classification* of factors; subsequent sections will consider the different classes of factors, their possible importance and mode of action. Compare the table with the one presented by the tutor (Table 11.1) and discuss any differences.

11.2 The inoculum's intrinsic factors

Exercise 11.4

In small groups, discuss the following questions, then draft individual answers.

1. Number of sporozoites inoculated

- a. *How many sporozoites does a vector inoculate?*
- b. *How can the number of sporozoites be measured?*
- c. *Does the number of sporozoites affect the outcome?*

2. Differences of “virulence” among parasite species

- a. Why is *P. falciparum* the most pathogenic species? (see Learning Unit 10).
- b. Do other species of *Plasmodium* cause lethal forms of malaria?

3. Differences of “virulence” within a parasite species or local parasite population

- a. What observations suggest that there are such differences, within a species and within a local population of a species?

Consider the following:

- i. Some children who develop severe malaria, presumably after a recent inoculation, have received many previous *P. falciparum* inoculations without developing severe malaria.
- ii. Some asymptomatic parasitaemic children develop clinical malaria (uncomplicated malaria or severe malaria) following superinfection; can that be explained by the quantity of parasites added? Example: a child with an asymptomatic parasitaemia of 1000 parasitized RBC/ μ l, and a blood volume of 2000 ml, in which superinfection leads to the successful maturation of 20 liver schizonts.
- iii. If you conclude that the outcome – disease or no disease, uncomplicated malaria or severe malaria – is related to the quality of the parasites rather than their quantity, can you also conclude that the parasite’s variable intrinsic virulence is a sufficient explanation of such differences of outcome? Discuss the answers and discrepancies with the tutor.

11.3 The human host’s intrinsic factors

11.3.1 Genetic traits and susceptibility

Exercise 11.5

List and discuss briefly examples of genetic traits that decrease or increase the human host’s susceptibility to malaria.

11.3.2 Acquired immunity (active)

Exercise 11.6

- a. What stimulates active immunity to malaria? Is it “all or nothing” or a gradual process? Is it species-specific? Is it reversible? If so, how is it reversed? Discuss the questions in group, then draft individual answers.
- b. Draw a diagram of the effect(s) of active immunity on the natural history of malaria in the human host. After discussing the subject in group, draw individual diagrams. Suggestion: on another copy of the flowchart of malarial states (Fig. 11.1) draw, to the right of the flowchart, two additional, modified, flowcharts corresponding to “moderate” and “high” levels of active immunity.

Compare the diagram to the tutor’s (Fig. 11.2). The diagram suggests that successive inoculations are progressively less pathogenic and less dangerous. However, according to a previous statement (see above), some children developing severe malaria, presumably after a recent inoculation, have received many previous *P. falciparum* inoculations without developing severe malaria. *Is there a contradiction?* Discuss.

- c. Discuss, in relation to the diagram, the expected effects of different malaria control measures, such as vector control, control of human-vector contact, treatment of cases, potential vaccines.

11.3.3 Acquired immunity (passive)

Exercise 11.7

- a. How is passive immunity acquired? Is it reversible? If so, how is it reversed? After discussing in group, answer individually.
- b. Draw a diagram of the effect(s) of passive immunity. After discussing in group, draw individual diagrams. Suggestion: on the copy of Figure 11.2 on which the effect(s) of active immunity have already been indicated and add, to the left of the original flow-chart, a modified flowchart, corresponding to passive immunity.
- c. Compare the answers and diagrams with the tutor's, in particular comparison with Figure 11.3.

11.4 Other human biological factors

Exercise 11.8

Discuss how pathogenesis is affected by:

- a. Pregnancy
- b. Nutritional status
- c. Age *per se* (i.e. separately from its association with immunity)

11.5 Interaction between parasite diversity and host diversity

It appears that intrinsic parasite and host factors can explain only part of the variation in outcome of host-parasite encounters, and that *interaction* may be important.

Exercise 11.9

- a. Consider the parasite:
- Does a parasite present one, a few, or many antigens to the host?
 - Do different parasites of the same species present much antigenic diversity, or a little, or none?
- b. Consider the human host:
- Can every host acquire protective immunity against every antigen?
 - Does the set of antigens to which a host can respond, i.e. can acquire protective immunity, differ among hosts?
- c. Do the answers to (a) or (b) suggest something about pathogenesis, other than the intrinsic virulence of the parasite and the intrinsic susceptibility of the host?

11.6 Age-specific distribution of malaria

Exercise 11.10

Working in small groups, carry out the following exercise.

- a. Suppose that exposure (to vectors) does not vary with age; show on a diagram the kinds of age-specific distributions that would be expected for:
 - i. Malaria infection (parasitaemia)
 - ii. Malaria disease
 - iii. Malaria deaths
- b. How would those distributions change if transmission increases or decreases? Show on a separate diagram the effect of transmission changes.
- c. Does exposure to vectors vary with age? If so, is this important?

How will the diagram appear in case of sudden exposure of a non-immune population to intense transmission?

Compare the graph with the one provided by the tutor (Fig. 11.4) and discuss the differences.

11.7 Malaria mortality

In Figures 11.1 and 11.2 (presented by the tutor) the diagrams show that malaria (*P. falciparum*) kills through severe malaria, i.e. clinical forms of malaria such as cerebral malaria, likely to be lethal if left untreated. Is that the only way that malaria is responsible for death? Consider the risk of death associated with some other diseases, e.g. pneumonia, measles, malnutrition. Among children suffering from pneumonia, for example, some may suffer from uncomplicated malaria at the same time. Is the risk of dying the same among the children suffering from pneumonia plus uncomplicated malaria, as among the children suffering from pneumonia alone? More generally, is the addition of uncomplicated malaria likely to affect the case fatality rate (CFR) of some other diseases?

If the addition of uncomplicated malaria increases the CFR of some other diseases, the additional deaths may be termed indirect malaria deaths, while the deaths due to severe malaria may be termed direct malaria deaths, and the sum of the two may be termed total malaria deaths. Participants should add these concepts to Figure 11.1, then compare the new diagram to the tutor's Figure 11.5 and discuss the differences.

Exercise 11.11

- a. If there is both direct and indirect mortality from malaria, is their relative magnitude of practical importance, and, if so why?
- b. What kind of data would allow estimation of their relative magnitude?
- c. If such data are known to the participants, what do they show?

LEARNING UNIT 12

Intensity of malaria transmission

Learning Objectives:

by the end, participants should be able to...

- Define the major parameters of intensity of transmission which are used in malaria epidemiology
- Identify the relationships between the vectorial capacity, the basic reproduction rate, the inoculation rate, and the incidence and prevalence of malaria infection
- Describe the expected impact of mass drug administration and/or vector control activities on malaria transmission at different levels of endemicity
- Distinguish what models can or cannot contribute to the planning of malaria control
- Indicate the epidemiological methods for measuring malaria morbidity and mortality and how information can be collected
- Describe how the relationship between vectorial capacity and other concepts of the intensity of malaria influence the selection of control methods in different epidemiological situations

12.1 Intensity of transmission

The concept of “intensity” can be applied to the transmission of the malarial infection, to the disease, and to the related mortality.

Exercise 12.1

Name and define the different concepts of intensity that are *applicable to malaria infection and to its transmission*.

12.2 Vectorial capacity and basic reproduction rate

12.2.1 Vectorial capacity (C)

Vectorial capacity **C** is defined as the potential number of secondary cases originating from one primary case in one day, assuming that the population is, and remains, fully susceptible. In malaria, where transmission is indirect, the anopheline mosquito’s circumstances determine vectorial capacity. Note that the term refers to the combination of the components determining the effectiveness of a local mosquito population to transmit malaria and, although the human host is the beginning and end of the sequence, the term refers to the insect stages, **not** those occurring in humans.

Understanding the concept of vectorial capacity helps in understanding the factors that determine malaria transmission, and is therefore important for planning malaria control strategies. The vectorial capacity is a measure of the efficiency of a local vector population in potentially transmitting the parasite.

12.2.2 Basic reproduction rate (R_0)

The basic reproduction rate R_0 is the potential number of secondary cases that could potentially originate from one primary case during the whole period of the patient’s illness, assuming that the community is and remains fully susceptible to malaria infection. Note that the basic reproduction rate is a potential multiplication factor, **not** an actual secondary attack rate.

12.2.3 A revision of some definitions

Exercise 12.2

Working in small groups:

- Revise and discuss the definitions of primary and secondary cases.
- If a malaria patient has gametocytes in the blood for 14 days only (during which he/she can transmit the infection), and this generates 5 new cases which can be added every day, then how many new cases would be added to the community?
- What is the vectorial capacity in the example above? What is the basic reproduction rate?

Note: The definition of vectorial capacity presented here includes the word ‘potential’. If a malaria patient is present in the area, vectorial capacity is the number of cases that could potentially originate from this person. Vectorial capacity is a measure of the potential for malaria transmission in an area, and it is one of the characteristics and of the combined capabilities of anopheline mosquito population present in an area; malaria itself may not be present in the area. In other words, vectorial capacity can be calculated for regions which have anopheline mosquitoes but no malaria.

12.2.4 Derivation of a formula for vectorial capacity (C)

Exercise 12.3

Create a formula for vectorial capacity that considers the relation between the factors involved in transmission by reviewing the events in malaria transmission from one patient to another through mosquitoes.

Note: The following stages can be considered in malaria transmission:

- ▶ Stage 1: The primary case is bitten by a certain number of mosquitoes per day.
- ▶ Stage 2: A fraction of these vectors acquire the infection. Infection is transmitted by a proportion of mosquitoes that have sucked blood. (Not all mosquitoes will become infected by sucking blood from a malaria-infected patient and later produce sporozoites. Many variables affect this process resulting in a situation where the probability of transmission of infection to the insect is less than 100 %.)
- ▶ Stage 3: Some of the mosquitoes that have sucked blood survive the sporogonic cycle (the parasite's incubation period in the vector) and become infective.
- ▶ Stage 4: Some of the infective mosquitoes will live for a period of time during which they will bite a number of humans.
- ▶ Stage 5: A fraction of humans bitten by infective (sporozoite-carrying) vectors acquire the infection and go on to develop the disease – these are the secondary cases of malaria. It is important to remember that the disease does not develop in all bitten persons.

12.2.5 Relationship between vectorial capacity and basic reproduction rate

Exercise 12.4

- a. Write an equation for the relation between vectorial capacity and basic reproduction rate variables
- b. Define the possibility of recovery of a patient, or recovery rate, in a day "r".
- c. Is there a relation between a patient's recovery rate and the duration of disease?
- d. Keeping in mind the answers to questions (b) and (c), enter "r" in the relation between vectorial capacity and basic reproduction rate.

12.2.6 Derivation of a formula for basic reproduction rate (R_0)

Exercise 12.5

Based on the relationship between vectorial capacity (C) and basic reproduction rate (R_0), write an equation for the basic reproduction rate R_0 .

12.3 Vectorial capacity, basic reproduction rate, and control of transmission

A number of deductions concerning malaria control can be made from the formulae for vectorial capacity and basic reproduction rate.

Exercise 12.6

a. Identify for each control measure below the factor(s) affected.

Control measures	Factors affected (among m , a , p , n , $1/r$) ^a
Residual spraying	
Space spraying	
Source reduction	
Larviciding	
Reduction of human-vector contact	
Insecticide-treated mosquito nets	
Treatment of cases	

^a m = vector density in relation to human; a = vector's biting rate on humans; p = survival of the vector; n = duration of sporogony cycle; $1/r$ = duration of infectivity (in humans)

b. On the basis of formulae for C and R_0 evaluate the extent to which the variation in the different factors listed above affects the magnitude of the vectorial capacity or the basic reproduction rate.

c. Calculate C , given $m = 10$, $a = 0.5$, $p = 0.8$, $n = 10$. Calculate the effect on C of reducing either m , a or p by half. Why is a reduction of n not included in the exercise?

d. What can be concluded concerning the relative efficacy of the different control measures?

12.3.1 Identification of simplifying assumptions

Exercise 12.7

In deriving the formulae for vectorial capacity and basic reproduction rate, and in making deductions about control, some simplifying assumptions were made. What are these assumptions? Are they important, and if so, why? (see Learning Unit 11).

12.3.2 Measurement of intensity

Exercise 12.8

Working in small groups, consider successively the five kinds of "intensity" identified at the start of this unit. For each one, go through the following exercise:

a. Can it be measured?

b. If so, how?

c. Discuss with your colleagues the measurements in terms of:

i. *Technical feasibility*

ii. *Cost*

iii. *Reliability*

d. Can the concept – especially those of vectorial capacity and basic reproduction rate – be useful in the absence of the corresponding measurements?

12.3.3 Relationship between prevalence and incidence

Exercise 12.9

- Discuss (in the group) the relationship between prevalence and incidence.
- Express the relationship between prevalence and incidence as a formula.
- Give a numerical example. For example: if the incidence rate is 200/1000/year, and a "case" lasts on the average two months, what is the expected prevalence rate?

12.3.4 Qualitative relation between the different dimensions of intensity of malarial infection and its transmission

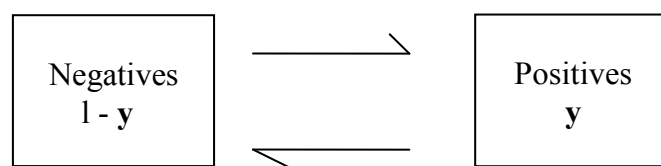
Exercise 12.10

Working in small groups, construct a diagram in which the five dimensions of intensity previously identified are connected by arrows indicating what determines what; you may need to introduce some other factors, perhaps the duration of infection, immunity?

Discuss with your colleagues the relationships between the parameters of intensity of malaria shown in the figure 12.1 provided by the tutor.

12.3.5 Quantitative relationship between prevalence and vectorial capacity

To examine the relationship between vector capacity and prevalence of disease, Ronald Ross divided the community into two groups – the ill group and the healthy group. In his model, each day a number of the healthy acquire malaria and a number of ill individuals are cured and return back to the healthy group. Note that drug treatment has no place in this model and it is assumed that the ill individuals recover once the 1–5 year course of the disease is over (recovery rate "r"). On the other hand, the healthy people become ill at a rate that is the product of the prevalence (represented by "y") multiplied by vectorial capacity (represented by "C"); his model can be represented as follows:



On this basis Ross defined the mathematical model of malaria as follows:

$$y_{(t+1)} = y(t) + y(t) C [1 - y(t)] - r y(t) \quad \text{FORMULA 1}$$

where

y = proportion of positives in the human population

$1 - y$ = proportion of negatives in the human population

C = vectorial capacity (per time unit)

r = recovery rate (per time unit)

(t) means "at time t "

$(t+1)$ means "at time $t + 1$ time unit"

The logic behind **formula 1** is as follows: the prevalence at time $(t+1)$ is equal to the prevalence at time "t", **plus** the new cases occurring in the interval and **minus** the old cases recovering in the interval.

Exercise 12.11

Working in small groups

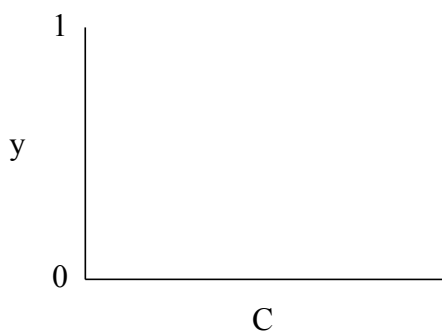
a. Discuss the components of **formula 1** and their relationship to each other.

If malaria in the region is in a state of equilibrium, i.e. the disease prevalence is neither rising nor declining. Derive a formula (**formula 2**) for y as a function of C :

$$y = 1 - \frac{r}{C}$$

FORMULA 2

b. Using **formula 2**, draw the relationship between vectorial capacity (**C**) and disease prevalence (**y**) in a graph. Note that in **formula 2**, prevalence is negatively related to recovery rate (**r**) and positively related to vectorial capacity (**C**). Compare this graph with figure 12.2 provided by the tutor.



c. Assuming $r=0.5$, what are the changes in y for each unit change in C ? Fill the following table:

C	y
0.5	
1.5	
2.5	

What should be y , if $C=0.25$? justify your answer.

d. Draw this graph in MS-Excel by simulating it for different rates of recovery and vectorial capacity.

e. Compare the graphs with figure 12.2. Discuss various sections of the graph and try to interpret and adjust it with different epidemiologic circumstances and conditions of malaria (study the ascending slope and plateau of the curve).

f. Discuss the point of intersection of the graph with the X axis.

g. Having established the relationship between vector capacity (C) and basic reproduction rate R_0 , prepare **formula 2** and the graphs according to the basic reproduction rate R_0 (discuss the graph and equation obtained).

h. What would be y for different values of R_0 in the following table:

R_0	y
0.5	
1	
2	

i. What should be the number of cases after four generation, if $R_0=2$ and the primary number of cases be 8? Re-calculate the number of cases for $R_0=0.5$.

In summary, the following can be deduced from the Ross model:

1. There is a non-zero critical value of vectorial capacity below which malaria cannot maintain itself in an area (C^*). Vectorial capacity does not have to reach zero, nor does the anopheline mosquito have to be completely eradicated in an area in order to eliminate endemicity. This implies that malaria could disappear without the elimination of all vectors.
2. There is no linear relationship between the prevalence of disease and vectorial capacity above the critical value stated for vectorial capacity. Near the critical value minor changes in vectorial capacity lead to major changes in prevalence or endemicity of malaria in the region, i.e. malaria is unstable in the region. But a little above the critical value, where the curve comes to plateau, even large changes in vectorial capacity will not affect endemicity and do not displace it, i.e. malaria is stable in the region. Stable malaria, in classifications of endemicity, is characterized by a high level of transmission and prevalence of disease without marked seasonal changes, and regardless of environmental events such as reduction or increase in rainfall in the region.
3. The danger of regional outbreaks is near the critical value where malaria is unstable. Consequently, problems in the health sector and malaria control are more pronounced in the area. In fact, it is near this critical value that vector density control has a significant effect on malaria control and elimination.
4. The critical value for vectorial capacity that is represented by C^* occurs when the vectorial capacity and recovery rate 'r' are equal. It can be concluded that the lower the recovery rate of malaria (or the longer lasting the infection), the higher is the vectorial capacity. Thus the critical vectorial capacity below which the transmission cycle is interrupted is lower for *P. vivax* than for *P. falciparum*.

Hint: $R_0=1=\frac{c}{r}$. Therefore, whenever $C = r$, R_0 is at the situation that the epidemics cannot occur. Therefore, when $r=C$, y will be zero. In this critical value we will have C^* .

12.3.6 The value of the vectorial capacity below which malaria transmission cannot be maintained

Exercise 12.12

Discuss in small groups why malaria transmission cannot maintain itself if C is below a certain value and complete the following exercises.

- What is the critical value of C below which malaria cannot maintain itself, i.e. C^* ?
- What is the critical value of the vector density (represented as m^*)?
- Calculate m^* for an efficient and an inefficient vector respectively, using the following numerical values

	r	n	a	p	m^*
Efficient vector	0.01	10	0.5	0.9	
Inefficient vector	0.01	10	0.1	0.5	

- Add on the graph (Fig. 12.2) the incidence rate, the entomological inoculation rate, and the proportion seropositive as functions of C or R_0 . Compare the group's graph with the one provided by the tutor (Fig. 12.3). Discuss the differences.
- What does the graph imply in terms of selection of measurement methods to describe malaria situations? Can a useful approximation of the vectorial capacity (or of the basic reproduction rate) be obtained indirectly, i.e. without actually measuring them?

12.3.7 Effects of a reduction in prevalence or in vectorial capacity

Exercise 12.13

Working in small groups, discuss the effects of a reduction in prevalence or in vectorial capacity, then complete the following exercise.

- If the prevalence of infection (or the "parasite reservoir") has been suddenly reduced to a low level by a single mass drug administration, what would be expected to happen to the prevalence after that?
- If the vectorial capacity has been suddenly and permanently reduced to a lower level, what would be expected to happen to the prevalence after that?

Ross used the model represented by **formulas 1** and **2** to explore these two questions, and reached conclusions which are generally accepted today; participants could try to do the same.

Formula 1 is easy to calculate on a pocket calculator, especially if programmable.

To explore question (a), use $C = 1$ and $r = 0.5$, and start at $y(0) = 0.5$; calculate $y(1) \dots y(5)$; change arbitrarily $y(5)$ to 0.1, calculate $y(6)$, $y(7)$, etc., and study the result – it may be helpful to plot the values on a graph.

To explore question (b), use $C = 1$ and $r = 0.5$, and start at $y(0) = 0.5$; calculate $y(1) \dots y(5)$; reduce C from 1 to $2/3$, then calculate $y(6)$, $y(7)$, etc. and study the result – again, it may be helpful to plot the values on a graph.

Compare the group's graphs with the ones provided by the tutor (Fig. 12.4). Discuss the differences.

12.3.8 Is there a place for models in planning malaria control?

Exercise 12.14

- a. Are any (or all) of the following statements correct?
 - i. Facts are preferable to models
 - ii. Models make questionable assumptions
 - iii. Models use questionable numerical values
 - iv. Models have failed – and will continue to fail – to make accurate predictions
- b. If some (or all) of the statements are correct, is there any place left for the use of models in planning malaria control?

12.4 Measuring the burden of malaria

Exercise 12.15

- a. Of the five concepts applicable to the “intensity” of malaria in terms of infection, which ones are applicable to malaria in terms of disease?
- b. The burden of malaria is due to which circumstances?
- c. Are there any other measurement(s) that could be applicable to the quantification of malarial disease in a population?
- d. How can the mortality from malaria be quantified?

LEARNING UNIT 13

Overview of stages in malaria programme phases

PART 3

Learning Objectives:

by the end, participants should be able to...

- Compare and contrast the concepts of malaria control, elimination and eradication
- Describe the different objectives for each phase of malaria programme

13.1 Phases of a malaria programme

In 2012, malaria transmission occurred in 99 countries in tropical and subtropical zones, spanning all continents of the world except Antarctica and Australia, with intensities of transmission that vary from very low to extremely high.¹ The objectives of malaria control programmes range from reducing the disease burden and maintaining it at a reasonably low level, to eliminating the disease from a defined geographical area and, ultimately to eradicating the disease globally.

History shows that new goals and targets for global malaria control and elimination must be realistic in order to avoid disappointment and disillusionment and the devastating implications of disease resurgence, as experienced in the past when intensified control efforts were interrupted. The prevailing state of health systems and the epidemiology of malaria must be taken into account in setting realistic targets.

Exercise 13.1

- a. Define malaria control, elimination, and eradication.
- b. Match the levels of malaria transmission (1, 2, 3 and 4) with the appropriate phases of malaria programme (a, b, c, and d) in the box below.

1. Areas where parasite rate (PR) has been reduced to < 1 malaria case/1000 population/ year	a. Control
2. Areas where malaria parasite rate has been reduced to < 5% among fever cases in health facilities	b. Elimination
3. Areas where transmission has been interrupted	c. Pre-elimination
4. High to moderate transmission	d. Prevention of re-introduction

- c. Illustrate the phases of malaria programmes on a separate sheet. Compare your diagram with Figure 13.1 provided by the tutor.

There are four different levels of malaria transmission as described in Table 13.1.

Table 13.1 Different levels of malaria transmission

Transmission level ^a	Characteristics ^b	
	Endemicity level	Parasite prevalence
Low transmission	Hypoendemic	≤ 10% in children aged 2–9 years
Moderate transmission	Mesoendemic	11–50% in children aged 2–9 years
High transmission	Hyperendemic	Constantly > 50% in children aged 2–9 years
High transmission	Holoendemic	Constantly > 75% in infants aged 0–11 months

a. WHO 2012. *Disease surveillance for malaria control: an operational manual*. Geneva, World Health Organization. http://www.who.int/malaria/surveillance_monitoring/operationalmanuals/en/index.html

b. WHO 1963. *Terminology of malaria and of malaria eradication. Report of drafting committee*. Geneva, World Health Organization.

¹ WHO 2012. *World Malaria Report*. Geneva, World Health Organization. http://www.who.int/malaria/publications/world_malaria_report_2012/en/index.html

13.2 Transition from malaria control to elimination

Countries are engaged in different phases of malaria programme according to the malaria transmission levels:

- ▶ **High to moderate transmission areas:** In areas where the geographical distribution of malaria cases is widespread and intensity of transmission is high, the prime objective is to reduce malaria mortality, morbidity and intensity of transmission. In these areas, the malaria control programme should make all possible efforts to achieve universal coverage of cost-effective preventive, diagnostic testing and treatment interventions. In addition, intensified monitoring and surveillance, and cross-border collaboration are critical to reduce the burden of malaria to consistently less than 5% parasite positivity rate among febrile patients with suspected malaria at health facility level or among people of all ages with current fever or history of fever in the past 24 hours identified in population based surveys.
- ▶ **Low transmission areas:** In some areas, natural conditions and/or control efforts have reduced the transmission intensity to low levels and localized geographical areas, allowing programme re-orientation towards elimination. The goal of the pre-elimination phase is to reduce the malaria burden to an incidence rate of less than 1/1000 people at risk at a sustainable level. This is achievable by perfecting the surveillance system and targeting of case management and vector control operations, in residual and new active foci. A notification system, and regulation of the private sector, must be established at this stage. In this phase, the subsequent aim is to halt local malaria transmission through targeted interventions to populations at risk in malaria foci.
- ▶ **Areas where transmission has been interrupted:** In these areas, the goal will be to prevent re-establishment of local transmission from imported cases. Once the entire country has been free from local malaria transmission for three consecutive years, the process for certification of the malaria-free status can be started.

Countries engaged in the different malaria programme phases

Of the 99 countries that were considered malaria-endemic in 2012, 79 countries are in malaria control phase; 10 countries are in pre-elimination phase; 10 countries are elimination phase. An additional 5 countries are in the prevention of re-introduction phase. During and after the Global Programme for Malaria Eradication, 30 countries were certified by WHO as malaria-free in the period up to 2012. In addition, 53 countries malaria never existed or disappeared without specific measures.

Moving from the control to the elimination phase requires changes in strategies. The priority of the malaria control phase is the achievement of universal coverage with preventive methods and access to treatment. Discuss the priorities of malaria elimination programmes in relation to:

- ▶ Detection of all malaria cases
- ▶ Prevention of onward transmission
- ▶ Management of malaria foci
- ▶ Management of importation of malaria parasites.

Elimination programmes require more advanced technical malaria expertise than control programmes, particularly in malaria epidemiology, entomology and surveillance. Most countries adopt the elimination strategy in a phased approach, targeting specific parasite species (e.g. *P. falciparum* first) or geographical areas. When the number of locally acquired cases becomes very low (e.g. below 100, 10 or even fewer nationwide), importation of malaria parasites from abroad becomes a greater threat, and prevention of reintroduction of malaria becomes increasingly important.

The differences in units of intervention show the significance of classifying patients on the basis of (i) source of infection/transmission, (ii) time (recent or very recent), (iii) location (a specific region), and (iv) mode of transmission (blood and/or mosquito). Malaria cases can be therefore classified in 5 groups as follows:

- ▶ **Induced:** a case resulting from contamination with infected blood
- ▶ **Imported:** a case contracted outside a given place
- ▶ **Relapsing:** a case of *P. vivax* or *P. ovale* contracted locally some time ago or detected after a period of unrecognized latency
- ▶ **Introduced:** a case contracted locally from an imported case
- ▶ **Indigenous:** a case contracted locally from any other category of cases, including other indigenous cases

Exercise 13.2

- a. Different malaria programme phases have different programme objectives. Specify in Figure 13.1 'main objectives' in each phase. Compare the results with the Figure 13.2 provided by the tutor.
- b. Do malaria programme phases differ in their (i) epidemiologic objectives and (ii) transmission objectives? Show these objectives on Figure 13.2. Compare the figure with the Figure 13.3 provided by the tutor.
- c. Based on Figures 13.3, what are the units of intervention in each phase of the programme?
- d. Working in small groups, prepare a flow chart illustrating the classification of malaria cases by origin of infection and compare it with Figure 13.4 provided by the tutor.
- e. Which type of cases are difficult to classify
- f. Using a copy of Figure 13.1 (to which 'milestone for transition to next programme type' has been added), state the most important data sources for measuring progress towards reaching a milestone. Compare the results with the Figure 13.5 provided by the tutor.

LEARNING UNIT 14

Surveillance system

Learning Objectives:

by the end, participants should be able to...

- Define the term *surveillance*
- List the uses of a surveillance system
- Give examples of a surveillance system's objectives
- Explain the connection between the objectives of a surveillance system and its ability to detect cases

14.1 Definition of surveillance

Surveillance in the context of malaria control programme is defined as ongoing, systematic collection, analysis and interpretation of disease-specific data for use in planning, implementing and evaluating public health practice. In the context of malaria elimination programmes, surveillance is that part of the programme designed for the identification, investigation and elimination of continuing transmission, the prevention and cure of infections and final substantiation of claimed elimination.¹

Data collection, analysis and reporting should guide necessary interventions in the health system. Interventions may include needs assessment, planning, malaria prevention and control and/or health programme² evaluation.

Surveillance is also carried out in the context of other public services, to monitor and improve the service concerned.

14.2 Uses of surveillance

Examples of surveillance in daily life

The city's traffic control can be considered a surveillance system. The relevant organizations continuously and systematically provide information on the traffic status with various tools (cameras set up in the city and/or traffic unit reports).

The important point is that the necessary interventions in traffic control are done on the basis of the data gathered in this surveillance system. For example, individuals are guided in choosing less crowded routes by hearing announcements on the radio about which routes have most traffic.

In public health, surveillance may be focused on a specific disease such as tuberculosis or malaria and/or intervention coverage such as the rate of use of bednets, compliance with the indoor residual spraying of insecticide etc. The distribution and density of vectors (such as different species of *Anopheles* mosquito) is part of malaria surveillance.

A public health surveillance system is usually designed to provide data for one or more of the following purposes:

1. **Provide baseline data:** Surveillance data can be used to determine baseline information on malaria cases and deaths, and also on risk factors such as rainfall.
2. **Set the programme's goals:** Surveillance can be used to gather information on prevalence and incidence for the design of health interventions.
3. **Identify the groups at risk:** Surveillance may be used identify areas or populations at increased risk of developing a disease.
4. **Evaluate the progress made by interventional programmes:** Surveillance data can be used to assess progress in reducing malaria cases and deaths.

¹ WHO 2012. *Disease surveillance for malaria elimination: an operational manual*. Geneva, World Health organization. http://www.who.int/malaria/surveillance_monitoring/operationalmanuals/en/index.html

² Health programme: a collection of activities carried out for the purpose of solving a health-related problem and/or promotion of an existing strategy.

5. Identify epidemics: Surveillance will permit the early detection of epidemics to enable containment efforts.

The different types of surveillance systems

Passive case detection (reporting of cases)

Passive case detection is the regular or periodic collection of data from case reports or registers from health facilities where patients seek treatment on their own initiative. The health facilities (public and private) include facilities for outpatient or inpatient services. However, some countries with inadequate health service coverage, or with mobile populations (e.g. immigrants, nomadic population), often organize mobile health services (outreach sessions) to reach remote communities on a regular basis. Malaria cases reported through such arrangements should be considered as passive case detection as the patients report for treatment.

In addition, many national programmes are establishing networks of community agents to diagnose and treat malaria cases through integrated community case management of childhood illnesses – iCCM, especially in areas with little access to formal fixed health facilities. In summary, data coming from public and private fixed health facilities, mobile clinics and community agents are considered from passive surveillance.

Active case detection (looking for cases)

Active case detection is an active search for malaria cases and diagnostic testing at the community or at household level, either through regular or random visits by health-care providers. Testing may be confined to patients with fever, or everyone may be tested (mass screening). Active case detection can be done to fill gaps in passive case detection systems (e.g. to detect cases in populations with limited access to services, such as migrant populations). This is sometimes known as ‘proactive’ case detection, in which a population is examined even though there may be no evidence of confirmed cases. Active case detection may also be undertaken in response to a confirmed case or cluster of cases, in which a defined population potentially linked to a confirmed case is identified, and symptomatic cases are tested (possibly with a RDT then by blood slide for confirmation) as well as asymptomatic cases (by blood slides only). This is sometimes known as ‘reactive’ case detection.

Sentinel site surveillance

Surveillance is based on the collection of data from a sample (random or non-random) of collecting sites as indicator data for the rest of the population. The purpose is to identify cases of a disease early in order to obtain indicative data about trends of the disease or health event. Standard case definitions and protocols must be used to ensure validity of comparisons across time and sites despite lack of statistically valid sampling.

The usual sources of data collected in surveillance systems

The sources for data collection are different, but mainly public and private health facilities such as hospitals, clinics and laboratories are used. It is important to remember that generally data are produced by the same people who provide service. Therefore, the data collection system should have the following characteristics:

- ▶ Simple to be carried out by workers who have not received special training
- ▶ Focused on the minimal core data to be collected
- ▶ Feasible and cost-effective

The characteristics of a surveillance system must be based on its objectives. If the objective is to detect an epidemic, the cases need to be identified rapidly and reported accurately. For detection of epidemics, the surveillance system should target patients and people at risk. On the other hand, if the objective is to monitor disease trends, the expected characteristics of the surveillance system will be different. These characteristics include timeliness of reporting such as monthly report versus weekly report.

The surveillance system's capacity to identify cases is assessed by 4 indicators: *Sensitivity*, *Specificity*, *Positive Predictive Value* and *Negative Predictive Value*. *Sensitivity* and *Positive Predictive Value* are the indicators of greater significance.

Consider the table below:

		Disease (and/or risk factor)	
		Present	Absent
Surveillance system	Reported	True positive	False positive
	Not reported	False Negative	True Negative

Sensitivity will be:

$$\frac{\text{True positive}}{\text{True positive} + \text{False negative}} = \frac{\text{True cases reported by surveillance system}}{\text{All cases in the population}}$$

The significance of the surveillance system's sensitivity lies in its ability to identify the cases in the population. The surveillance system's Positive Predictive Value is as follows:

$$\frac{\text{True positive}}{\text{True positive} + \text{False positive}} = \frac{\text{True cases reported by surveillance system}}{\text{All cases reported by the surveillance system}}$$

The Positive Predictive Value is important when interventional measures must be taken, e.g. if extensive case finding is to be undertaken when a single case of measles is reported then the Positive Predictive Value of the measles surveillance system should be high.

Consider the design of a surveillance system for SARS or plague, and the necessary predictive value of the surveillance system. The more expensive and complex are the measures following reporting of the cases, the higher should be the predictive value of the surveillance system.

Definition of the terms

An essential initial step in a disease surveillance system is the establishment of the case definition. The definition must be practical and clear. Figure 14.1 shows classifications used for definition of the cases in malaria control programmes.

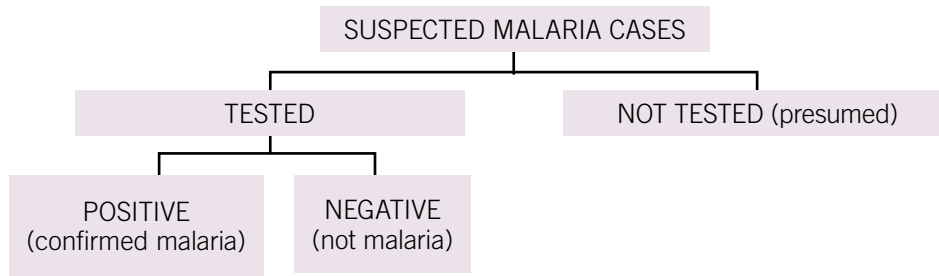


Figure 14.1 Flow diagram of malaria case definitions

U14

Suspected malaria cases: Patient illness is suspected by a health worker to be due to malaria. The criteria for suspected malaria usually include fever or a history of fever, but the precise criteria vary according to local circumstances and are established by the national malaria control programme. All suspected cases of malaria are tested by either microscopy or an RDT.

Tested malaria case: Suspected malaria case that received a laboratory examination for malaria parasites by microscopy or RDT.

Not tested malaria case (presumed malaria): Suspected case that did not receive a laboratory confirmation of malaria diagnosis but was nevertheless treated for malaria.

Positive case (confirmed malaria): Suspected case that was positive after a laboratory examination for malaria.

Negative case (not malaria): Suspected case that was negative after a laboratory examination for malaria.

Among all suspected malaria cases, the most specific for the diagnosis of malaria is confirmed malaria. Presumed cases include many febrile cases which do not have malaria infection.

Case definitions and the health system: Health care is usually provided by different health workers at different levels of health care system: at community level by community health workers and/or volunteers, at primary health care levels (clinics/health centres at periphery) by clinicians/health workers and at referral facilities (district or provincial hospitals) by physicians. If deemed necessary, the patient will be referred to hospital level with more specialized health care. The definition of cases is adapted to the skills and facilities of the health care system. Case definitions are of greater sensitivity in peripheral levels: all possibly affected cases are registered and reported to the surveillance system and the specificity is low. Conversely, at higher levels of service delivery such as hospitals, both sensitivity and specificity are high and the possibility of a false positive is reduced to a minimum.¹

¹ Note that a similar method is used in the diagnosis of a disease. Questions with high sensitivity are used first. In these cases if the questions are negative then it can be known with certainty that the disease does not exist. Eventually high quality tests are used in the differential diagnosis for approving the diagnosis which has high positive predictive value.

Performance of the health-care providers in detection of cases can affect the sensitivity of the surveillance system at each level.

In addition, the important factors affecting the surveillance system's performance are as follows:

- a. *People's seeking of medical care*
- b. *Performance of diagnostic tests*
- c. *Registration and reporting of cases*

Two important points should be noted regarding case definitions for surveillance systems:

- a. *The case definition may differ at different levels of the health care systems.*
- b. *Different countries may not use the same case definitions in their surveillance systems.*

Therefore disease definitions and/or special conditions in the country's service delivery may not be exactly identical, as the following example illustrates.

The presence of parasitaemia has different significance for the malaria case definition in different settings. In areas of high malaria transmission, detection of parasitaemia is not always predictive of malaria illness. Because of acquisition of immunity, a significant proportion of the population may have parasitaemia regardless of the main cause of the illness. On the contrary, in many low transmission areas, parasitaemia is often associated with clinical symptoms.

Some important concepts in surveillance

The surveillance system

The purpose of surveillance is to guide public health action.

Figure 14.2 shows the formation of the surveillance system. The first step is to identify the surveillance system's objectives, after which the case definitions and necessary staff can be determined.

In general, the objectives of surveillance systems for communicable diseases focus on identification and reporting of cases, but for non-communicable diseases, notification and distribution of risk factors are also of great importance. Surveillance programmes for non-communicable disease risk factors such as smoking, alcohol abuse, nutrition, physical activity,

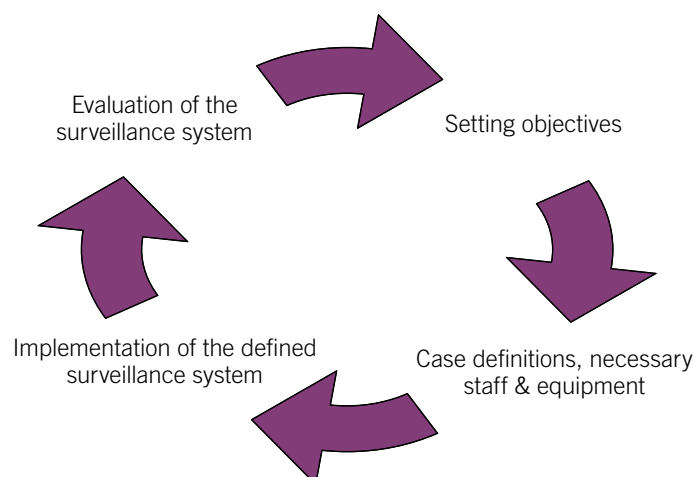


Figure 14.2 The surveillance system cycle

obesity, blood pressure, blood sugar and cholesterol are carried out in many countries. Risk factors are also important for a number of communicable diseases, e.g. behavioural surveillance in HIV/AIDS programmes.

Timeliness

For data to be useful, they should be timely. Every effort should be made to report the data promptly on a regular basis. Data should be examined and processed without delay at each level.

Feedback

For a system to operate well, those collecting the data need to receive feedback. Many countries have surveillance systems in place for a variety of diseases. The following (Figure 14.3) is the typical flow of information which is present in most surveillance systems.

Feedback is essential to motivate those actually collecting the data and to provide health care providers with data from other geographic areas. Feedback is also useful for planning purposes, especially in decentralized systems. The reporting system is strengthened if suitable feedback is given to health workers involved in reporting on diagnosis and treatment (private and public sector), health managers, and to the public.

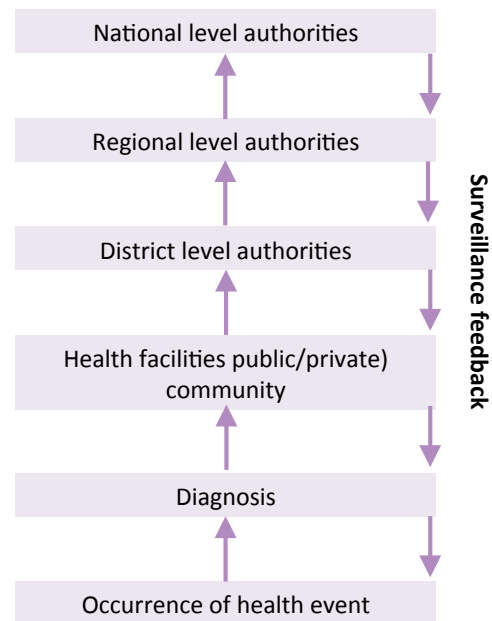


Figure 14.3 Flow of information in the surveillance system

14.3 Evaluation of the surveillance system

Evaluation of the surveillance system addresses the following questions:

- a. *Is the surveillance system necessary?*
- b. *If necessary, is its performance satisfactory?*

The function of surveillance system includes the following:

- ▶ identify the areas or population groups most affected by malaria;
- ▶ identify trends in cases and deaths that require additional intervention, e.g. epidemics; and
- ▶ assess the impact of control measures.

The performance of the surveillance system is evaluated in 4 stages:

1. Description of the surveillance system
2. Determining the benefit (usefulness)
3. Examining its characteristics
4. Evaluation of resources

14.3.1 Description of the surveillance system

This stage requires a description of the following:

- ▶ The events under surveillance (disease, risk factor ...)
- ▶ Practical case definitions
- ▶ The population covered
- ▶ The surveillance system's goals (diagnosing epidemics, monitoring disease trends ...)
- ▶ Data flow, including:
 - ▶ Who completes the form?
 - ▶ How is the data reported and collated?
 - ▶ Where does data analysis take place?
 - ▶ Is feedback provided?
 - ▶ Are the surveillance reports distributed?
 - ▶ At what intervals are data gathered?

14.3.2 Determining its benefit (usefulness)

The significance of the surveillance system lies in the utilization of its results. It is important to assess:

- ▶ Who are the users of the information?
- ▶ What measures are taken on the basis of the surveillance reports?
- ▶ Are the data submitted appropriately and adequately to the decision-makers?

14.3.3 Examining its characteristics

It is important to evaluate the surveillance system in relation to the following attributes:

- **Simplicity:** the data entry and reporting should be easy to carry on
- **Flexibility:** the system should have flexibility to collect new or different information as required
- **Acceptability:** the system should be well accepted by the people who collect and use the data. People's willingness to report and participate in the surveillance will ensure its success.
- **Sensitivity and positive predictive value:** the system should detect a high percentage of cases. In addition, of the persons identified by the surveillance system as having the disease, a high proportion actually have the disease. These are performance indicators of a surveillance system for identification of cases.
- **Timeliness:** It is important to have access to data on time to contribute to decision-making. Therefore the time spent on each stage of surveillance is important.
- **Representativeness:** the findings from the surveillance system should be representative of the population covered by the system, in relation to time and geographical distribution taking in to the source of data referring to the public sector hospital wards, community services etc.

- **Completeness:** The surveillance data should be complete, in terms of data entries and number of facility reports per expected reporting period.
- **Ethical considerations:** It is important to ensure that information on individuals remains confidential.

14.3.4 Evaluation of resources

The costs incurred in carrying out the surveillance activities must be specified. These expenses relate to:

- ▶ Human resources
- ▶ Equipment and supplies

Exercises

Evaluation of a surveillance system

You have been assigned to the Office of Statistics within the Ministry of Health for a 3-month period to make an evaluation of the existing surveillance system – the government is considering making the system more useful for decision-makers.

You decide to follow the data along the chain of reporting, beginning at clinic level, through the District Medical Officer (DMO) and Regional Medical Officer to the Office of Statistics and the Minister. You decide to examine the chain of reporting in a particular district where you used to work and still know many of the health officers there.

You meet with the Chief of the Statistics Office in the Ministry of Health, who says: “The system was established by the British, and we still use the same form we were using when I started working here 20 years ago. In the late 1990s, the Minister decided to add 6 diseases to the list. We now collect data on 43 different diseases by sex for 3 different age groups”.

Asked what problems he sees in the system, he replies, “Nobody seems to care much. It takes at least 9 months to get the reports from the regions. By the time we get all the data and put our reports together, they are out of date. I sometimes wonder if anyone ever makes use of them”.

He says he will be happy to help and gives you a copy of the most recent annual report, which was sent out last month to all district and regional medical officers. This contains data for 2001, although we are now in 2006. It has over 200 pages, with tables of each disease by reporting site, sex, age, region and district; without graphs or text.

In the district you visit a hospital, a clinic and two smaller rural dispensaries. All the health personnel interviewed tell you that they learned how to fill out the forms as part of their initial training, but have no official guidelines on how to fill them out, and their supervisor rarely checks their work. You do an audit of the past month and find that for one of the dispensaries the figures in the report differ markedly from those in the register.

You ask the health workers what happens to the data after they are sent to the district level. All say they don't know; that is the last time they ever see the data. One of them says, “I think that the forms just sit on the DMO's desk and after a while he throws them away. This surveillance system is just useless paperwork that keeps me from more important work like seeing my patients”.

You then visit the DMO. He explains that filling out forms is a big part of his job. He fills out 8 forms a month (surveillance report, hospital reporting forms, essential drugs list, number of vaccines administered, sanitation worker report, supplementary food distribution form, hospital budget form, clinic budget form). Every month he plans to spend a little more time on surveillance but never gets around to it. He is aware that some of the clinics do not report routinely and that the numbers sometimes look suspicious, but he does not have time at the moment to fix the problem.

When asked how he uses the surveillance data, he admits he does not use them for anything. He shows you the 2001 report he just received from the Ministry and says, “How can you make any sense out of this jumble of numbers?” Asked if he has ever used surveillance to detect an epidemic in the district, he says if there is a big outbreak he usually hears about it, although sometimes it is too late to do anything. He discovered a meningococcal meningitis epidemic last March when 11 cases showed up in the district hospital on the same day. When he later reviewed the surveillance records, he found that in January and February the number of cases had been 3 times higher than they had been in January and February of the previous year.

The Regional Medical Officer repeats many of the concerns expressed by the DMO. She states that the data might be useful for monitoring trends in priority diseases. Every time she looks at the annual report, however, there seem to be more and more cases of everything, even those diseases for which she knows there are good control programmes. Even if she could work out what was going on, it is difficult to make programme decisions using information that is 4 years old or more.

Finally, the assistant to the Minister of Health tells you that he remembers from his primary health care courses that surveillance is a good thing; however, he and the Minister do not really make use of surveillance data because they think that these data are old and rather unreliable. The information is rarely used in health planning for the country; they tend to rely more on disease prevalence data collected as part of a national health survey in 1995. He hopes that you will work out a way to get more timely information, especially since this could be useful in following the progress of the new primary health care programme. As part of the bilateral funding agreement for this project, a modest amount of money will be set aside for improving disease surveillance.

Exercise 14.1

Identify the problems you consider to be present within the system in terms of :

- ▶ Data collection
- ▶ Data analysis
- ▶ Use of information
- ▶ Relevance
- ▶ Feedback

Exercise 14.2

For three of the problems that you have identified, suggest a solution.

LEARNING UNIT 15

Indicators for monitoring and evaluation of malaria control programmes

Learning Objectives:

by the end, participants should be able to...

- Describe the importance of monitoring and evaluation
- Explain the difference between monitoring and evaluation indicators
- Give suitable examples of input, process, output, coverage and impact indicators
- Explain the relation of indicators with global objectives of the malaria control programme, and also their internal relationships

15.1 Monitoring and evaluation

An important managerial task is to assess whether the programme is proceeding as planned and is reaching its goals. Hence monitoring and evaluation are key components of programme management.

The *goal* of a national monitoring and evaluation system is to provide reliable information on progress in controlling malaria in the country.

The specific *objectives* of a national monitoring and evaluation system can be summarized as follows:

- ▶ To collect, process, analyse, and report on malaria-relevant information
- ▶ To verify whether activities have been implemented as planned, to identify problems and address them in a timely manner
- ▶ To provide feedback to relevant authorities to ensure accountability and to improve future planning
- ▶ To document periodically whether planned strategies have achieved expected outcomes and impact

Usually, the different stages of implementation of a programme – from provision of resources to reduction of burden of disease – are indicated by the terms input, process, output and impact (Fig. 15.1).

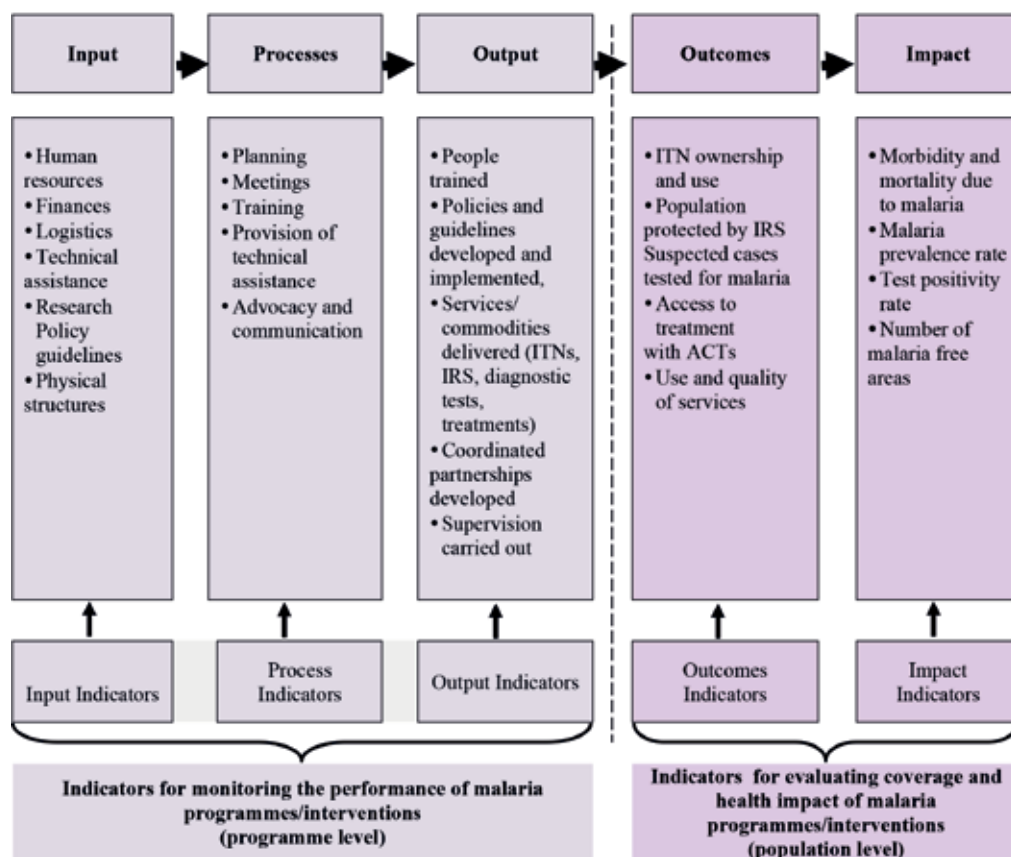


Figure 15.1 Monitoring and evaluation framework

15.2 Indicators

Exercise 15.1

- Give an example of indicators for each stage (input, process, output and impact) of the malaria control programme.
- List five measurements of intensity of malaria transmission (e.g. rates, etc.) as discussed in Learning Unit 13.
- Are these measurements enough for assessment of the malaria programme?

Monitoring and evaluation should cover all aspects of malaria implementation to be informative for decision-making, e.g. showing burden of malaria as well as logistics of the programme.

A good indicator has the following characteristics:

- ▶ **Validity:** The indicator should be able to assess its target with precision, i.e. with high Sensitivity and Specificity.
- ▶ **Reliability:** Upon repeated measurements of a single state the value should not vary greatly.
- ▶ **Simplicity:** The data required for indicators should be easy to gather.
- ▶ **Cost:** The cost for gathering the information for the indicators should be locally reasonable.
- ▶ **Representativeness:** The indicator must represent the target population, and should not be affected by selection bias.
- ▶ **Consistency:** Stability of the indicator over time allowing to study changes over time.

Finally, the set of indicators chosen should be **measurable and feasible**.

- Did the measurements introduced in the Learning Unit 13 on 'Intensity of Malaria' meet these criteria?

15.3 Difference between monitoring and evaluation

Indicators are used for monitoring and evaluation of a programme. It is important to know the difference between monitoring and evaluation.

Monitoring is the *routine* tracking of the key elements of programme/project performance over time (usually inputs and outputs). Monitoring reports provide information on progress made in the implementation of planned activities and the constraints and/or bottlenecks that have been faced in implementation of those activities. Monitoring helps programme or project managers determine which areas require greater effort and identify areas which might contribute to an improved response.

Evaluation is the *periodic* assessment of the change in targeted results related to the programme or project intervention. In other words, evaluation attempts to *link* a particular output or outcome directly to an intervention after a period of time has passed. Evaluations can be used to link any two parts of the monitoring and evaluation framework (inputs, processes, outputs, outcomes, or impact), e.g. evaluation of whether financial inputs are effectively generating the

desired training or service deliveries. Evaluation thus helps managers to determine the value of a specific programme or project.

Usually, monitoring indicators measure *inputs, process and outputs*, while evaluation indicators assess *outcome and impact* of interventions. The output is an immediate result of the interventions, while outcome is a more distal result of the interventions and it can be determined at whole target population level. This is the reason that the coverage is used interchangeably or instead of outcome in this categorization.

Exercise 15.2

- List some of the indicators for the stages from Input to Impact for ITN intervention.
- Is there any difference in requirement for indicators at different levels (regional, national and international)?

15.4 Monitoring and evaluation objectives and methods

The objectives and the methodology used in monitoring and evaluation are different. In general, evaluations are more difficult in view of the methodological precision needed: without this, wrong conclusions on the value of a programme or project can be drawn. Evaluations are also more costly, especially outcome and impact evaluations which often require population-based surveys or rigorous designs.

Evaluation must assess the programme goals. Below are the goals and targets set in the Global Malaria Action Plan and Millennium Development Goals for malaria control at the global level and type of indicators (Box 15.1).

Box 15.1 The goals, targets and indicators for malaria control at global level		
Initiative	Target	Type of indicator
GMAP ^a	• Reduce global malaria deaths to near zero	Impact
	• Reduce global malaria deaths from 2000 levels by 75% in 2015	Impact
	• Achieve universal access to and utilization of preventive measures (100% of population at risk)	Outcome
	• Achieve universal access to case management (100% of suspected malaria cases are tested and those confirmed are treated with appropriate and effective antimalarial medicines)	Outcome
WHA ^b	• Reduce global malaria deaths from 2000 levels by 75% in 2015	Impact
	• Reduce global malaria cases from 2000 levels by 75% in 2015	Impact
MDGs ^c	• Target 6: Have halted and begun to reverse the incidence of malaria and other major diseases	Impact

^a Global Malaria Action Plan; ^b World Health Assembly 2005; ^c Millennium Development Goals

15.5 The purpose of different types of indicator

Impact (or epidemiological) indicators describe the size of the malaria burden in a country.

Coverage indicators measure the extent to which *implementation* of effective interventions meets the need for programme interventions at population level.

Performance indicators measure the extent to which *supply* meets the *need* of programme interventions, usually at the service delivery point.

Exercise 15.3

a. Table 15.1 shows some of the malaria indicators. State the purpose of each indicator as either monitoring performance, coverage or impact evaluation.

Table 15.1 Some of the malaria indicators and their targets¹

	Indicator	Target	Purpose
1	Confirmed malaria cases (microscopy or RDT), per 1000 persons per year	Reduction in cases by 75% by 2015 compared to 2000	
2	Inpatient malaria death per 1000 persons per year	Reduction in deaths by 75% by 2015 compared to 2000	
3	All-cause deaths in < 5 children per 1000 <5 children per year (<i>for high-transmission areas</i>)	Reduction of global malaria deaths to near zero by end 2015	
4	Proportion of individuals who slept under an ITN the previous night	100%	
5	Proportion of population at risk protected by IRS in the last 12 months	No specific target set	
6	<i>In moderate to high transmission areas:</i> Proportion of women who received three doses or more of intermittent preventive treatment (IPT) during their last pregnancy	100%	
7	Proportion of suspected malaria cases that receive parasitological test	100%	
8	Proportion of confirmed malaria cases that received first-line antimalarial treatment according to national policy	100%	
9	Proportion of health facilities without stock-outs of first-line antimalarial medicines, ITNs and diagnostics, by month	100%	
10	Percent of districts reporting monthly numbers of suspected malaria cases, number of cases receiving a diagnostic test and number of confirmed malaria cases	No specific target set	

b. Considering these indicators, what are the main interventions/strategies of malaria control?

c. In Table 15.2, suggest indicators for each category and corresponding intervention.

¹. WHO (2012). *World Malaria Report*. Geneva, World Health Organization. http://www.who.int/malaria/publications/world_malaria_report_2012/en/index.html

Table 15.2 WHO indicators according to the steps (Input → Impact) of Monitoring and Evaluation

Intervention	Input/Process	Output	Outcome(coverage)	Impact
Insecticide Residual Spraying (IRS)				
Insecticide-treated mosquito nets (ITNs)				
Case management				
Intermittent preventive treatment (IPT) (only in moderate to high-transmission areas of sub-Saharan Africa)				

d. Why is there only a single box for impact indicators as opposed to the box per row?

15.6 Interventions and indicators by programme phase

In practice, different countries implement different strategies for malaria control based on programme phases. That is why their indicators are also different. Table 15.3 summarizes interventions/strategies applicable to the different programme phases.

Not all of the indicators listed in Table 15.1 should be measured in all countries. Indicators 3 and 6 are specifically used in regions with moderate to high transmission and those countries in control programme phase. However, several of these indicators provided are applicable at a national level and beneficial for decision-making. And, based on country-specific programme activities, national programmes need to develop appropriate monitoring indicators for malaria control.

Another well-known indicator is the Annual Parasite Index (API), with which is calculated as: confirmed cases during 1 year/population under surveillance × 1000. API is the most commonly used indicator for estimating the actual intensity of malaria transmission. Various countries use API for comparing the risk between cities, provinces and/or countries if the diagnostic coverage is high and kept fairly constant. When percentage of suspected malaria cases that are tested is unknown or inconsistent (<80–90% over time) then it is difficult to interpret trends using this indicator.

Table 15.3 Interventions and strategies by programme phase

Programme phase		Intervention/strategy specific to different phases
Control	Moderate to high transmission	<p><i>Surveillance</i></p> <p><i>Prevention</i></p> <p>ITNs/LLINs, especially for all of the at risk population</p> <p>IRS where appropriate</p> <p>Intermittent preventive treatment in pregnancy (IPTp) in moderate-high transmission areas in sub-Saharan Africa</p> <p>Intermittent preventive treatment in infancy (IPTi) in moderate-high transmission areas in sub-Saharan Africa</p> <p>Seasonal Malaria Chemoprevention in areas with highly seasonal transmission in the Sahel subregion of Africa</p> <p><i>Treatment</i></p> <p>Prompt diagnosis and effective treatment, including at the community level where appropriate</p>
	Low transmission	<p><i>Surveillance and epidemic response</i></p> <p>Surveillance; epidemic response capacity</p> <p><i>Prevention</i></p> <p>IRS</p> <p>ITNs/LLINs</p> <p><i>Treatment</i></p> <p>Prompt diagnosis and effective treatment of suspected cases</p>
Pre-elimination (transition phase)		<p><i>Surveillance and epidemic response</i></p> <p>Surveillance; epidemic response capacity</p> <p><i>Focalized prevention</i></p> <p>IRS</p> <p>ITNs/LLINs</p> <p><i>Treatment</i></p> <p>Prompt diagnosis and effective treatment of suspected cases</p>
Elimination and prevention of reintroduction		<p><i>Surveillance and epidemic response</i></p> <p>Active surveillance to inform and guide active case detection and epidemic response (if area is receptive to malaria transmission)</p> <p><i>Prevention</i></p> <p>Chemoprophylaxis for travelers going to malarious areas</p> <p><i>Treatment</i></p> <p>Prompt diagnosis and effective treatment in confirmed cases</p>

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Points to note in comparing the API of different regions:

- ▶ Malaria definitions should be the same, e.g. reported malaria should be defined as confirmed through laboratory testing
- ▶ Reports are usually the result of active and passive case-finding but these should be reported separately as dilution by either of them may affect the trend of the rates.
- ▶ If cases are compared in two regions, and the active case-finding differs, then the API of these two regions can no longer be compared. In other words, if the risk of malaria is the same in two regions, but case-finding is more active in one, then its API will be estimated lower.
- ▶ In order to overcome this shortcoming, another indicator is used: the Annual Blood Examination Rate (ABER). API is useful for monitoring trends when the annual blood examination rate (ABER) is constant and higher than 10%. ABER is the number of slides examined/population at risk. When Region A and Region B have the same API, and the ABER is lower in Region B, then Region B has higher malaria transmission. This is because the same numbers of infected cases per 1000 population are found with less case detection efforts in Region B.

Exercise 15.4

- a. *Do interventions have the same applicability and impact in different programme phases?*
- b. *Considering the current programme phase and epidemiological situations in your country, identify the key indicators required. Prepare a table of indicators similar to Table 15.1.*

Annex 1 provides details about core indicators for malaria control.

LEARNING UNIT 16

Data collection methods

Learning Objectives:

by the end, participants should be able to...

- Name different sources of data collection related to the main indicators of malaria
- Specify which source is important for each group of indicators (performance, coverage and impact)
- From a numerator and denominator of an indicator, explain from which source it should be calculated and why that source is chosen.
- Name the main types of surveys that can estimate coverage indicators at a national level

16.1 Sources of information

Three categories of indicators were studied in Unit 15 to monitor:

1. Impact
2. Coverage
3. Performance

The sources of data collection for calculation of epidemiologic indicators can be classified in the following groups:

- ▶ Disease surveillance
- ▶ Health Information System (routine and logistic data)
- ▶ Surveys (household, health facility)
- ▶ Vital registration
- ▶ Meteorological monitoring (see Learning Unit 19 for details on this)

Exercise 16.1

The following Table 16.1 is a modified form of Table 15.3 in Unit 15, with one additional column.

- a. Identify the measurements for the impact indicators of the corresponding interventions.
- b. Define the numerator and denominator for impact indicators (morbidity and mortality).
- c. What is the source of the data elements for the numerator of impact indicators?

Table 16.1 Indicators for each Monitoring and Evaluation category and corresponding interventions

Intervention	Monitoring Performance		Evaluation		
	Input/ Process	Output	Outcome (coverage)	Impact	
				Morbidity	Mortality
Insecticide Residual Spraying (IRS)					
Insecticide-treated nets (ITNs)					
Case management					
Intermittent preventive treatment (IPT) in moderate-high transmission areas in sub-Saharan Africa)					

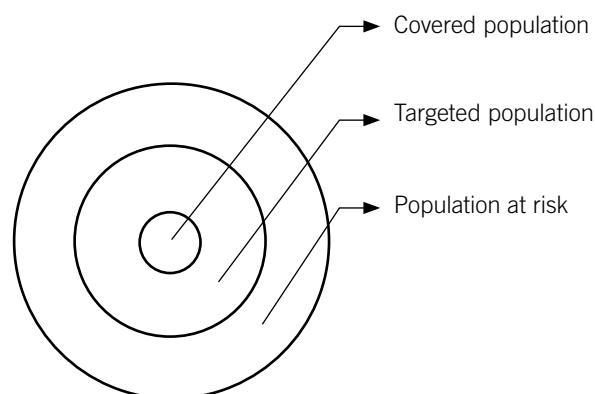


Figure 16.1 Representation of populations related to malaria control

activities and that is why they target specified populations. The targets differ according to whether the interventions are preventive or curative. Where primary prevention is concerned, the target is the population at risk, whereas for treatment the target is those with malaria.

There are several different concepts of “population” related to malaria control, as represented in Figure 16.1:

1. Population in areas where both vectors and malaria parasites are currently present
2. Target populations for interventions:
 - ▶ *Universal*: covering total population at risk living in areas where malaria is endemic (assuming unlimited resources)
 - ▶ *Targeted*: limited to the more vulnerable groups in the population at risk (planned based on available resources)
 - ▶ *Covered*: population covered by programme implementation (e.g. population actually covered by IRS this year)
 - ▶ *Access*: population which has access to the programme interventions

This ‘**population at risk**’ will be used as the denominator to calculate national malaria incidence rates. In high/moderate transmission countries, often the population at risk and the target populations are similar for calculating rates and estimating the population targeted for treatment, ITN, and IRS. In low-transmission countries, target populations for each intervention (ITN, treatment, IRS) may be different. The number of persons targeted for ITN may be different from those targeted for IRS. This is because areas targeted for ITN and for IRS may vary depending on suitability or other operational factors. A national programme may decide to make rural populations eligible for IRS but not urban populations (because of acceptability). In another country, the contrary may be true if the rural population is highly dispersed or is too mobile to conduct IRS.

Exercise 16.2

- a. In evaluating coverage and performance indicators, explain who is responsible for delivering malaria interventions.
- b. Explain how data related to coverage of ITN, IRS, diagnosis, treatment and IPTp (in Table 16.1) are collected.
- c. Using copy of the Table 16.1, provide the data collection sources for the indicators of the corresponding interventions. Compare your table with Table 16.2 in the Guide for Tutors.

16.2 Surveillance and survey

Exercise 16.3

- Describe the applications of survey and surveillance in malaria control.
- Compare the applications of survey and surveillance in relation to the different programme phases using Table 16.3. (Each participant should work separately with this table.)

Table 16.3 Applications of surveys and surveillance in malaria programmes

Programme phase	Objective	Surveillance		Survey	
		Question to be answered	Indicators/ data elements	Question to be answered	Indicators/data elements (e.g. use LLIN as intervention)
Control					
Pre-elimination					
Elimination					
Prevention of reintroduction					

- Which data are required in a surveillance system for patients?

Samples of surveillance forms and registers are provided in Annexes 2 to 9. Note that the data collected in surveillance systems are in two forms: individual records and aggregated data.

- Should data for surveillance be collected in aggregated form and or as data for each individual (case-based)?

The rationale, objectives and applications of surveillance and survey therefore differ by programme phase (epidemiologic conditions) as well as by transmission levels.

Exercise 16.4

Compare the characteristics of malaria surveillance in the different transmission settings and programme phases using Table 16.4.¹

¹ WHO 2012. *Disease surveillance for malaria control: an operational manual*. Geneva, World health Organization. http://www.who.int/malaria/surveillance_monitoring/operationalmanuals/en/index.html

Table 16.4 Characteristics of malaria surveillance in different transmission levels and programme phases (control and elimination)

Characteristics	Guide for responses ^a	Control phase		Elimination phase
		High & moderate transmission	Low transmission	Very low transmission
Incidence				
Cases and deaths	Common, less common, sporadic			
Temporal variation	Limited, variable			
Geographical variation	Limited, heterogeneous, focal			
Fevers (proportion due to malaria)	Large, small, very small			
Health facility attendance (proportion due to malaria)	High, low			
Vectors	Efficient, inefficient			
Programme objectives	Mortality reduction, case reduction, eliminate transmission			
Surveillance system				
Resources	Low expenditure per head, resources to investigate cases			
Data recording	Aggregate numbers, lists of inpatient and deaths, lists of all cases, case details			
Investigation	Inpatient cases, all cases, individual cases			

^a second column of Table 16.4 contains possible responses which the participants should use to fill columns 3, 4 and 5.

16.3 Core analyses

There are five (or six if more than one species of malaria is present) core analyses recommended by WHO for use by programme managers in moderate to high malaria transmission areas.¹

These core control graphs are on (i) malaria incidence rates, (ii) proportional malaria incidence, (iii) general patient attendance, (iv) diagnostic activity, (v) quality of diagnosis and reporting, and (vi) percentage of cases due to *P. falciparum*. Each month, districts should update these graphs showing trends in malaria incidence and other indicators. The core graphs can be discussed at monthly and quarterly performance assessments, and during supervisory visits. Health services without inpatient facilities can use graphs pertaining only to outpatient cases. Depending on the epidemiological setting, the graphs may be disaggregated by age.

¹ WHO 2012. *Disease surveillance for malaria control: an operational manual*. Geneva, World health Organization. http://www.who.int/malaria/surveillance_monitoring/operationalmanuals/en/index.html

Exercise 16.5

Working in small groups, summarize the application and interpretation of each of the following 6 core surveillance graphs over time.



Exercise 16.6

a. What differences should be considered in designing surveillance systems when the rate of transmission is decreasing from high to low level?

Note: consider the following issues for the comparison between high and low transmission areas regarding surveillance systems:

- ▶ The phase of malaria programme, target for the programme, distribution of malaria foci
- ▶ Proportion of malaria diagnostic testing and treatment delivered:
 - a. at community level
 - b. in the private sector
- ▶ Number of cases
- ▶ Type of patients (inpatients and or outpatients) which have malaria
- ▶ Age pattern in cases

- ▶ *Plasmodium* species, proportional identification in malaria cases
- ▶ Information technology platform(s) available

b. Based on the differences identified above, what are the parameters of surveillance in low-transmission settings?

Note: consider the following items to describe the characteristics of the surveillance system.

- ▶ Level of analysis (district/health facility catchment area)
- ▶ Level of details on individual cases (inpatients versus all cases)
- ▶ Aggregate data gathering versus individual case reporting
- ▶ Any other features

16.4 Expected impact of improved diagnosis and treatment of malarial illness

Exercise 16.7

a. Suppose that in an area of high transmission of *P. falciparum*, a programme of improved diagnostic testing, treatment and reporting of malarial illness, and of severe malaria is introduced. Indicate in Table 16.5 the changes to be expected in the various variables listed. Present separately (i) what you expect in reality and (ii) what you expect to receive in reported information. Indicate expected changes by arrows. If you wish to indicate the change expected in other variables, add them to the list.

Once Table 16.5 is completed, compare it with the one provided by the tutor. Use the following symbols: (no change \rightarrow); (increase \rightarrow); (decrease \rightarrow).

Table 16.5 Expected impact of improved diagnosis and treatment of malarial illness

Variables	Expected change	
	In reality	Reported information
Incidence of infection		
Prevalence of infection		
Incidence of disease		
Prevalence of disease		
Incidence of severe malaria		
Death rate (all causes)		
Malaria mortality rate		
Case fatality rate of malaria		
Case fatality rate of severe malaria		

b. What are the epidemiological and operational objectives of a programme of diagnostic testing and treatment of malaria?

Table 16.6(a) lists numbers that could be used for the calculation of indicators. Note the distinction between real – but unknown – numbers, and the accessible numbers listed in Table 16.6(b). The purpose of the table is not to recommend the measurement/calculation of all numbers/indicators listed but to help the participants to discuss the relationship of indicators to reality.

Table 16.6(a) Potentially relevant numbers

Real numbers (unknown)	Numbers that are (or can) be known (and can be used instead of the real numbers)
a. Number of cases of malarial illness	g. Number of cases treated as malaria ^b
b. Number of cases of severe malaria	h. Number of cases treated as severe malaria ^b
c. Number of deaths due to malaria	i. Number of deaths attributed to malaria
d. Population at risk ^a	j. Estimated population at risk k. Total number of attending patients l. Total number of hospitalized patients
e. Total number of deaths	m. Total number of registered deaths n. Total number of deaths attributed to a cause

^a Depending on the context, either the total population or only a part of it

^b Currently WHO recommends that all suspected malaria cases are testing before treatment. For a malaria programme to be successful, it must adopt universal diagnostic testing

Table 16.6(b) Potentially relevant indices

Real rates (unknown)	Alternative (measurable) indices
Incidence of malaria illness (a)/(d)	(g)/(j); (g)/(k)
Incidence of severe malaria (b*)/(d)	(h)/(j); (h)/(k); (h)/(l)
Proportion of severe malaria (b)/(a)	(h)/(g)
Mortality rate (all causes) (e)/(d)	(m)/(j)
Malaria mortality rate (c)/(d)	(i)/(j)
Proportion of deaths due to malaria (c)/(e)	(i)/(n)
Malaria case fatality rate (c)/(a)	(i)/(g)
Case fatality rate of severe malaria (c)/(b)	(i)/(h)

Assuming "a" is inclusive of "b"

Exercise 16.8

After studying Table 16.6 (a, b), consider the following questions:

- Is the reported incidence of malarial illness equivalent to the true incidence of malarial illness?*
- If there is a difference, can it be either greater or lesser? What are the principal explanations for errors in reporting by excess and omission?*
- Could the difference between real incidence and reported incidence vary in:*
 - Different places?*
 - Different times in the same place?*
 - Different indices, e.g. incidence of malarial illness, incidence of severe malaria and malaria mortality?*
- Is it necessary to improve the collection and reporting of information until it becomes equivalent to the reality represented? Would this be possible?*
- What would be required to make reported information equivalent to reality? Is this necessary? Is it possible? How could the imperfections of reported information be taken into account?*
- Are all reported cases of malarial illness sufficiently similar to each other to be counted together in reports? If not, how do they differ from each other (e.g. distinguish true differences from differences of assessment)? Can the main differences be taken into account in reporting? If so, how can this be done?*

- g. How authentic are the malaria-associated mortality measurements?*
- h. If all the data are not received from the health delivery units, does this affect the results obtained?*
- i. What is the role of sentinel sites in gathering data from selected sources?*

As discussed in Learning Unit 13, supervision of the surveillance system is one of the main activities which can contribute to quality control of the malaria control programme.

Annex 10 provides a sample of supervisory checklist for use during visits to health facilities. Note that the data collected in surveillance systems are in two forms: individual and aggregated data.

16.5 Surveys

Three types of population survey specifically gather information related to malaria. These are:

- ▶ Demographic and Health Survey (DHS)
- ▶ Multiple Indicator Cluster Survey (MICS)
- ▶ Malaria Indicator Survey (MIS)

These three surveys are explained below.

16.5.1 Demographic and health survey (DHS)

The DHS are representative national household surveys for calculation of indicators used in monitoring and assessment of impacts of health interventions on population, health and nutrition. The typical DHS is undertaken once every 5 years on a large sample size of representative population (5000–30 000 households), with the purpose of comparing changes over time. The Interim type of DHS is done between standard studies and on a smaller representative population (2000–3000 households), and has a shorter questionnaire. These studies give some information on the key indicators used in monitoring performance, but they might not have the necessary data for assessment of impact.

The domains under study in DHS include: anaemia, child health, education, family planning, female circumcision, fertility, domestic abuse, knowledge, perspective and behaviour regarding HIV and AIDS, prevalence of HIV, characteristics of household and person responding, infant and child morbidity and mortality, malaria (awareness of malaria transmission, use of mosquito nets among women and children, prevalence and treatment of fever), maternal health, maternal mortality, nutrition, wealth and socioeconomic status and empowerment of women. (<http://www.measuredhs.com>)

The advantage of measuring malaria indicators for population coverage using either the DHS or multiple indicator cluster survey (MICS) surveys (see below) is due to the rigour of the sampling design, and reliability over time and across countries. However, these surveys are only carried out every 5 years. If immediate data collection is required that does not fit within the implementation schedule of either the DHS or MICS surveys within a particular country, it is recommended that the MIS survey be used to obtain the necessary data for measuring malaria coverage indicators.

16.5.2 Multiple indicator cluster survey (MICS)

The MICS is a survey designed by UNICEF to help countries monitoring the status of children and women. By using a statistical approach, the MICS offers comparable indicators of nations' socio-economic status. This survey has been carried out since 1995 at 5-year intervals. With each survey new indicators are added so that in addition to monitoring change, the current priorities are also monitored. By 2012 more than 200 MICSs had been undertaken in 100 countries worldwide. Half of the Millennium Development Goal indicators and many international commitment assessment indicators are collected in the form of MICS.

The domains under study in MICS include the following indicators: nutrition, child health (including malaria), environmental health, fertility, education, AIDS and vulnerable children. These programmes are mainly implemented by governments and with technical support from UNICEF and other related organizations. (www.childinfo.org).

These surveys are only conducted periodically (every 4 to 5 years), so if a country needs to obtain data on the core malaria indicators in the interval between large national surveys, the Malaria Indicator Survey (MIS) is the recommended survey methodology.

16.5.3 Malaria indicator survey (MIS)

The MIS provides much-needed information about all of the internationally recognized malaria indicators including household ownership of ITN and their use, treatment, IRS and IPT coverage. The survey also gathers background data on the characteristics of household members and ownership of household assets such as electricity, bicycles, radios, and indoor plumbing. The MIS can also include measurement of parasitaemia and anaemia and for this the MIS should be timed to coincide with the malaria transmission season. The MIS package (<http://rbm.who.int/merg.html>) contains guidelines, questionnaires, and manuals to support the conduct of the survey as well as recommended tabulations for analysing the data.

There are several basic requirements for identifying a survey to which malaria indicator questions could be added. The survey must be a household-level survey that is designed to collect nationally representative data (similar to the DHS, MICS, or MIS surveys). This means that the sampling frame for the survey is based on a complete enumeration of primary sampling units across the entire country.

The survey should include a household schedule that collects basic demographic information on all individuals who usually reside in the household or who slept in the household the previous night. This listing provides the necessary information to select the target individuals for the various indicators such as children under 5 years old or women of reproductive age.

In this Learning Unit, the aim is for the participants to know which kind of questions should be added to the surveys, and to have reviewed the type of questions that these surveys use for obtaining malaria-related indicators.

Exercise 16.9

- a. Has a survey been carried out on malaria in your country?
- b. If yes, in what year? Which survey? Have you seen its results? Are the results available on the web? If

- not, is it planned to publish them on the web? Do you think that the survey was necessary?*
- c. If the survey was necessary, what role has it played (or will play) in complementing the data on malaria in your country?*
- d. Can these data replace the routine disease surveillance system?*

LEARNING UNIT 17

Burden of malaria

Learning Objectives:

by the end, participants should be able to...

- Explain how an estimate of malaria morbidity and mortality can be obtained from the surveillance system
- Explain the need for indicators of disease burden
- Describe the difference between inequity and inequality

Morbidity and mortality due to malaria are key measures of burden of malaria. This Learning Unit has three sections. The first section presents a method to estimate malaria morbidity and mortality on the basis of data available in the health surveillance system. The second section discusses an indicator of disease which is obtained by combining morbidity and mortality, providing a summary indicator of the burden of malaria in a region or country. The third section discusses estimation of inequity and inequality in the presence of diseases, health outcomes and access to health care, and the differences between them.

17.1 Malaria morbidity

Surveillance systems usually have some degree of under-reporting. Under-reporting was introduced in Learning Unit 13, and is measured by measuring the completeness of reporting. As a reminder, completeness of reporting is:

$$\text{Completeness of HF}^a \text{ reporting} = \frac{\text{No of HF reports received through the surveillance system}}{\text{No of HF reports expected through the surveillance system}} \times 100$$

^a HF = health facility

The completeness of reporting measures the rate of underreporting. For example, if the malaria completeness of reporting is 50% in a country, and if underreporting is random and not associated with malaria case loads, this means that the system reports half of the cases, and so to estimate the actual number of cases, the number reported must be multiplied by 2.

Exercise 17.1

- If the completeness of reporting is 20% in a country, then what number should the notified individuals be multiplied by
- What are the limitations in using reported morbidity data generated from the malaria surveillance system?
- Illustrate in an algorithm the malaria cases reported in public sector through the malaria surveillance system.

Compare it with the Figure 17.1 provided by the tutor. What are the differences between them? Explain these differences. The algorithm allows to identify the factors affecting the malaria surveillance system. If these factors are known, then the correction factor can be quantified, and the true number of cases can be estimated.

- Point out and name the measurements that are required to calculate the real number of cases in Figure 17.1.

Compare the result with the Figure 17.2 provided by the tutor.

- Where can the data on factors affecting surveillance system sensitivity be obtained?
 - Utilization of public health facilities (**u**)
 - Completeness of health facility reporting (**r**)

Since r and u are both probabilities, their values are less than 1; u = proportion of individuals that use public services for malaria diagnosis and treatment; r = percentage of health facilities (HF) reports that are received in the surveillance system compared to all HF reports expected.

Exercise 17.2

- Examine Figure 17.3 (provided by the tutor) to arrive at the correct diagnosis of a malaria case.
- Which data are needed to arrive at the correct diagnosis of a malaria case?
- Where can the data for these variables be obtained?
- List the variables that are required to calculate the number of malaria cases (Morbidity: M), and show whether the relationship is direct or inverse when estimating M .

Numerical example:

In 2009, 4 500 000 persons were tested for malaria in a country, of which 150 000 tested positive. Therefore:

$$\text{SPR} = \frac{150\,000}{4\,500\,000} = 3.3\%$$

4 000 000 malaria cases were reported from public health facilities which did not have a microscopic examination and/or RDT, and are therefore possible or unconfirmed malaria cases. Therefore if $\text{SPR} = 3.3\%$, then:

$$U \times \text{SPR} = \text{estimated true malaria cases among probable cases} = 4\,000\,000 \times 3.3\% = 132\,000$$

The total number of confirmed cases reported in the public sector will be:

$$C + (U \times \text{SPR}) = 150\,000 + (132\,000) = 282\,000$$

It has also been observed that only half the public centres have sent their reports:

$$\frac{C + (U \times \text{SPR})}{r} = \frac{282\,000}{50\%} = 564\,000$$

So the total estimated number of cases in the public sector should be 564 000. If the household survey indicates that only 20% of individuals with malarial symptoms have consulted the public sector and 80% have either not consulted or consulted the private sector then:

$$M = \frac{C + (U \times \text{SPR})}{r \times u} = \frac{564\,000}{20\%} = 2\,820\,000$$

2 820 000 is the total number of estimated malaria cases in 2009.

- Following the numerical example above, generate an estimate of malaria cases in your country.

If this is not possible, which data are missing and where can they be found?

17.2 Malaria mortality indicator

Exercise 17.3

a. Which sources can be used to estimate the number of malaria deaths?

In order to estimate malaria mortality indirectly, the number of P. falciparum malaria cases can be multiplied by the Case Fatality Rate (CFR).

The CFR of P. falciparum malaria varies in different countries, and has been estimated to be 0.01–0.3% outside Africa, whereas the number appears to be around 0.45% in African countries.

b. From the numerical example given above, how many persons have died as a result of malaria in 2009, assuming the proportion of P. falciparum and its CFR were 50% and 0.09%, respectively?

17.3 DALY: a summary indicator of disease burden combining morbidity and mortality

Traditionally, assessments of population health status were made from a variety of data sources including mortality rates, cause of death data, as well as information on the incidence and prevalence of disease injury and disability. Each of these (and others) are useful sources of data in their own right but each only addresses a limited aspect of the disease burden in a population. There is a need for a more comprehensive measure of disease burden that simultaneously takes into account levels of mortality, disability and ill-health.

This need arose in the context of assessment of public health impact of different diseases. The main question is how can different diseases that have different outcomes be compared using a single metric? What are the impact of different interventions on the health of a society? For example, which disease is of higher priority, tuberculosis or malaria? Should more resources be allocated to malaria or gastric cancer? In order to respond to such questions, a common metric among diseases was necessary for measurements of disease burden and assess the results of the health interventions.

To illustrate the application of these indicators, suppose that the mortality rate of malaria and of a certain type of cancer is 1/1000. Which one of these creates a heavier burden? To assess the disease burden, it is necessary to know: (i) at what age the disease occurs – death occurring at a younger age involves greater loss of future productive years, and (ii) which disease creates disability, and how long will this disability last? The single indicator should take all these aspects into account.

These indicators have been created taking into account the goals of the health system.

Health system goal: to increase the quality of life and life expectancy for all.

This definition can be divided into three parts:

- ▶ Life expectancy is the average number of years of life remaining at a given age
- ▶ Quality of life refers to the general well-being of individuals
- ▶ Everyone has the right to health, a state of complete physical, mental and social well-being (benefit from health equity)

Assessment of health therefore involves considering a) life expectancy and b) the years lost because of poor health or disability. To know how much health has been lost, it should be possible to calculate mortality (which reduces life expectancy) and years lost with disability which results from non-fatal illnesses, and then combine these two together.

The Disability Adjusted Life Years (DALY) indicator was created to compare the burdens of disease based on the principle that the most appropriate measure of the effect of chronic illness is time. This indicator is the sum of years of life lost (mortality) and years lived with disability (Table 17.1).

Table 17.1 Relationships between disability adjusted life years, years of life lost and years lived with disability

DALY	=	YLL	+	YLD
Disability		Years of		Years
Adjusted		Life		Lived with
Life	=	Lost	+	Disability
Years				
DALY	=	Mortality	+	Morbidity

For example, consider the next two tables Table 17.2 and 17.3, and see how DALY can be calculated from YLL and YLD.

There is Life Expectancy (column 2) for each Age Group (column 1). This Life Expectancy means how long on average this age group is expected to live. In the 'Global Burden of Disease' study carried out in the early 1990's, the life expectancy of the Japanese (the longest, 82 years at birth) was considered as the standard. On this basis, all individuals all over the world are considered to have the right to the highest life expectancy, and if they die before 82 years, they are considered to have lost the number of years of life between age at death and this life expectancy. The number of years lost is calculated by multiplying the number of deaths (column 3) of that age group by the number of years they should have lived (Standard life expectancy-column 2), giving the results in column 4. From the sum of years of life lost in different age groups, the amount of YLL resulting from a particular disease is obtained, as shown below.

Table 17.2 Calculation of years of life lost (YLL)

Age group (1)	Standard life expectancy (2)	Number of deaths (3)	Years of life lost (4) YLL
....			
20–24	63	2312	145 656
25–29	58	3887	225 446
30–34	53	4512	239 136
35–39	48	5321	255 408
....			
Total YLL			865 646

Table 17.3 below is used for calculating YLD. For each type of disabilities related to the diseases in question, the following parameters should be calculated: the incidence of each type of disabilities, the level of incapacitation produced by them and their duration.

Table 17.3 Calculation of years lived with disability

	Number (or incidence) of disability	Disability weight	Duration of disability (year)	Years lived with disability (YLD)
Outcome A	453	0.70	7.0	2219.70
Outcome B	348	0.20	0.6	41.760
Outcome C	945	0.45	0.5	212.62
Total YLD				2474.08

In calculating malaria in the Global Burden of Disease Study, three disabilities were considered: symptomatic episodes, anaemia, and neurological sequelae following cerebral malaria. Neurological sequelae include a range of conditions such as hearing impairment, quadripareisis, epilepsy and visual impairment.

The disability weight must be known in order to calculate YLD. Thus a number of 0–1 has been allocated to each disability, where 0 stands for full health, 1 for death, and disabilities caused by disease are in the range 0–1. If the disease causes major disability (e.g. Bi-polar major depression) the disability burden will be nearer to 1, and if it causes minor disability (e.g. a scar that is not visible to others under ordinary circumstances) it will be nearer to 0.

Therefore, in simple terms, one DALY represents the loss of one year healthy life. Two other prerequisites (other than disability weight) are considered in the calculation of DALYs: (1) All ages are not of the same value in the DALY calculation; (2) In this calculation there is discounting over time, so that the value of a year lost in the future is worth less than one lost now.

Considering malaria, best estimates currently describe the annual global burden of malaria as: 44 million disability-adjusted life years (DALYs). In 2002, malaria was ranked the 8th highest contributor to the total global DALYs and 2nd in Africa. According to these estimates, 3% of the world's DALYs are due to malaria.

It is clear from the natural history of malaria in humans that the major contribution of malaria-associated DALYs is from *P. falciparum*-associated deaths, especially in children aged <5 years.

A disease that has a higher DALY is not necessarily of higher public health priority. Variables other than burden of disease need to be considered in the prioritization of diseases, e.g. availability of suitable interventions and international commitments, e.g. inclusion in the Millennium Development Goals.

The validity of the DALY as a universal indicator is the subject of debate. Some criticism concerns the method of choosing certain parameters such as disability weight, age weight, and rate of discount. The disability weight may be different in different countries – for example the social stigma attached to sexually transmitted diseases is not the same in all countries. Therefore the validity of choosing a single disability weight for all countries is questioned.

17.4 Inequality and inequity

Health Inequality refers to differences of health and health care across populations. Health Inequity is difference in presence of disease, health outcomes or access to health care, which is not only unnecessary and avoidable, but is also considered unfair and unjust.

Consider these examples:

- ▶ Malaria is unequal in people who use and those who do not use ITN.
- ▶ IRS coverage is different in different areas.
- ▶ Access to proper malaria diagnostic testing and treatment in many countries is affected by family income.

In all of these cases, individuals are unequal, but which of the situations are unnecessary, avoidable and unfair? The specific of health inequalities that are judged unjust or unfair constitute health inequities.

There are many ways of calculating inequity. Most of them provide a means of assessing the degree of income-related differences in the distribution of a health variable. For example, an assessment could be made whether child mortality is related to level of family income, measuring the relation between child mortality and quintile of family income in different regions of the same country or in different countries.

LEARNING UNIT 18

Introduction to malaria epidemics

PART 4

Learning Objectives:

by the end, participants should be able to...

- Define a malaria epidemic
- Identify contributing/triggering factors

18.1 Definition of a malaria epidemic

Exercise 18.1

- Have you ever been directly involved in prevention and/or control of a malaria epidemic?
- What is your definition of a malaria epidemic, or a malaria outbreak?
- What different types of malaria epidemics do you know? Could you assign these types to the situations (i), (ii) and (iii) indicated in Figure 18.1?

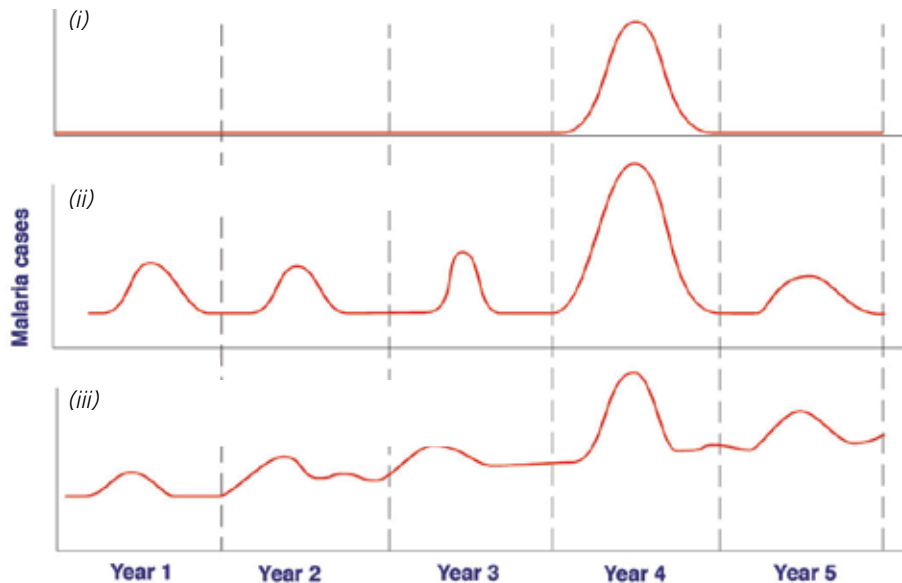


Figure 18.1 Major malaria epidemic types based on the epidemic patterns

18.2 Population at risk of malaria in epidemic-prone regions

Exercise 18.2

- Where do malaria epidemics most frequently occur, and why?
Briefly describe the main epidemiological settings in which epidemics occur.
- In epidemic-prone regions, are only children aged <5 years and pregnant women at risk?
Explain the reasoning for your answer.
- In your country, are there malaria-free areas, or malaria epidemic-prone areas?
If there are epidemic-prone areas, is the population at risk well identified, and regions at risk mapped?
- Why is assessment of risk of malaria epidemics important? Explain briefly the reasons.
- Identify at least 3 conditions that make human populations vulnerable to malaria epidemics. (Consider immunity, parasite and environment).
- What are the characteristics of epidemic-prone areas? Provide some examples of environmental settings.

18.3 Indicators of malaria transmission and monitoring epidemic risk

Exercise 18.3

a. For successful malaria transmission by the vector, state at least 2 epidemiological requirements (consider the parasite, vector and host interaction)

b. What does the **basic reproduction rate** (R_o) equation express? (describe the equation in words)

$$R_o = m a^2 p^n / r - \log_e p$$

A key indicator of actual malaria transmission in a given area is **entomological inoculation rate** (**EIR**), i.e. the number of infective bites per person per time. Based on the R_o , there are direct and indirect factors responsible for malaria transmission. Direct factors appear in the equation, but these parameters are frequently difficult or impossible to measure.

c. In Table 18.1:

- State the factors that have influence in positively or negatively affecting the determinants of malaria transmission given in the first column.
- Which of the two categories (direct or indirect factors) can be used as indicators to predict epidemics?

Table 18.1 Direct and indirect factors that contribute to occurrence of malaria epidemics

Determinants (direct)	Influencing factors (indirect)
Vector density	
Human biting	
Rate of gametocyte carriers	
Length of sporogony	
Daily survival rate of vectors	

The use of health statistics to differentiate endemic and epidemic prone areas

d. Are health statistics (national/local epidemiological characteristics) useful for differentiating between endemic and epidemic-prone areas?

Explain your answer. List some of the limitations of using health data.

18.4 Precipitating factors for malaria epidemics

The level of immunity acquired by the exposed population plays a decisive role in the occurrence and severity of malaria epidemics. Malaria immunity is not generally maintained unless exposure and human-vector contact are frequent and regular.

Exercise 18.4

a. List the main precipitating factors for malaria epidemics in your country/other places.

b. Working in small groups, fill Table 18.2 and link/correlate these factors to the main epidemiological and environmental consequences.

Table 18.2 Precipitating factors for malaria epidemics and their consequences

Cause	Potentially leading to:
1. Human activity	
Economic development activities (legal or not)	
Overpopulation	
War/civil disturbances	
Road construction/ improvement in transport facilities	
Urbanization	
2. Natural disasters	
Expected or unexpected meteorological events (heavy rainfall, unusual heavy flooding, cyclones, climatic changes...)	
Global and local climate changes	
3. Degradation of preventive and curative health services	
Deficient surveillance within the control services	
Malaria prevention activities are deteriorating (such as lack/shortage of insecticide and/or inadequate or poor spray coverage)	
Reluctance of villagers concerning some malaria control activities (especially spraying operations)	
Increasing resistance of vectors to insecticide and/or parasites to antimalarials	
4. Success of prevention and control efforts	
Waning population immunity	

c. *Is it necessary to identify precipitating / contributing factors? Explain your answer.*

Discuss the following information required to explore potential contributing factors to malaria epidemics

- ▶ In case of past epidemics in an area: Ask whether the epidemics were well documented and go back to reports if available.
- ▶ Epidemiological data from the health information system: Study the malaria transmission pattern in the region and classify it as a high, short- seasonal or cyclical epidemics, or other.
- ▶ Meteorological data: Look for unusual rainfall, temperature, humidity pattern correlated with epidemics in the past or correlated with current epidemics.
- ▶ Population movements: Observe whether there had been a large group of people coming (or passing through) from high transmission areas recently [refer to camps and refugee situations].
- ▶ Increase in population vulnerability/susceptibility: Population affected by hunger and malnutrition as result of unusual drought, (forced) migration (e.g. due to civil war), HIV/AIDS prevalence, etc.
- ▶ Check whether control measures are in place.
- ▶ Examine whether these control measures are effective, e.g. case management affected by high parasite resistance to national recommended drugs, or affected by vectors resistant to insecticides in use, etc.

d. *Indicate where to obtain the necessary information for each of the questions above.*

LEARNING UNIT 19

Early warning, detection, notification and verification of a malaria epidemic

Learning Objectives:

by the end, participants should be able to...

- Describe the usual channels for notification
- Explain the concept and rationale of an early warning and detection system
- Describe how to identify/detect a malaria epidemic on a timely basis
- Describe how to rapidly confirm a malaria epidemic
- Describe urgent measures to contain the epidemic

19.1 Systems for early detection of malaria epidemic

Exercise 19.1

- Working in small groups, discuss and sketch a diagram showing how any unusual events/epidemics including malaria epidemics are usually reported/notified.
- Working in small groups, explain the rationale for setting up an early detection system.

19.2 Methods for determining epidemic thresholds

Exercise 19.2

- What system(s) would you propose for routine early detection of malaria epidemics and what kind of data would it be important to use?

Many epidemics occur in situations where previous data is either not available, or unreliable due to significant contextual changes. In these circumstances, precise thresholds will be difficult to establish. What sort of indicators should be used to monitor malaria epidemics in situations like this?

- Median and 3rd quartile

Work in small groups. Table 19.1 provides data on malaria cases reported during a 5-year period from Province X. Respond the questions (i) – (iv) and present the findings to the class.

Table 19.1 Malaria cases reported from Province X from 2001 to 2005

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
2001	1609	2235	2035	1597	4927	2442	2857	5159	9245	1490	1299	2267
2002	1214	1322	1784	1880	1863	1958	398	2815	4761	5845	2588	
2003	1198	1099	2010	1411	1449	2018	1737	1902	1939	1842	2332	2321
2004	2597	2219	2988	2977	5276	3534	2822	4028	3188	3395	2269	2223
2005	2941	2449	2619	2462	2973	2200	2612	2424	8658	10158	4274	2944

- Calculate the median and the quartiles of the cases for each month and show them on a table. Compare your results with Table 19.1 provided by the tutor.
- Plot the numbers in Excel or spread sheet. If a computer and Microsoft Excel are not available, use graph paper or simple squared paper to construct a graph of the median and the 3rd quartile.
- What does the 3rd quartile indicate on the graph?
- Given the median and quartiles obtained for the years 2001–2005 and the malaria situation for the year 2006 with the data shown in Table 19.2 below, which month of 2006 shows an epidemic situation? Explain why.

Table 19.2 Malaria cases reported from Province X in 2006

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
2006	1364	2560	2817	1656	1958	2021	2255	3169	4897	9158		

Exercise 19.3

- a. From the malaria morbidity data given below in Table 19.3, determine the median, lower (1st) and upper (3rd) quartiles (by bolding or shading the columns). Then compare the data for year 2005 in the last column of the table.
- b. Plot the Median, Upper and Lower Quartiles derived from the weekly data on a graph.
- c. What do you conclude from the graph?

Table 19.3 Malaria morbidity data of Province Z (1996–2005)

Month/Week	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005 data	
Jan.	1	48	20	121	76	44	47	24	9	40	63
	2	50	8	83	65	39	45	29	6	37	41
	3	105	13	112	108	43	48	31	8	32	56
	4	88	15	130	96	49	52	35	1	46	69
Feb.	1	72	9	88	84	44	46	38	7	41	41
	2	58	14	100	76	41	48	23	4	31	45
	3	52	11	74	70	35	38	27	3	28	50
	4	70	14	98	97	49	68	41	8	43	39
Mar.	1	42	11	69	50	33	39	30	4	32	50
	2	66	10	80	77	39	45	24	3	25	52
	3	45	18	67	59	39	44	32	5	35	46
	4	49	9	83	63	34	45	9	8	33	38
Apr.	1	44	18	62	47	40	44	25	5	35	42
	2	45	14	76	48	36	44	23	6	25	30
	3	35	22	61	53	34	35	31	8	33	23
	4	57	19	60	60	42	54	27	18	42	36
May	1	53	15	106	77	43	44	24	9	35	36
	2	54	23	72	55	38	42	25	9	31	45
	3	69	23	95	80	34	37	27	5	33	44
	4	94	37	113	95	71	76	40	24	57	76
Jun.	1	81	25	113	93	54	74	31	21	52	44
	2	69	39	123	72	55	60	48	17	50	61
	3	69	23	157	116	58	67	40	15	51	64
	4	100	41	200	113	59	94	46	18	57	79
Jul.	1	94	29	184	110	60	62	29	19	55	93
	2	69	25	200	129	56	60	44	11	51	62
	3	92	24	129	123	53	63	31	15	40	68
	4	92	23	216	96	64	74	31	16	64	89
Aug.	1	86	23	112	89	41	77	29	9	39	81
	2	95	23	202	109	73	81	26	5	29	112
	3	99	28	156	154	60	90	41	13	55	132
	4	159	29	271	200	104	118	41	9	62	188
Sept.	1	93	19	136	128	80	84	75	13	79	162
	2	159	30	221	193	126	141	95	9	116	188
	3	149	26	259	181	127	137	108	11	109	258
	4	272	62	540	279	139	183	101	31	105	346
Oct.	1	165	27	302	190	100	161	28	23	85	350
	2	185	36	272	220	131	174	69	28	88	322
	3	159	33	181	170	100	123	68	23	83	343
	4	182	46	276	221	169	179	71	25	109	413

Table 19.3 Malaria morbidity data of Province Z (1996–2005) (continued)

Month/Week	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005 data	
Nov.	1	122	30	230	139	103	104	42	19	85	487
	2	96	13	192	128	73	86	41	11	71	378
	3	79	23	153	100	58	74	32	18	51	383
	4	116	18	248	147	95	114	53	12	66	265
Dec.	1	93	17	143	108	62	69	45	11	50	106
	2	76	25	115	99	53	65	41	12	46	113
	3	55	12	114	67	50	53	33	7	41	163
	4	50	19	102	69	36	37	21	15	26	223

19.2.2 Cumulative-sum methods

Exercise 19.4

a. Use Table 19.1 to practice the *cumulative-sum (C-SUM) method* as follows:

To calculate the C-SUM for January, add the sum for December, January and February for the previous 5 years, and divide the total by 15. Similarly the C-SUM for February is calculated by adding the sum of January, February and March for the previous 5 years and dividing by 15.

Then complete the C-SUMS for each month in Table 19.4 below.

Table 19.4 Cumulative-sum of malaria cases for each month, from Province X from 2001 to 2005

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
C-SUM												

b. Plot the results on a graph. The line represents the threshold above which one should be on alert for an epidemic.

c. Add the data for 2006 to the graph. Show both lines on the same graph and interpret them.

d. These methods use monthly data. What could be the disadvantages of using monthly data?

Ideally, data should be collected and analysed at the peripheral level on a weekly basis, and the methods described can be used to analyse weekly figures. It is possible to use the thresholds developed from 5 years of monthly data and apply them to current weekly data.

e. Use graph paper with the quartile threshold or C-SUM clearly marked as in exercises 19.2 (b) and 19.4 (b). As the weekly data are collected, mark the number as a column under the month in question. The next week, add the number to that of the first week, and extend the column in the same figure. Using a different colour for each week will make it clearer. Do the same for the 3rd and 4th weeks. If the column is already at the threshold by the 2nd or 3rd week, it will be possible to raise the alert of an epidemic much sooner than waiting for the whole month's figures. Compare the graph you have developed with the one given by the tutor.

19.2.3 Incidence thresholds

Exercise 19.5

Working in small groups, discuss how the use of alert threshold and epidemic threshold could be applied to malaria.

19.3 Early detection and overall management systems

Exercise 19.6

Working in small groups, list the measures that should be set-up in a country to detect a malaria epidemic at an early stage, either as part of the routine information system or/and as part of the epidemic surveillance system. Organize the measures at peripheral, district and national levels.

19.4 Verification of malaria epidemics

Exercise 19.7

- a. Working in small groups, discuss and outline the steps that should be followed to verify malaria epidemics at peripheral level.
- b. Working in small groups, prepare a flow chart that covers early detection, verification and notification of malaria epidemics. The flow chart should indicate a logical flow from the peripheral to the district level. Present the findings to the class for discussion, and compare with the results provided by the tutor.
- c. In settings where parasitological confirmation is not available, it is necessary to monitor the percentage of suspected cases that have confirmed malaria, by regularly sampling a given number of suspected cases for parasitaemia in different epidemiological settings.

Working in small groups, discuss test positivity (SPR or positive RDT rate) at normal and epidemic times in arid/semi-arid areas; and highland regions with short seasonal transmission.

Where would positivity be higher during epidemics? Why?

Where would there be most need for laboratory diagnosis?

19.5 Monitoring areas of epidemic risk

- ▶ In 1980, a two-stage malaria epidemic forecasting system, based on the monitoring of meteorological variables and changes in the entomological inoculation rate (EIR), was proposed.¹ The system is suited to the forecasting of resurgent outbreaks where comprehensive surveillance systems have already been developed and operated for some time, as part of the routine malaria control services. However, the capacity to monitor EIR as a routine component in an epidemic forecasting system is at present beyond the capacity of most African countries.
- ▶ Experiences from intersectoral programmes (e.g. food safety) which use environmental information systems (EIS) could also be applied to the development of monitoring and early warning systems (MEWS).

¹ Onori E. and Grab B. (1980). Indicators for the forecasting of malaria epidemics. *Bulletin of the World Health Organization* 1980;58 (1):91–98.

- Kenya, Uganda and the United Republic of Tanzania, in conjunction with HIMAL have proposed the development of a three-tiered approach for malaria epidemic forecasting, early warning and early detection in the highlands of East Africa,¹ with each tier being associated with specific indicators and responses.

Exercise 19.8

Analyse the model in Figure 19.1 and answer the questions below. It shows forecasting, early warning and early detection model resulting from the Salt Rock Meeting, South Africa (Anon, 1999).

- At which level should one consider (i) long range weather forecasting, (ii) early warning based on meteorological indicators (iii) early detection?
- What would be the possible indicators and responses for flag 1, flag 2 and flag 3?

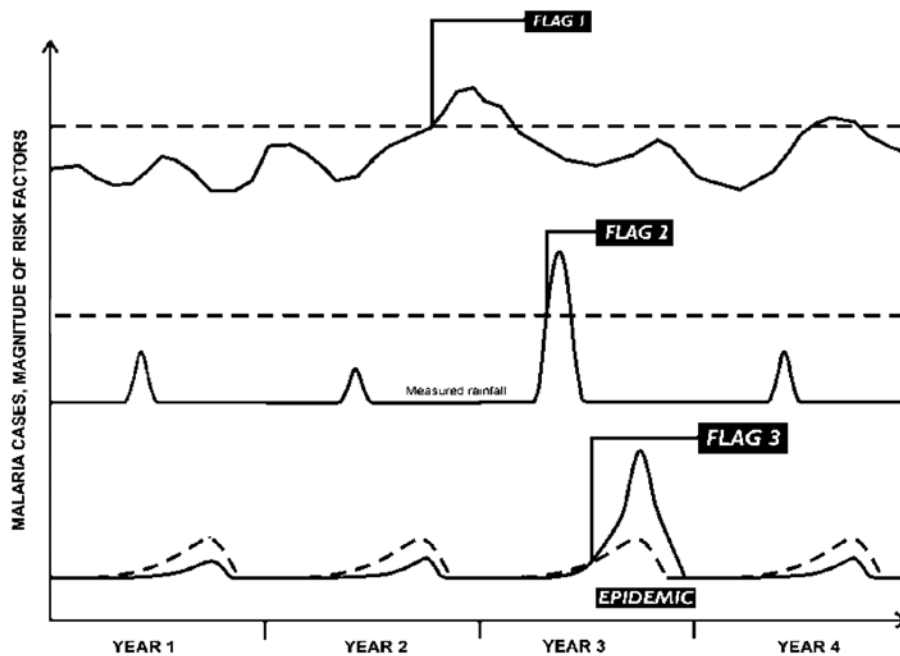


Figure 19.1 Forecasting, early warning and early detection model resulting from the Salt Rock Meeting, South Africa, 1999

¹ Anon (1999). Developing new approaches for the surveillance and control of malaria epidemics in the highlands of East Africa. Highland Malaria Project and Mapping Malaria Risk in Africa: Salt Rock, South Africa.

LEARNING UNIT 20

Prevention and early response to confirmed malaria falciparum epidemics

Learning Objectives:

by the end, participants should be able to...

- Describe the main malaria epidemic control options
- Describe how to identify the most cost-effective malaria epidemic prevention and control options

20.1 Cost-effective interventions for control of *P. falciparum* malaria epidemics

Exercise 20.1

- a. Working in small groups, propose a list of the most important interventions for control of malaria epidemics.

Rank the listed interventions according to their cost-effectiveness.

Of the listed interventions, which would need to be set up at early stages of any notified malaria epidemics?

- b. What should be the guiding principle/s for a drug to have a significant effect on transmission during epidemics?

- c. Do good case management procedures have a significant effect on transmission if drugs such as chloroquine and sulfadoxine-pyrimethamine are used?

Should artemisinin-based combinations and/or primaquine be used?

In emergency situations, should effective drugs be provided free of charge?

- d. During emergencies or epidemics what is a common problem for provision of care to those sick at home in affected remote communities? What operational solutions would you propose to reach those affected communities?

Exercise 20.2

- a. Work in small groups. For operational and biological reasons vector control options may or may not be applicable in epidemics. Discuss under which circumstances these options should be considered in epidemic-prone districts.

- b. What stage of the vector should be targeted by vector control measures in order to have significant impact on malaria transmission and hence on the malaria burden?

- c. Under what circumstances is IRS a viable option?

- d. Under what circumstances is the use of ITNs or impregnated materials considered to be a viable option?

- e. What specific vector control options/methods would you recommend in situations of complex emergencies, e.g. in setting up refugee camps?

- f. Where and when would you consider other vector control options?

Exercise 20.3

Work in small groups. Use the data in Table 20.1 to test different scenarios of early detection and interventions for epidemics, and the implications if these measures are not taken. Data in Table 20.1 (columns 2–5) show the number of malaria cases corresponding to time in months (column 1). Plot them on graph paper (or by computer).

Table 20.1 Number of cases recorded at different stages of detection of malaria epidemics

Time (month)	No intervention	Late detection & intervention	Some delay in detection & intervention	Early detection & intervention
1	12	12	12	12
2	13	13	13	13
3	14	14	14	14
4	13	13	13	13
5	11	11	11	11
6	24	24	24	24
7	49	49	49	35
8	199	169	129	39
9	190	160	120	38
10	185	155	115	15
11	150	120	90	14
12	70	40	12	13
13	60	35	14	12
14	50	25	13	13
15	26	11	12	12
16	14	14	13	13
17	13	13	12	12

- From the data in Table 20.1, show each column (number of cases) against time on a graph. Produce one graph for each column by comparing with **column 2**. Shade the graphs differently to show the different areas under curve in each graph.
- What are the differences between these scenarios? What does the area under the curve show in each graph?
- Which column (from the graph produced by the group) shows the existence of proper preparedness and response (better malaria control programme) when compared to **column 2** where no intervention was done?
- If climate forecast, early warning and early detection for a complete prevention of the epidemics would work well for your programme, how would you indicate them on the same graph of column 2 and what will be their time sequence? What would result from this system?

20.2 Case management and drug policy during epidemics

Managing malaria cases during epidemics

Prompt diagnosis and access to effective antimalarial medicines during a malaria epidemic is a key intervention to minimize the malaria burden in the affected population. Most malaria patients in epidemics are non-immune, partially immune, or otherwise vulnerable to severe disease. The antimalarials to be used for treatment must be highly efficacious (> 95% cure), safe and well tolerated so that adherence to treatment is high. Complete courses of treatment should always be given in all circumstances. See module on *Malaria Case Management* for further information.

Exercise 20.4

- Currently WHO recommends parasitological confirmation prior to antimalarial treatment during non-epidemic situations. Is this applicable to epidemic situations?
- In a country that has epidemic-prone regions, for managing uncomplicated malaria cases during epidemics, is it possible to use a different antimalarial medicine from the one used as first-line drug treatment for uncomplicated malaria in endemic areas in the country? Explain your answer.
- Epidemics can overwhelm health services and severe malaria is common if prompt effective treatment is not made widely available. In addition to individual patient-based treatment of uncomplicated cases through fixed or mobile clinics, is there another complementary strategy for using antimalarials?
- What antimalarial drugs should be recommended for use in treating severe malaria cases during epidemics? Specify the recommendations for referral and peripheral health facilities.

20.3 Vector control options for prevention and control of malaria epidemics

Epidemics can be either prevented or controlled by using vector control interventions like IRS which have a direct impact on transmission in the affected areas. If the interventions are not well implemented, epidemics will continue to progress over time and space up to their final natural resolution and ending. If well planned and carried out at the appropriate time (early stages of the epidemic) as a result of accurate warnings, vector control interventions can reduce transmission by killing adult mosquitoes before they transmit the disease. The list below summarizes the type of vector control options that may or may not be relevant to prevention and control of malaria epidemics:

- ▶ Indoor residual spraying of insecticides (IRS)
- ▶ Insecticide-treated nets (ITNs/LLINs) and other materials
- ▶ Space spraying of insecticides (limited role)
- ▶ Larval source management (larviciding)

The available insecticides for prevention and control of epidemics are listed in Table 20.2.

Table 20.2 Insecticides for prevention and control of epidemics

<p>For indoor residual spraying:</p> <ul style="list-style-type: none"> • Organochlorines (DDT) • Organophosphates (Fenitrothion, Malathion; Pirimiphos-methyl) • Carbamates (Bendiocarb, Propoxur) • Pyrethroids (Alpha-cypermethrin; Bifenthrin, Cyfluthrin, Deltamethrin, Etofenprox, Lambda-cyhalothrin)
<p>For larval control:</p> <ul style="list-style-type: none"> • Temephos pirimiphos-methyl, fenthion, novaluron etc.
<p>For impregnation of bednets, curtains, blankets and clothes:</p> <ul style="list-style-type: none"> • Pyrethroids (Permethrin, Delatamethrin, Alphacypermethrin, etc.)

20.3.1 Indoor residual spraying of insecticides (IRS)

During epidemics, when political pressure is high and appropriate preparedness lacking, vector control measures like IRS are frequently employed after the transmission peak or even after transmission has almost ceased (see exercise 20.3 and scenarios of epidemic detection and response).

Many epidemic-prone regions in Africa practice some form of routine vector control, mainly indoor residual house spraying. However, in many countries, the practice may have lost the required operational quality and effectiveness. Shortage of skilled vector control staff and lack of adequate planning and supervision often compromise the effectiveness of IRS. Despite these problems, IRS is the most effective measure to prevent malaria epidemics when there is a reliable early warning system, and where the basic requirements of logistics, expertise and personnel exist.

Exercise 20.5

- a. Taking the biological factors (life-cycle of the parasite and the vector) into account, what would be the minimum time (in weeks) needed for application of IRS to effectively prevent a malaria epidemic?
- b. Is it possible to apply IRS once an epidemic has started? If so, within what period of time?
- c. Why is coverage so important for effectiveness of IRS?
- d. Would IRS be more effective in areas where there is high vectorial capacity or in areas with low vectorial capacity?
- e. Working in small groups, discuss and identify the important issues (criteria) that need to be considered when IRS operations are planned.

20.3.2 Insecticide-treated mosquito nets (ITN) and other materials

Another vector control strategy involves the use of insecticide-treated mosquito nets and other materials. The use of ITNs is high in many parts of Africa where malaria is endemic, although the coverage in many epidemic-prone areas is still low. If distribution of ITNs is not a practical option given the urgency of epidemic prevention and control operations, re-treatment of nets could provide a sufficient degree of protection in areas where a high level of coverage has been achieved. In such situations, the re-treatment service should be provided free of charge.

Exercise 20.6

- a. For ITNs to be fully effective, what coverage and re-treatment rate must be attained? Why is coverage an important criterion?
- b. Why is coverage and acceptance by the community in epidemic areas/regions far less than in most endemic areas?
- c. Under which circumstances would ITN be effective in preventing epidemics?

20.3.3 Space spray application

There is little evidence of any impact of space spraying on malaria. Thus, this measure is generally not recommended, but can be considered in exceptional circumstances (e.g. outdoor biting and resting mosquitoes). Such activity would need to be maintained over time to have any impact, and entomological expertise is required if this intervention is deployed.

Exercise 20.7

- a. *What stage of the mosquito do aerial sprays mainly target?*
- b. *Is aerial spraying a viable option? If it is possible only in limited circumstances, specify some of them.*

20.3.4 Larval source management

Larval source management (LSM) includes breeding site modification and manipulation; larviciding and the use of biological control agents. Larviciding, in conjunction with other vector control interventions (IRS and ITNs/LLINs), may play a role to control malaria epidemics in areas where the breeding habitats are few, fixed and findable. This is based on the assumption that larviciding is applied at the early stages of the malaria epidemic to potential breeding sites.

Exercise 20.8

- a. *Given the limitations, where should larval control be applied in relation to prevention and control of malaria epidemics?*
- b. *What biological and operational factors should be taken into account when considering larval control?*

20.4 Malaria in relation to epidemic diseases

Standard case definitions need to be agreed upon and peripheral staff trained to use the definitions and report to district authorities. Epidemiologically, the consistency of definitions of malaria cases over time is very important and needs to be well monitored (while every effort should be made to improve access to diagnostic testing). In known epidemic-prone districts, malaria cases are generally reported on a weekly basis together with other epidemic diseases.

Exercise 20.9

- a. *In areas where there are no laboratory facilities, how would be malaria defined? And should all patients who received antimalarial treatment be classified as malaria cases?*
- b. *Should malaria epidemic control interventions be set up as isolated / vertical interventions or integrated with other epidemic interventions?*
- c. *If malaria interventions should be integrated with other epidemic interventions, which ones?*
- d. *Of the preventive and control interventions for malaria epidemics, which one do you think is most effective?*

20.5 Measuring the impact of preventive/control measures

From historical records there is little documented information on the impact of epidemics. In general, epidemics took the population by surprise and health authorities often lack a preparedness plans of action. The magnitude of the malaria burden during epidemics has been linked to the stock-out or absence of efficient drugs, absence or long delay of measures to reduce transmission, and limited knowledge of the population and media on how the disease is transmitted, cured, and can be avoided.

Exercise 20.10

Work in small groups. When preventive measures are undertaken in advance, or control options implemented at an early stage, deaths and severe cases averted in a targeted population can be calculated based on some conservative assumptions. Identify the underlining assumptions for measuring impact of prevention and of control.

20.6 Other managerial issues for preparedness and response during epidemics

The NMCP is responsible for advising the government on strategic technical measures to be taken when malaria epidemics occur. It recognizes defining areas and populations at risk and pre-defined cost-effective control options, drugs and insecticides to be used, etc. In epidemic-prone areas, the district management teams are in charge of establishing a plan of action which includes early warning and detection systems coordinated with field partners including NGOs. The process to elaborate a preparedness plan of action is described in the Learning Unit 21.

Malaria epidemics can also occur in complex emergency situations and there are specific strategies for responding to such situations.

Exercise 20.11

- Working in small groups, discuss the best options for malaria control that would be employed in a complex emergency situation, when there is limited knowledge of the local malaria situation.
- Work in small groups. Consider the three graphs in Figure 20.1 showing different stages of epidemic detection. Use the checklist in Table 20.3 to mark each intervention as correct (tick) or incorrect (cross), if it is applicable or not applicable for the particular phase of an epidemic. You may add specific comments in the corresponding box.

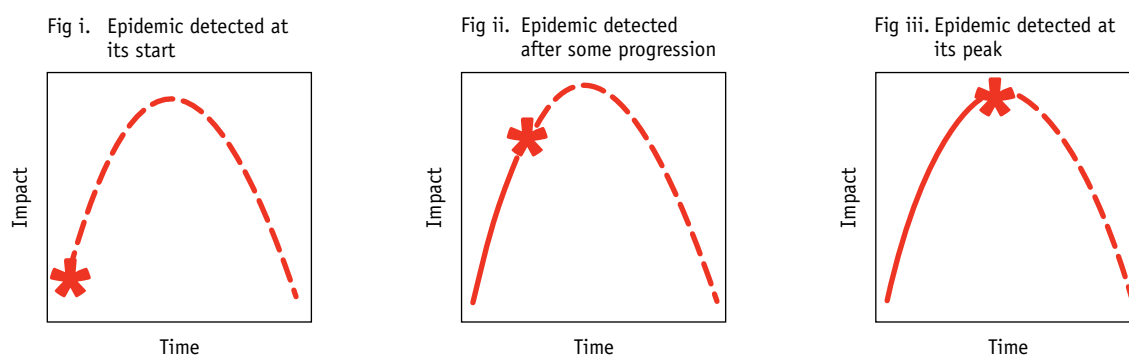


Figure 20.1 Detection of malaria epidemics at different stages

Table 20.3 Operational responses to different stages of malaria epidemics

No.	Interventions or operational measures	Starting epidemic	Accelerated epidemic	Epidemic peak
1	Ensure all clinics and health facilities are operational and have sufficient drugs, equipment and trained staff			
2	Establish treatment centres (temporary clinics or mobile clinics) where access is difficult or health facility coverage is low			
3	Ensure that the correct diagnosis and treatment is provided at all health facilities and at community level			
4	Promote pro-active clinical case detection and management/referral			
5	Reinforce the referral system and consider the introduction of artesunate suppositories and intra-muscular artemether as a temporary measure where these are not already used			
6	Intensify/maintain effective preventive measures for pregnant women as locally appropriate			
7	Reinforce health information systems for reporting and epidemic monitoring, preferably on a weekly basis			
8	Conduct specific epidemic health education campaigns			
9	Organize regular press releases/conferences/articles for public information			
10	IRS if area is previously sprayed			
11	IRS in areas previously not sprayed			
12	Space spraying			
13	Insecticide-treated mosquito nets (ITN) and other materials			

LEARNING UNIT 21

Post-epidemic assessment and preparedness plan of action

Learning Objectives:

by the end, participants should be able to...

- Undertake a quick assessment of the epidemic detection and control response
- Develop a preparedness plan of action

21.1 The post-epidemic assessment

Exercise 21.1

a. Working in small groups, discuss a logical flow and the steps of an epidemic cycle; produce a diagram of the cycle and present it for class discussion.

Consider what has been covered in Learning Units 18–20 and what should be included the post-epidemic assessment exercise. All elements which are part of the classical epidemic described earlier must be carefully analysed. Compare the diagram with Figure 21.1 provided by the tutor and discuss any discrepancies.

b. During the post-epidemic assessment exercise, for which factors should it be possible to make a careful analysis?

The essential elements to be assessed during the post-epidemic analysis are obtained using a questionnaire; an example of the questionnaire is provided in Annex 11.

NMCP staff from the MoH with responsibility for developing and monitoring strategic operations related to malaria epidemic prevention and control should lead the field exercise to the area affected by epidemic with clear expected outcomes. They should be accompanied in the field by the following experts:

- ▶ A national epidemiologist working in national health information system is expected to manage the overall epidemic surveillance system
- ▶ A national meteorologist and or an expert dealing with meteorological, other relevant issues and warning indicators
- ▶ A representative from the national disaster department
- ▶ A representative from the partners at national and/or district level

The team should preferably be from multiple sectors to provide a comprehensive overview of problems encountered at national and district level. Occasionally, external technical assistance can be requested by the MoH to WHO or other technical/funding agencies.

The post-epidemic assessment exercise is an essential step within the epidemic circle to identify success and failure of all interventions (planned or unplanned), and ultimately to assess whether the detecting systems and control options have had an impact on the malaria burden. This important exercise is frequently neglected by implementing partners and the MoH. Consequently, the lessons, both positive and negative, are not learnt and are not used to modify or strengthen existing interventions for the future. Building on experience should improve the preparedness plan of action, and encourage support provided by national and district partners. The report should be widely distributed for partners' information and input. The checklist provided as Annex 11 can be used and adapted for this purpose.

21.2 Preparedness plan of action

In epidemic-prone countries, NMCP from the MoH and partners develop a national document which defines strategic approaches to detect and control malaria epidemics, with the ultimate aim of minimizing the malaria burden. This strategic document should be part

of a comprehensive emergency plan covering all public health emergencies. The preparedness plan of action (PPOA) should be complete, accurate and agreed among partners based on understanding of the epidemiology, and best choice of preventive and control options for malaria in epidemic-prone areas. The PPOA should detail all planned interventions at all levels with all partners, and provide an estimated budget for these interventions.

Strategic elements of a preparedness plan of action should include all practical aspects which relate to each of the interventions listed in Table 20.3. The “how” and “where” should be explained in detail with attached additional budget if necessary. Ideally NMCP at central level should provide epidemic-prone districts with technical guidance and should facilitate collaboration with implementing agencies at district level, such as local authorities, media, civil society, private companies and NGOs. All stakeholders should be consulted at the planning stage and be involved in specific actions based on comparative advantages and mandates. Capacity building as a key component of success has to be part of the planned activities and should target all actors.

Exercise 21.2

Working in small groups, discuss what strategic elements need to be included in a preparedness plan of action for prevention and control of a malaria epidemic in a logical sequence. Produce a diagram of the steps and present it for class discussion. (Consider the discussion on indicators for epidemics, assessment/investigation, reporting and response.)

Exercise 21.3

- a. *Should the PPOA for a malaria epidemic be developed in isolation or linked to other epidemics and emergency situations?*
- b. *Should it be developed at inter-country, national or regional/district level?*
- c. *Working in small groups, discuss the reasons why most countries are not sufficiently prepared to cope with epidemics.*

List some key reasons and rank them according to their importance and potential for solution.

ANNEX 1

Core surveillance indicators for malaria control

1. Confirmed malaria cases (number and rate per month or per year)	
Formula	$1000 * \frac{\text{number of confirmed malaria cases}}{\text{population at risk of malaria}}$
Numerator	The number of suspected malaria cases confirmed by either microscopy or RDT. The number should include both outpatient and inpatient cases. The number should include cases detected passively (attending health facilities or seen by community health workers) or actively (sought in the community); it is often useful to provide a breakdown of cases detected passively and actively. Regardless of transmission setting, any person with a positive result in a parasite-based test (microscopy or RDT), irrespective of clinical symptoms, should be considered to have a (confirmed) case of malaria.
Denominator	<p>The number of people living in areas where malaria transmission occurs. Areas with malaria transmission can be defined as those from which locally acquired, confirmed cases of malaria are reported. Population sizes should be adjusted for population growth according to projections from the national census or, when not available, United Nations Population Division projections.</p> <p>It is sometimes useful to use the total population of an area or country as the denominator in order to compare overall levels of risk among geographical areas or countries.</p> <p>If rates are calculated per month, as when plotting rates on a graph, the population size should be divided by 12 to obtain an annual incidence rate.</p>
Breakdown	<p>High and moderate transmission: Age group (all ages, < 5 years), parasite species, geographical area, time (year and month).</p> <p>Low transmission: Sex, 5-year age groups, type of detection (passive, active, community).</p> <p>Elimination: foci, village, source of infection: imported, local (introduced, indigenous, relapsing), induced.</p>
Purpose	To measure trends in malaria morbidity and to identify locations of ongoing malaria transmission. This indicator is the most important measure of progress and management in low-incidence areas.
Interpretation	<p>Trends can be affected by:</p> <ul style="list-style-type: none"> • completeness of reporting: trends can change if the percentage of health facilities reporting in a month changes or if different sets of health facilities are included e.g. including health posts or private hospitals. • number of tests undertaken (slides examined, RDTs performed) • changes in use of health facilities owing to greater availability of antimalarial drugs or implementation of user fees • actual changes in the incidence of malaria. <p>In order to conclude that changes in the value of the indicator reflect a real change in the incidence of malaria in the community, indicators for completeness of reporting, annual blood examination rate and total number of outpatient visits per 1000 population must be examined, to confirm that they are reasonably constant over time.</p>
Other	The indicator is also known as the annual parasite index.

2. Inpatient malaria cases (number and rate per month or per year)

Formula	$10\ 000 * \frac{\text{number of inpatient malaria cases}}{\text{population at risk of malaria}}$
Numerator	<p>The number of inpatients with a primary diagnosis of malaria at discharge or death. Patients who have absconded or been transferred should be excluded. All cases should have had a parasite-based test for malaria (microscopy and/or RDT) and a discharge diagnosis based on this test result.</p> <p>Malaria inpatient numbers should include patients from both hospitals and other facilities with beds.</p>
Denominator	<p>The number of people living in areas where malaria transmission occurs. Areas with malaria transmission can be defined as those in which locally acquired, confirmed cases of malaria are reported. Population sizes should be adjusted for population growth according to projections from the national census or, when not available, United Nations Population Division projections.</p> <p>It is sometimes useful to use the total population of an area or country as the denominator in order to compare overall levels of risk among geographical areas or countries.</p> <p>If rates are calculated per month, as when plotting rates on a graph, the population size should be divided by 12 to obtain an annual incidence rate.</p>
Breakdown	Age group (all ages, < 5 years), geographical area, time (year and month).
Purpose	To monitor the impact of programmes on severe disease. This indicator may reflect the impact of treatment, as treatment attenuates clinical progression from uncomplicated to severe disease.
Interpretation	<p>Inpatient cases are markers of severe disease and death and indicate failure of the health system to either prevent or effectively treat malaria.</p> <p>The numbers of inpatient cases are much larger than those of health facility deaths, allowing trends to be more easily discerned.</p> <p>This indicator is most useful in high- and moderate-transmission settings in which the rates of severe morbidity are significant.</p> <p>In some countries, inpatient cases may also include uncomplicated <i>P. falciparum</i> cases (according to national guidelines) to ensure full treatment, recovery and parasite clearance.</p> <p>Trends can be affected by:</p> <ul style="list-style-type: none"> • completeness of reporting: trends can change if the percentage of health facilities reporting in a month changes or if different sets of health facilities are included e.g. including private hospitals. • changes in diagnostic practice e.g. introduction of more diagnostic testing may reduce the number of inpatients in whom malaria is diagnosed. • changes in use of health facilities owing to greater availability of antimalarial drugs or implementation of user fees • actual changes in the incidence of severe malaria. <p>In order to conclude that changes in the value of the indicator reflect a real change in the incidence of severe malaria in the community, indicators must be examined for completeness of reporting, changes in the percentage of cases that have had a diagnostic test and total number of inpatient visits per 10 000, to confirm that they are reasonably constant over time.</p>

3. Inpatient malaria deaths (number and rate per month or per year)

Formula	$100\ 000 * \frac{\text{number of inpatient malaria deaths}}{\text{population at risk of malaria}}$
Numerator	<p>Cases in which the underlying cause of death is malaria. All recorded malaria deaths should have had a parasite-based test for malaria (microscopy and/or RDT) and a diagnosis based on the test result.</p> <p>Data on malaria deaths from hospitals and other facilities with beds should be included.</p>
Denominator	The number of people living in areas where malaria transmission occurs. Areas with malaria transmission can be defined as those in which locally acquired, confirmed cases of malaria are reported. Population sizes should be adjusted for population growth according to projections from the national census or, when not available, United Nations Population Division projections.

	<p>It is sometimes useful to use the total population of an area or country as a denominator in order to compare the overall level of risk among geographical areas or countries.</p> <p>If rates are calculated per month, as when plotting rates on a graph, the population size should be divided by 12 to obtain an annual incidence rate.</p>
Breakdown	Age group (all ages, < 5 years), geographical area, time (year and month).
Purpose	To monitor the impact of programmes on the number of malaria deaths.
Interpretation	<p>Inpatient deaths are markers of very severe disease and indicate failure of the health system to either prevent or effectively treat malaria.</p> <p>The numbers of deaths are generally small, and trends may be difficult to discern, but clusters of deaths may occur in time and space.</p> <p>This indicator is most useful in high-transmission settings in which malaria death rates are high. Trends can be affected by:</p> <ul style="list-style-type: none"> • completeness of reporting: trends can change if the percentage of health facilities reporting in a month changes or if different sets of health facilities are included e.g. including private hospitals. • changes in diagnostic practice e.g. the introduction of more diagnostic testing may reduce the number of malaria deaths diagnosed. • changes in use of health facilities owing to greater availability of antimalarial drugs or implementation of user fees • actual changes in the number of malaria deaths. <p>In order to conclude that changes in the value of the indicator reflect a real change in malaria mortality in the community, indicators should be examined for completeness of reporting, changes in the percentage of cases that had a diagnostic test, total number of inpatient visits per 10 000 and number of deaths per 100 000, to confirm that they are reasonably constant over time.</p>

4. Malaria test positivity rate (RDT and/or blood slide)

Formula	$1000 * \frac{\text{number of confirmed malaria cases}}{\text{number of patients receiving a parasitological test}}$
Numerator	Number of cases of suspected malaria confirmed by either microscopy or RDT. The number should include both outpatient and inpatient cases. The number should include cases detected passively (attending health facilities or seen by community health workers) or actively (sought in the community); it is often useful to provide a breakdown of cases detected passively and actively. Any person with a positive result in a parasite-based test (microscopy or RDT), irrespective of clinical symptoms, should be considered to have confirmed malaria case.
Denominator	Total number of suspected malaria cases tested
Breakdown	Type of diagnostic test (microscopy or RDT), parasite species, geographical area, time (year and month), type of detection (passive, active, community)
Purpose	To reflect trends in malaria morbidity and identify areas with the most intense malaria transmission. partially 'corrects' for incompleteness of reporting and RDT stock-outs because the numerator is derived from the same source as the denominator.
Interpretation	<p>RDT and slide positivity rates can differ and should therefore be reported separately. RDT reflects the presence of antigens and may remain positive after parasites have been cleared by treatment.</p> <p>Test positivity rates can change if parasitological diagnosis has been extended to populations living in intense transmission areas that previously did not have access to testing. Care should be taken, therefore, to take into account possible confounding factors when interpreting trends.</p> <p>Changes in test positivity rates do not reflect percentage changes in malaria cases or incidence, as the number of malaria cases is part of the denominator.</p>

5. Percentage of cases due to *P. falciparum*

Formula	$100 * \frac{\text{number of confirmed } P. falciparum \text{ malaria cases}}{\text{number of confirmed malaria cases}}$
Numerator	<p>Number of <i>P. falciparum</i> cases confirmed by either microscopy or RDT. The number should include both outpatient and inpatient cases. Mixed infections with <i>P. falciparum</i> should be counted as <i>P. falciparum</i>.</p> <p>The number can include cases detected passively (attending health facilities or seen by community health workers) or actively (sought in the community); it is often useful to provide a breakdown of cases detected passively and actively.</p>

Denominator	Total number of cases of malaria confirmed by either microscopy or RDT. The number should include both outpatient and inpatient cases. The number should include cases detected passively (attending health facilities or seen by community health workers) or actively (sought in the community); it is often useful to provide a breakdown of cases detected passively and actively.
Breakdown	Type of diagnostic test (microscopy or RDT), geographical area, time (year and month), type of detection (passive, active, community).
Purpose	To reflect the proportion of cases due to <i>P. falciparum</i> and provide information on the likelihood of observing severe cases
Interpretation	<p>Can provide information on the likelihood of observing severe cases and the extent to which programmes should be adjusted to address <i>P. vivax</i> or other species.</p> <p>Can provide information on the degree of malaria control, as, in areas where control measures are scaled up, the proportion of cases due to <i>P. falciparum</i> may decrease; <i>P. vivax</i> appears to be respond less quickly to control measures because it can tolerate a wider range of environmental conditions and because the dormant liver stage (hypnozoite) enables infections to persist in the absence of mosquito transmission. <i>P. ovale</i> and <i>P. malaiiae</i> may also become more frequent, but these are rare in most settings.</p> <p>As the ability to detect <i>P. falciparum</i> may vary by type of test (microscopy or RDT), care should be taken to ensure that the proportion of cases due to <i>P. falciparum</i> is not influenced by changes in the ratio of different types of test used, i.e. the results of microscopy and RDT should be analyzed separately.</p>

6. Percentage of inpatient cases with a discharge diagnosis of malaria

Formula	$100 * \frac{\text{number of inpatient cases with a discharge diagnosis of malaria}}{\text{total number of inpatients}}$
Numerator	<p>Number of inpatients with a primary diagnosis of malaria at discharge or death. Patients who have absconded or been transferred should be excluded. All cases should have had a parasite-based test for malaria (microscopy and/or RDT) and a discharge diagnosis based on this test result.</p> <p>Malaria inpatient numbers should include patients from both hospitals and other facilities with beds.</p>
Denominator	<p>Total number of inpatients discharged or died (inpatients who have absconded or been transferred should be excluded).</p> <p>Total inpatient numbers should include patients from both hospitals and other facilities with beds.</p>
Breakdown	Age group (all ages, < 5 years), geographical area, time (year and month).
Purpose	To monitor the impact of programmes on severe disease. Partially 'corrects' for incompleteness of reporting because the numerator is derived from the same source as the denominator.
Interpretation	<p>Inpatient cases are markers of severe disease and death and indicate failure of the health system to either prevent or effectively treat malaria.</p> <p>The number of inpatient cases is generally larger than the number of health facility deaths, so that trends can be more easily discerned.</p> <p>This indicator is most useful in high- and moderate-transmission settings in which the rates of severe morbidity are significant.</p> <p>In some countries, inpatient cases may also include uncomplicated <i>P. falciparum</i> (according to national guidelines) in order to ensure full treatment, recovery and parasite clearance.</p> <p>Trends can be affected by:</p> <ul style="list-style-type: none"> • completeness of reporting: trends can change if different sets of health facilities are included, e.g. private hospitals with different proportions of inpatients due to malaria. • changes in diagnostic practice e.g. introduction of more diagnostic testing may reduce the number of malaria inpatients diagnosed. • changes in attendances for conditions other than malaria e.g. malaria inpatient proportions may decrease if the number of skilled deliveries increases. • actual changes in the incidence of severe malaria.

In order to conclude that changes in the value of the indicator reflect a real change in the incidence of malaria, indicators should be examined for completeness of reporting, percentage of cases that had a diagnostic test and the numbers of inpatient cases of malaria and other conditions, to confirm that they are reasonably constant over time.

Changes in the percentage of inpatients with a discharge diagnosis of malaria do not reflect changes in the number of malaria inpatient cases or inpatient case incidence as the number of malaria cases is part of the denominator.

7. Percentage of inpatient deaths due to malaria

Formula	$100 * \frac{\text{number of inpatient deaths due to malaria}}{\text{total number of inpatient deaths}}$
Numerator	Number of inpatients with a primary diagnosis of malaria at death. All cases should have had a parasite-based test for malaria (microscopy and/or RDT) and a diagnosis based on this test result. The numbers of malaria deaths should include patients from both hospitals and other facilities with beds.
Denominator	Total number of inpatient deaths. The numbers of deaths should include patients from both hospitals and other facilities with beds.
Breakdown	Age group (all ages, < 5 years), geographical area, time (year and month).
Purpose	To monitor the impact of programmes on the number of malaria deaths. Partially 'corrects' for incompleteness of reporting because the numerator is derived from the same source as the denominator.
Interpretation	Inpatient deaths are markers of very severe disease and indicate failure of the health system to either prevent or effectively treat malaria. The numbers of deaths are generally small, and trends may be difficult to discern, but clusters of deaths may occur in time and space. This indicator is most useful in high-transmission settings, in which malaria death rates are high. Trends can be affected by: <ul style="list-style-type: none"> • completeness of reporting: trends can change if different sets of health facilities are included, e.g. private hospitals with different proportions of deaths due to malaria. • changes in diagnostic practice e.g. introduction of more diagnostic testing may reduce the number of cases of malaria diagnosed in inpatients. • changes in attendance for conditions other than malaria e.g. malaria inpatient proportions may decrease if the number of skilled deliveries increases. • actual changes in malaria death rates. <p>In order to conclude that changes in the value of the indicator reflect a real change in malaria death rates, the indicators must be examined for completeness of reporting, percentage of cases that had a diagnostic test and the numbers of deaths from malaria and other conditions, to confirm that they are reasonably constant over time.</p> <p>Changes in test positivity rates do not reflect percentage changes in the number of malaria cases or incidence, as the number of malaria cases is part of the denominator.</p>

8. Annual blood examination rate

Formula	$100 * \frac{\text{number of patients receiving a parasitological test}}{\text{population at risk of malaria}}$
Numerator	Total number of suspected malaria cases tested. This can include active and passive case detection. Patients tested by both RDT and microscopy should be counted only once.
Denominator	Number of people living in areas where malaria transmission occurs. Areas with malaria transmission can be defined as those in which locally acquired, confirmed cases of malaria are reported. Population sizes should be adjusted for population growth according to projections from the national census or, when not available, United Nations Population Division projections. If rates are calculated per month, as when plotting a graph, the population size should be divided by 12 to obtain an annual rate.
Breakdown	Type of diagnostic test (microscopy or RDT), geographical area, time (year and month), type of detection (passive, active, community).

Purpose	To reflect the extent of diagnostic testing in a population; aids interpretation of other surveillance indicators.
Interpretation	Higher annual blood examination rates generally reflect more complete malaria surveillance. Some past guidance suggests that the annual blood examination rate should be about 10% in order to provide reliable trends, but the empirical evidence for such a target is not strong. In high- transmission settings, the rate is likely to greatly exceed 10% due to passive case detection alone.

9. Percentage of suspected malaria cases that have had a diagnostic test

Formula	$100 * \frac{\text{number of patients receiving a parasitological test}}{\text{number of suspected cases of malaria}}$
Numerator	Total number of suspected malaria cases tested. This should include those found by passive case detection only; patients identified by active case detection should be excluded. Patients tested by both RDT and microscopy should be counted only once.
Denominator	Number of suspected malaria cases attending health facilities (i.e. passive case detection).
Breakdown	Type of diagnostic test (microscopy or RDT), geographical area, time (year and month)
Purpose	WHO recommends that all suspected malaria cases should receive a diagnostic test by microscopy or RDT, regardless of age. The indicator reflects the extent to which malaria programmes are able to achieve this goal and where further effort may be required.
Interpretation	A value less than 100% may indicate problems in data recording, policy adoption, financing, stock-outs of RDT at national or health facility level or clinician adherence.

10. Completeness of health facility reporting

Formula	$100 * \frac{\text{number of health facilities reports received}}{\text{number of health facilities expected}}$
Numerator	Number of monthly reports received from health facilities. It may be necessary to consider the number of health facility reports for different data elements e.g. if outpatient cases are reported on different forms from inpatient cases. If a health facility does not submit a report, e.g. because it is temporarily closed, a null report showing zero cases and activities should be created and the reported marked as received.
Denominator	Number of health facility reports expected. Generally, this is the number of health facilities expected to report multiplied by the number of months considered.
Breakdown	Geographical area, time (year and month), report type (e.g. inpatient, outpatient)
Purpose	Regular monitoring and follow-up can improve the completeness of reporting until all health facilities are consistently reporting every month. Aids interpretation of other surveillance indicators.
Interpretation	The completeness of reporting of health facilities should be near 100%. Values < 100% may indicate problems with supplies of stationary, communications, staff availability, motivation or skills. The indicator gives equal weight to all health facilities and therefore may not reflect the completeness of case reporting; missing reports from district hospitals are likely to account for a larger number of missing cases than missing reports from remote rural health facilities.
Other	If data reported from district to regional or national level are summarized by district (rather than by health facility), the district summary form should contain two variables: number of health facilities expected to report and number of health facilities that reported. If community workers report malaria information to health facilities every month, the completeness of reporting by community workers should also be calculated. The health facility reporting form should contain two additional data elements: number of community workers expected to report and number that reported during the month.

ANNEX 2

Suggested register for community health workers, health posts and outpatient departments of health centres and hospitals

AN2

No.	Date	Name	Residence (village, neighborhood)	Sex	Age in years	Provisional diagnosis	New visit?	Malaria	Final	Treatment
								test result	diagnosis	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

- (6) Age in years: Age should be recorded as < 1 or 0 for children < 1 year of age.
- (7) Provisional diagnosis: may be amended in column 11 if the result of a malaria diagnostic test result is negative.
- (9) Malaria test result: The result should be recorded as +ve, -ve, or not done. If more than one species is possible, the parasite species (*P.f.*, *P.v.*, *P.m.*, *P.o.*) should be recorded for positive test results.
- (11) Final diagnosis: Will include presumed malaria if no test was performed.
- (12) Treatment: Specify if artemisinin-based combination therapy or other antimalarial treatment was given and if patient referred. The number of suspected malaria cases can be derived from column 7.

The number of confirmed cases can be derived from column 9. The number of presumed malaria cases can be derived by subtracting the number of confirmed malaria cases in column 9 from the number of malaria diagnoses in column 10. Counts should apply only to new visits, which are indicated in column 8; sometimes, columns for repeat visits are added to the right of column 11.

ANNEX 4

Daily and weekly records of outpatient attendance at health centres and hospitals

Month: April 2012	1	2	3	4	5	6	7	Weekly total	8	9
Day:	S	M	T	W	T	F	S		S	M
Patient attendance										
Suspected malaria	8	59	47							
Microscopy										
Patients examined		56	42							
<i>P. falciparum</i>		18	16							
<i>P. vivax</i>		3	6							
<i>P. malariae</i>										
<i>P. ovale</i>										
Mixed										
Positive tests (confirmed malaria) <5		8	12							
Positive tests (confirmed malaria) ≥5		13	10							
RDT testing										
Patients tested with RDT	8	2	4							
Positive tests (confirmed malaria) <5	2	0	1							
Positive tests (confirmed malaria) ≥5	1	0	0							
Treatment										
Confirmed cases receiving antimalarial	2	0	1							
Presumed cases receiving antimalarial (presumed cases = cases not tested)	1	0	0							

AN4

ANNEX 5

Discharge register for inpatient departments of health centres and hospitals

No.	Date	Name	Residence (village, neighbourhood)	Sex	Age	YMD	Diagnosis	Length of stay (days)	Reason for leaving
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

- (7) YMD: units in which age is recorded: days should be used for children < 1 month, months for children < 1 year, years for others).
- (8) Diagnosis: Should follow ICD classifications as far as possible; some facilities may add a column for the ICD code.
- (10) Reason for leaving: discharged, died, transferred or absconded

The total number of malaria inpatient cases should be the number discharged plus died, i.e. excluding transferred and absconded, as a final diagnosis will not have been made.

ANNEX 6

Reports from health posts and community health workers to health facilities

Patient attendance

Suspected malaria

Testing

Patients tested with RDT

Confirmed malaria <5 years

Confirmed malaria \geq 5 years

Treatment

Confirmed malaria treated with antimalarial medicine

Cases not tested treated with antimalarial medicine

Cases referred

The number of variables to be reported each month should be kept to a minimum, to enhance the completeness and quality of reporting. All health workers should understand the terms used, i.e. 'confirmed malaria': suspected malaria cases with a positive test. Notes can be placed at the bottom of a form and in standard treatment manuals as a reminder.

ANNEX 7

Reports from health facilities to the district level

Areas with *P. falciparum* only

Outpatients

Suspected malaria

Total outpatients

Testing

Patients tested by microscopy

Confirmed malaria <5 years

Confirmed malaria 5+ years

Patients tested with RDT

Confirmed malaria <5 years

Confirmed malaria 5+ years

Inpatients

Malaria <5

Malaria 5+

Total discharges <5

Total discharges 5+

Deaths

Malaria <5

Malaria 5+

Total deaths <5

Total deaths 5+

Treatment

Confirmed malaria treated with antimalarial medicine

Cases not tested treated with antimalarial medicine

Areas with more than one species of Plasmodium

Outpatients

Suspected malaria	
Total outpatients	

Testing

Patients with microscopic slide examination	
<i>P. falciparum</i>	
<i>P. vivax</i>	
<i>P. malariae</i>	
<i>P. ovale</i>	
Mixed	
Total confirmed malaria <5 years	
Total confirmed malaria 5+ years	

Patients tested with RDT	
Confirmed malaria <5 years	
Confirmed malaria ≥5 years	

Inpatients

Malaria <5	
Malaria ≥5	
Total discharges <5	
Total discharges ≥5	

Deaths

Malaria <5	
Malaria ≥5	
Total deaths <5	
Total deaths ≥5	

Treatment

Confirmed malaria treated with antimalarial medicine	
Cases not tested treated with antimalarial medicine	

The number of variables to be reported each month should be kept to a minimum, to enhance the completeness and quality of reporting. All health workers should understand the terms used, i.e. 'confirmed malaria': suspected malaria cases with a positive test. Notes can be placed at the bottom of a form and in standard treatment manuals as a reminder.

The tally sheet should be locally adapted. For example, if there is no *P. vivax* or *P. ovale*, those can be removed. In settings where a multi-species RDT is used, the RDT section should be adapted to report those results.

ANNEX 8

Line lists of inpatient malaria cases and deaths to be reported to district level in low-transmission settings

- (7) Type of test: RDT, microscopy or none.
 (8) Species: If only *P. falciparum* is present, this column is not needed. If more than one species might be involved, the parasite species (*P.f.*, *P.v.*, *P.m.*, *P.o.*) should be recorded for positive test results.
 (9) ITN: insecticide-treated net.
 (11) IRS: indoor residual spraying.
 (16) Medicines used: Specific details to be provided to determine possibility of expired or counterfeit medicines.

No.	Date admitted	Name	Residence (village, suburb)	Sex	Age	Pregnant? (Y/N)?	Type of test (RDT/micr.)	Species	Malaria prevention			Antimalarial treatment				Reason for leaving (discharged/died/absconded/transferred)		
									ITN owned by household (Y/N)?	ITN used in 2 weeks before admission (all nights some/ none)?	House received IRS (Y/N)?	Date of onset of symptoms	Date contacted health system	Received antimalarial treatment (Y/N)	Date started		Medicines used	
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		

(1)

(2)

(3)

(4)

(5)

(6)

(7)

(8)

(9)

(10)

(11)

(12)

(13)

(14)

(15)

(16)

(17)

ANNEX 9

Line lists of all confirmed malaria cases to be reported at district level in low-transmission settings

- (6) Type of test: RDT, microscopy or none
 (7) Species: If only *P. falciparum* is present, this column is not needed. If more than one species might be involved, the parasite species (*P.f.*, *P.v.*, *P.m.*, *P.o.*) should be recorded for positive test results.
 (8) ITN: insecticide-treated net.
 (10) IRS: indoor residual spraying.
 (15) ACT, artemisinin-based combined therapy; CQ, chloroquine.

No.	Date admitted	Name	Residence (village, suburb)	Sex	Age	Type of test (RDT/micr.)	Species	Malaria prevention			Antimalarial treatment						
								ITN owned by household (Y/N)?	ITN used in 2 weeks before admission (all nights some/ none)?	House received IRS (Y/N)?	Date of onset of symptoms	Date contacted health system	Received antimalarial treatment (Y/N)	Date started	Medicines (ACT, CQ, others)		
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
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16																	
17																	
18																	
19																	
20																	

(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) (15)

ANNEX 10

Example of supervisory checklist for malaria surveillance for countries with high to moderate transmission

During visits to health facilities, supervisors should check that registers are kept up to date, with all fields completed; data on report forms correspond to information in registers and tally sheets; core analysis graphs and tables are up to date; and discussions are held about interpretation of the trends and potential action. Health facility staff should be encouraged to investigate all malaria inpatient cases and death.

Record keeping	Not present	Present but not up to date	Present and up to date	Present, up to date and no mistakes
Outpatient register				✓
Discharge register				✓
Daily attendance summary book				✓
Monthly attendance summary book				✓
Graph of suspected cases	✓			
Graph of number of tests performed	✓			
Graph of number of confirmed cases				✓
Graph of test positivity rate			✓	
Reporting	None	1	2	3
Number of monthly reports sent on time in last 3 months				✓
Investigations performed in past 3 months	Not done	Done	Done & action taken	
Malaria deaths			✓	
Malaria inpatients			✓	
Malaria cases	✓			
Disease or programme delivery issues that need attention				
<i>Large number of inpatient cases still from Lacienda village</i>				
Recommendation				
<i>Calculate test positivity rates as demonstrated.</i>				
<i>Work with Lacienda village chief to encourage residents to use LLINs and attend health centre promptly if ill with fever.</i>				

ANNEX 11

Example of questionnaire for malaria post-epidemic assessment

The following questionnaire should provide the basic principles for post-epidemic assessment and help to identify potential defects in the key components. It could also provide a framework to assess the level of success in responding to the epidemic.

1. Have epidemic-prone areas for the country been demarcated?

If so, did the epidemic occur in a high-risk area?

2. Are early warning systems using, for example, real-time weather data made available and shared and discussed by district management teams?

- a. Did this data predict a possible epidemic in the region?
- b. Was the regional malaria control station aware of the risk?
- c. Was this information disseminated to all levels of malaria control?
- e. Was there adequate time for planning for interventions if the predictions were confirmed?

3. Early detection system

- a. Is there a well equipped surveillance system for early detection of epidemics, including malaria, at district level in areas which are epidemic prone?
- b. Were these data recorded, analysed in relation to defined thresholds at district level, providing regular feed back to peripheral health-care facilities?
- c. Were records of previous years available for comparison?
- d. What method was used to analyse anomalies and define / validate thresholds (i.e. mean + 2 standard deviations, 3rd quartile, etc)?
- e. Were these data regularly reported to a central facility?
If yes, what communication channels were used?

4. Recognition of anomalies and preliminary action taken at the periphery

- a. Are unexpected increase in cases detected at the periphery and action immediately taken?
- b. If yes, what action was taken at the periphery first and then at district level?
- c. How was the verification of the epidemic implemented?
- d. How effective was the verification process? Fast enough (days)?
- e. How was notification to district made and what was the lag time (days)? If more than 2 days, what caused the delay?

5. Was the response timely?

- a. Was there effective communication between the local and district level?
- b. What was the lag time between confirmation of the epidemic and response?
- c. Were there adequate drugs and medical supplies at district level for rapid distribution?
- d. Were insecticides and related supplies available (if relevant)?
- e. Were there sufficient trained personnel to handle the epidemic?
- f. Were there sufficient diagnostic facilities?

6. Disease and economic burden

- a. How long did the epidemic last (weeks)?
- b. What was the population affected?
- c. How many cases were fatal?
- d. What was the level of morbidity?
- e. If private companies were affected, was some attempt made by the company to measure the economic impact?

7. If the situation required mobilizing national emergency support:

- a. What was the time lag for communication between district and national levels?
- b. Who alerted the national level to stimulate a national response (district office, newspaper or other media, other source)?
- c. Was national support necessary? Was partners' support necessary?
- d. If other support was needed, was it effective in curbing the epidemic? [give some explanation]

8. Preparedness plan of action

- a. Was there a budget allotted for malaria epidemic response?
- b. Were partners involved in the development of the PPOA?
- c. Were source reduction measures employed?

If yes, were they technically appropriate? Were they effective?

The questionnaire, such as the example above, should make clear what problems were faced during the pre-epidemic and early epidemic periods when control options are expected to be the most efficient. This knowledge would enable NMCP and partners to understand how to strengthen or amend the existing epidemic preparedness plan.



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