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Part II

Malaria entomology and vector control

Tutor's Guide

World Health Organization
HIV/AIDS, Tuberculosis and Malaria
Roll Back Malaria

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Trial Edition

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Foreword

This module covers essential aspects of malaria entomology and vector control. It is multipurpose as the depth and selection of learning units depends on the background of the audience and learning objectives. It can be used to train field vector control workers, laboratory technicians, or health workers working in malaria vector control programmes at different levels. The latter audience may not need details of the field and laboratory techniques but rather focus should be given to the units that deal with epidemiological application of selective vector control options, strategies and management of vector control. The first two categories of audience may need additional resource materials if a course is entirely for laboratory and field techniques. It can be used to train those operating at national and district malaria (vector) control programmes with responsibility for planning, implementation, monitoring and evaluation of vector control activities.

The Tutor's Guide has two purposes: 1) to assist in planning, organization and implementation of training activities and 2) to assist the tutor to teach effectively. As the tutor, you will be responsible for the overall direction and coordination of training. You should be trained in entomology and have extensive experience in malaria vector control. To assist you, you should have three facilitators (or assistants), who are vector biology and control technicians or supervisors with field and laboratory experience. Specialists in particular topics such as insecticides resistance, mosquito taxonomy, or malaria can be of value to the course as they bring their own expertise to the class.

The course is designed for a 7 day period. Learning units 1-5 introduce malaria entomology and role of entomology in malaria control including identification of malaria vectors both adult and larval stages, collection techniques, laboratory skills to determine vector stages and sporozoit infection rates, and techniques for insecticide resistance and residual efficacy. You will examine the biology of vectors and their incrimination as vectors using real-life examples where you calculate the most important entomological indicators of malaria transmission. Learning Unit 6 gives the basic principles for the selection and implementation of vector control methods. The advantages and limitations of each method are discussed. You will examine the role of integrated vector control in a malaria programme.

Learning Unit 7 includes the epidemiological stratification of malaria and the role of vector control in different epidemiologic strata. Finally, Learning Unit 8 brings together the fundamentals of malaria entomology and the management of vector control as part of a malaria control programme, including the importance of monitoring and evaluating vector control implementation.

The module was originally prepared by Dr Tarekegn Abose Abeku and Dr Pushpa Herath, with technical inputs from Drs Maru Aregawi, Elil Renganathan and M.C. Thuriaux. Dr Yemane Ye-ebiyo contributed to the development of the unit that deals with malaria stratification. Two publications previously produced by WHO, namely, *Entomological Field Techniques for Malaria Control* and *Entomological Laboratory Techniques* have been used as background documents in developing Learning Units 1-5, although most of the material has been extensively re-written and adapted to the needs of malaria control programme managers. We are grateful to Dr M. Zaim for his valuable inputs and providing a background (unpublished) WHO document on judicious use of insecticides, which proved useful in writing Learning Unit 8. Other background documents used in the rest of the learning units have been acknowledged in the text. Finally, we would like to acknowledge comments provided by several experts in WHO Headquarters and WHO Regional Office for Africa, in particular Drs K. Cham, P. Guillet, L. Manga, M. Nathan and B. Ameneshewa. The last version of the module was updated by Dr Robert H. Zimmerman.

Introduction

Organization of the Tutor's Guide

The *Tutor's Guide* is arranged into learning units organized by topics and learning objectives. The sections correspond to the learning units of the *Learner's Guide* and are set out in the sequence in which they should be taught. The learning objectives are detailed in the *Learner's Guide* and are not repeated here. It is important that you elaborate and clarify the technical content of the *Learner's Guide* by using examples, giving demonstrations and responding to questions. You should therefore be adequately prepared to do this. Short presentations are needed and indicated where they should be presented.

Equipment and teaching aids

Under each Unit, a list of minimum essential equipment is suggested to help you in your teaching activities. You can use overheads of the objectives of the learning units and the important points in the *Learners Guide* to explain the material

Teaching and learning methods

The different teaching methods that you can use are given in the Timetable and under each Unit.

Assessment

Both you and the learners should be able to make regular assessments of progress in knowledge and skills. The tutor is given guidelines on types of assessment that might be used, and methods directly related to the learning objectives in the *Learner's Guide*.

Principles of the training programme

The training programme in this Tutor's Guide is based on the following principles:

- The purpose of the training is the acquisition of essential knowledge and the development of basic skills in malaria entomology.
- Effective learning is encouraged if learners understand the purposes of training and feel that the goals are important in their own malaria control programmes.
- Effective learning is encouraged if learners are actively involved in learning by themselves and from others, as well as from what the tutor tells them. The number of lectures should therefore be kept to a minimum, with learners being urged to find things out for themselves.
- Effective learning is encouraged if learners can see that they are making progress. It is thus important that the tutor try to understand any difficulties learners may be having and help to overcome them.

The learning and teaching methods to be used include:

- Reading by learners (ask learners to read the relevant Units for the next day before coming to class)
- Presentation by the tutor of salient points in each Unit using overheads
- Demonstration by tutor and assistants of equipment and techniques
- One-day field trip to a rural locality to practice mosquito collection techniques
- Laboratory practical sessions
- Group discussions followed by plenary discussions
- Film show on malaria entomology field and laboratory techniques.

Training facilities

The training facility should provide a classroom large enough to accommodate you, the facilitators, and all the learners, plus an entomological laboratory equipped with microscopes, and an insectary where local vector species are reared. You will also need some vector control equipment, especially compression sprayers, for demonstration. For the purposes of lecture sessions and demonstrations, you will require a chalkboard, a 35-mm slide projector, a screen (or plain white wall), an overhead projector, one or more flipcharts, a TV set (preferably 32-inch screen), and a video player. Additionally, there should be a reference collection of mosquitoes, consisting of preserved specimens of adult anopheline and culicine mosquitoes, larvae and pupae, and including all vector species that occur in your country or area. Transport for up to 35 people will also be required for a one-day fieldwork. Details of other equipment needed for laboratory and fieldwork are given in later sections of this Guide.

Due to the short time allocated to this course, you need to plan ahead and organize activities as efficiently as possible. Therefore, it is very important that every evening (including the evening before the start of the training course) you do the following:

- **explain the plan for the next day's activities** to assistants/facilitators and discuss how to efficiently carry out the activities
- **prepare equipment and materials required for the next day** of the training
- **assign responsibilities** to the assistants/facilitators regarding each task to be accomplished the next day

Note: The time allocated for the learning and teaching activities should not be spent preparing equipment and specimens. Preparation should be done in advance of the course or before you teach a particular learning unit.

Timetable – Malaria Entomology and Vector Control

Day	Topic	Teaching method*	Hrs
1	Introduction - tutor, facilitators and participants, course goal and objectives		1 ½
	UNIT 1 Introduction to malaria entomology	PRS/DEM	1 ½
	UNIT 2 Identification of malaria vectors	PRS/DEM/PRC	3
	Film (Malaria Entomology)	FLM	1
2	UNIT 3 Sampling malaria vectors	PRS/DEM	2
	UNIT 4 Susceptibility and bioassay tests	PRS/DEM/PRC	3
	UNIT 5 Vector incrimination and malaria control	PRS/PRC	2
3	UNIT 5 Vector incrimination and malaria control (continued)	PRC	1
	Field work (collection of adult mosquitoes and larvae)	PRC	6
	Organization and preservation field-collected specimens	PRC	1
	UNIT 4 Calculating mortality rates of susceptibility and bioassay tests		½
4	UNIT 4 Discussion of susceptibility and bioassay results	PRC	1
	UNIT 5 Identification and dissection of field-collected specimens (continued)	PRC	3
	UNIT 6 Malaria vector control - introduction	PRS/GRP	3
5	UNIT 6 Malaria vector control - demonstration of vector control methods	DEM	4
	Malaria vector control - implementation plan and integrated vector control	PRS/GRP	3
6	UNIT 7 Stratification and malaria vector control	PRS/GRP	3
	UNIT 8 Management of malaria vector control	PRS/GRP	4
	Closure	GRP/PRS	1

*PRS = Presentation by tutor
DEM = Demonstration
PRC = Laboratory practical
FLD = Field work
FLM = Film show
GRP = Group exercises or discussions followed by plenary discussion

Learning Unit 1

Introduction to malaria entomology

Learning objectives

By the end of this Unit the participants should be able to:

- describe how malaria is transmitted
- describe the life cycle of the mosquito and relate this to the transmission of malaria
- understand the purpose and role of entomological studies in malaria control
- describe different types of mosquito surveys and their purposes in malaria control

The aim of this Unit is to introduce learners to the field of malaria entomology, by emphasizing the importance and purpose of entomological studies in malaria control programmes.

Equipment and support

Have an insectary with live *Anopheles* eggs, larvae, pupae and adults available for this learning unit and the other units.

Teaching and learning methods

Presentation

Start the session by asking learners what they know about malaria, its transmission and control. Also ask them if they had any background in malaria entomology or any entomological activities before coming to the training programme.

To facilitate a smooth introduction to the field of entomology, give a presentation on an overview of malaria and its transmission, control measures, and the life cycle of the *Anopheles* vector, followed by a plenary discussion.

Demonstration

Demonstrations of the life cycle of *Anopheles* mosquitoes should take place in the insectary. The learners will visit the insectary in groups of 10. Together with the insectary supervisor:

- show live specimens of each of the stages of the *Anopheles* life cycle
- explain how an insectary functions

Guidelines for assessment

During the plenary discussions, ask the learners how and why they need to carry out entomological studies in malaria control programmes in their respective districts or countries. Have them give examples of their own entomological activities.

Learning Unit 2

Identification of malaria vectors

Learning objectives

By the end of this Unit the participants should be able to:

- Distinguish mosquitoes from other insects
- Tell male and female mosquitoes apart
- Distinguish female anopheline mosquitoes from female culicine mosquitoes
- Differentiate between anopheline and culicine eggs, larvae and pupae
- Describe major external morphological features of adult and larval anophelines used in species identification
- Use a species identification key

Equipment and support

Live and preserved *Anopheles* and *Culex* eggs, larvae, pupae and adults (both male and females), dissecting and compound microscopes, *Anopheles* wing mounted on a slide, Petri dishes, beakers, mosquito cages, a copy (for each learner) of *Anopheles* species identification keys (adult females and larvae), forceps, slides, cover slips, droppers.

Teaching and learning methods

Presentation

Using overhead slides, present as clearly as possible the distinguishing characteristics that help distinguish *Anopheles* mosquitoes from other insects and other mosquito genera at different stages of their life cycle. Using clear diagrams, describe the external structures of both the adult and larval stages of *Anopheles* mosquitoes that are useful for species identification. Do not waste time in explaining parts that are not normally used for identifying species.

Demonstration

Exercise 2.1
In the laboratory, show live and preserved specimens of anopheline and culicine mosquitoes at the various stages of their life cycle. To demonstrate the differences in the positions of the live larvae, use beakers or enamel trays. Similarly, use cages to demonstrate the resting positions of adult anophelines and culicines. Use preserved or pinned specimens to show differences at all stages of the life cycle.

Practical

Exercise 2.2
Form groups of two learners and provide each group with a compound and dissecting microscope, forceps, dissecting needles and two freshly pinned adult female anophelines and two larval specimens on slides. Ask each learner to identify one adult and one larva to the species (or species complex) level.

The third day of the training programme is devoted to fieldwork. Learners will also have another opportunity to identify anophelines after the fieldwork.

Guidelines for assessment

At the end of the practical, ask learners how they identified the species of the specimens they were given.

Ask learners also to draw and label an outline diagram of anopheline adult female and anopheline larva, with emphasis on the parts that are used for species identification.

Learning Unit 3

Sampling malaria vectors

Learning objectives

By the end of this Unit, participants should be able to:

- Understand the importance and use of different mosquito surveys
- Use different methods to collect mosquitoes and describe their purposes
- Describe the methods of handling and transportation of live mosquitoes
- Transport live larvae and pupae collected in the field to the laboratory and preserve them
- Describe breeding sites of malaria vectors

Equipment and support

Sucking tube, torch, paper cups with covering net, cotton wool, rubber bands, mosquito cages, chloroform, towels, white cotton sheets, pyrethrin solution, kerosene, small Petri dishes, hand lens, forceps, a card box container (preferably a picnic box) for transporting mosquitoes, live adult females in cages, live larvae and pupae in enamel trays, dippers, pipette, vials, 70% alcohol solution, cotton wool, safety match or lighter.

Teaching and learning methods

Presentation

Explain the different mosquito collection techniques, including:

- hand collection of indoor-resting mosquitoes
- spray-sheet collection of indoor-resting mosquitoes
- hand-collection of outdoor-resting mosquitoes
- direct collection from human and animal-baits
- human and animal trap-net collections
- collection of larvae and pupae

Also explain how to transport live adults, larvae, and pupae and the techniques used to kill and preserve specimens.

Demonstration

During the presentation, demonstrate each item of equipment used in mosquito collection.

In the laboratory, demonstrate the following:

- How to use the sucking tube to pick up mosquitoes from a cage and how to put them in paper cups
- How to pick live larvae and pupae using a dropper and put them in a vial
- How to kill and pack (preserve) larvae.

Practical after presentation

Exercise 3.1
Each learner should practice the following:

- Using a sucking tube, picking adult mosquitoes from a cage and putting them in paper cups;
- Picking live larvae and pupae using droppers and putting them in vials;
- Killing and preserving larvae and pupae.

Fieldwork

The fieldwork will take place on day 3 of the course.

Exercise 3.2
A one-day field trip will be required to allow learners to practice the mosquito collection techniques that were demonstrated to them. In the field, learners will work individually and in groups to carry out the following activities:

- Using sucking tubes, torches and paper cups, each learner will search for indoor-resting mosquitoes in three houses
- Using sucking tubes, torches and paper cups, each learner will spend at least 20 minutes searching for outdoor-resting mosquitoes
- In groups of four, learners will carry out spray-sheet collections in one house per group
- Using dippers, vials and pipettes, each learner will collect larvae and pupae from natural breeding sites for at least 30 minutes
- Learners will practice the proper ways of sitting with bare legs indoors and outdoor during night-landing collections (due to shortage of time, this will be done during the daytime for the sake of practice and demonstration)
- Learners will transport live specimens to the laboratory.

Practical after fieldwork

Exercise 3.3
In groups of two, learners will learn to kill anophelines and determine their abdominal conditions and identify them to species. They will also practice dissecting ovaries and salivary glands of the field-collected mosquitoes.

Guidelines for assessment

This learning unit is based on demonstrations and a practical. During the practical, evaluate the performance of the learners and correct any errors in mosquito collection, preservation, and identification.

Learning Unit 4

Susceptibility and bioassay tests

Learning objectives

By the end of this Unit, participants should be able to:

- calculate the level of insecticide resistance in a vector population
- determine the residual efficacy of an insecticide deposit on a sprayed surface at a specified time after the spraying
- determine the residual efficacy of an insecticide-treated bed net at any particular time after treatment of the net

This Unit includes demonstrations and some laboratory activities. Time constraints make it necessary that each learner be assigned part of the experiments and that the data is combined later.

Equipment and support

Fed and live female anophelines, susceptibility test kit, thermometer, wooden box with large holes, towels, cotton wool, paper cups with cover nets, rubber bands, markers or wax pencils, mosquito cage, bioassay kit, cardboard paper, adhesive tapes, insecticide-treated bed net, insecticide-free bed net.

Learning and teaching methods

Presentation

Explain briefly the principles and procedures of susceptibility and bioassay tests in the class while demonstrating the required equipment.

Demonstration and practical

Susceptibility tests

Exercise 4.1

- Demonstrate how to prepare exposure and holding tubes with paper linings, how to introduce mosquitoes into the tubes and how to transfer mosquitoes from one tube to another.

- Working in pairs, learners should prepare holding tubes and each pair should introduce 15 fed females to the holding tubes.

- When all groups have introduced the mosquitoes, ask half of the groups to prepare exposure tubes and the other half to prepare control tubes.

- After all tubes have been prepared, ask all groups to transfer the mosquitoes to the exposure and control tubes and ask tem to label each tube with the group number indicating whether it is an exposure or a control tube, and the time of the day.

- After one hour of exposure, each group should transfer back the mosquitoes to the holding tubes for 24 hours observation. After 24 hours, all results should be combined to calculate mortality rates.

Bioassay tests

Exercise 4.2
First demonstrate bioassay procedure on a wall. Then form pairs and ask half of the groups to install cones on treated bed nets and half on untreated bed nets. Each pair should transfer 10 fed mosquitoes to the cones; after three minutes the mosquitoes should be taken out and placed in paper cups for 24 hours observation. Results should be combined to calculate mortality rates.

Guidelines for assessment

This Unit is based on active involvement of the learners in the practical and thus performance should be assessed while they are doing their assigned tasks. Any shortcomings should be corrected accordingly.

Learning Unit 5

Vector incrimination and malaria control

Learning objectives

By the end of this Unit the participants should be able to:

- Describe the methods used to incriminate malaria vectors
- Identify the entomological indicators of malaria transmission
- Calculate the entomological indicators associated with the resting habits, feeding habits, human-vector contact and entomological inoculation rates for malaria vectors
- Measure the components of the vectorial capacity model and understand it's value for malaria control
- Interpret the entomological measurements and their implications for malaria vector control

This Unit is based on practical laboratory activities. Learners should be able to dissect ovaries and salivary glands of female anophelines and to determine the abdominal conditions of females correctly.

This Unit puts together the applications and implications of the entomological techniques learned so far in this course. Some of the materials are advanced and the tutor may want to walk through the examples rather than leaving the learners to do it themselves.

A major objective of the Unit is to illustrate how entomological information can be used to plan an effective vector control programme. It is based on an actual example of an entomological study carried out in Ethiopia during the early stages of the country's Malaria Eradication Service in the 1960s.

Equipment and support

You will need female anophelines at different abdominal stages (with a majority of unfed mosquitoes), dissecting microscope, compound microscope, dissecting needles, fine forceps, slides, dropper, distilled water, 0.65% saline solution.

Also, flip charts for group discussions are needed.

Learning and teaching methods

I. Vector incrimination techniques

Presentation

Give a brief presentation with slides on abdominal conditions, and determination and determination of infection. Mention oocycte examination, although this will not be covered in the module.

Demonstration and practical

Exercise 5.1
Recognizing abdominal conditions - Demonstrate an assortment of abdominal conditions under a dissecting microscope. Then have the learners determine the abdominal conditions of several mosquitoes in groups of two.

Exercise 5.2
Dissection of ovaries and determination of parity - Explain and demonstrate the correct methods for dissection, and demonstrate ovaries which have been dissected.

In pairs, learners should dissect ovaries of unfed and of freshly fed females, demonstrating to each other. Observe their techniques and point out errors individually. Give the learners plenty of opportunity for individual practice.

Explain how ovaries should be dried and how they should be protected from ants and flies. Demonstrate parous and nulliparous ovaries under the microscope, giving all learners the time to practise dissections correctly and plenty of individual opportunities to classify dried ovaries as parous or nulliparous until they can make these distinctions accurately.

Exercise 5.3
Dissecting salivary glands - This requires more practice that dissecting ovaries. First demonstrate how to dissect the salivary glands and show the size and shapes of the lobes under the dissecting microscope. In pairs, the learners should dissect out salivary glands. Demonstrate the glands under the compound microscope; all learners should be able to do so with their own specimens.

Demonstrate how to flip the cover slip with adhesive in order to look for infection under microscopic examination of salivary glands, and how to stain.

Exercise 5.4
There will be a field trip to allow the participants to practice the various mosquito collection techniques that they learned in Learning Unit 3, and the dissection techniques demonstrated in the current learning unit. In the field, they will carry out the following activities:

- Using sucking tubes, flashlights and paper cups, search for indoor-resting mosquitoes in three houses

- Using sucking tubes, torches and paper cups, spend at least 20 minutes searching for outdoor-resting mosquitoes
- In groups of four, carry out spray-sheet collections in one house per group
- Using dippers, vials and pipettes, collect larvae and pupae from natural breeding sites for at least 30 minutes
- Practise sitting with bare legs indoors and outdoor during night-landing collections (because time is short, this will be done during the daytime for the sake of practice and demonstration)
- Transport live specimens to the laboratory

Exercise 5.5

When the participants return to the laboratory they should work in groups of two and kill the mosquitoes they collected during the field trip and identify the abdominal conditions and species. Then they should practice dissecting ovaries and salivary glands of the field-collected mosquitoes.

II. Entomological indicators of transmission

Present a short introduction to this part of the learning unit and if necessary go through an example of the exercises. You should carefully review with the learners the calculations of the entomological indicators. For example, do a "worked-out solution" for the calculation of *f* (proportion of blood meals taken on man and followed by indoor resting), longevity and infectivity of mosquitoes and the entomological infection rate (EIR).

Exercise 5.6

a. Indoor density

The learners should be divided into groups of five and asked to calculate the indoor resting density per house per day for each species for the month of October 1964. You can ask them to do other months and compare their results by month.

Solution: Density/house/day: *A. gambiae* s.l. = 1765/18 = 98.06; *A. pharoensis* = 91/18 = 5.06.

b. Feeding habits

Solution: The results indicate that both species will bite freely outdoors throughout the night if a suitable host is found there, which shows a more exophagic behaviour. The ratio of outdoor to indoor biting is 30:2 = 15 for *A. pharoensis* and 136:50 = 2.7 for *A. gambiae* s.l. *Anopheles pharoensis* is thus more exophagic than *A. gambiae* s.l.

c. Man-biting rates

A. gambiae	August:	$M = M_x + M_y = 360.25 + 4.75 = 365.0$
	Sept.:	$M = M_x + M_y = 4.13 + 1.5 = 5.63$
A. pharoensis	August:	$M = M_x + M_y = 23.10 + 4.63 = 27.7$
	Sept:	$M = M_x + M_y = 18.4 + 17.9 = 36.3$

Resting habit

Exercise 5.7

Solution: Ninety seven percent of the *A. gambiae* s.l. feeding on humans rested indoors (species highly *endophilic*), whereas only 4.0% of the resting *A. pharoensis* fed indoors (species highly *exophilic*).

Longevity and infectivity

Exercise 5.8

The working groups will answer the two questions in the learners guide. They should present their results in plenary.

Solutions:

a) *A. gambiae* s.l. is more important as a vector in the area compared to *A. pharoensis*, because, (a) it lives longer; (b) it has been found infected, whereas no infection was confirmed in the latter species; (c) the former has more man-vector contact that the latter (average of 13.3/man/night versus 10.8/man/night).

b) From the following table, it can be seen that most man-vector contact with *A. gambiae* s.l. takes place indoors, in spite of the fact that this species tends to be exophagic if given equal opportunity indoors and outdoors. However, from the indoor resting densities and man-biting rates, it can be seen that the month of June is the best option to apply the insecticide, and that the insecticide can be applied once a year even though the residual activity is six months due to low densities and man-biting rates after the sixth month until the month of June of the following year.

   This result also show how the night-time habits of the local people affects transmission, despite the basic feeding habit of the vector. The use of insecticide-treated bed nets may be feasible in this particular case.

Month and year	No. of nights of catch	No. of baits		Total catches indoor		Total catches outdoor 6 - 10pm	Man-biting rate		
		Indoor	Outdoor	6-10pm	10pm - 6am		Indoor component (3+8 hrs)	Outdoor component (1 hr)	Total (12 hrs)
Jun 64	-	-	-	-	-	-	-	-	-
Jul 64	2	2	2	12	84	16	23.3	1.0	24.3
Aug 64	2	2	2	81	340	76	100.2	4.8	105.0
Sep 64	1	2	2	5	7	12	5.4	1.5	6.9
Oct 64	2	2	2	4	21	34	6.0	2.1	8.1
Nov 64	2	2	2	2	1	9	0.6	0.6	1.2
Dec 64	2	2	2	0	0	4	0.0	0.3	0.3
Jan 65	2	2	2	0	0	2	0.0	0.1	0.1
Feb 65	2	2	2	0	0	0	0.0	0.0	0.0
Mar 65	2	2	2	0	0	0	0.0	0.0	0.0
Apr 65	1	2	2	0	0	0	0.0	0.0	0.0
May 65	2	2	2	0	0	0	0.0	0.0	0.0

Closure discussion

You should lead a review of the key concepts of the vector biology and how they relate to malaria transmission and vector incrimination. Your should raise the question in the *Learner's Guide* and have the class develop a list of the components of a vector's biology that increases the risk of malaria. Place the class results on a flip chart.

Guidelines for assessment

The learners should be able to:

- differentiate unfed, freshly fed, half gravid and gravid mosquitoes correctly
- dissect both ovaries completely and without damage
- accurately discriminate between parous and nulliparous ovaries
- dissect salivary glands without damaging the lobes

Also, the groups should be able to work out all exercises. During the plenary, you can ask a representative of each group to give solutions to one exercise question.

Learning Unit 6

Malaria vector control

Learning objectives

By the end of this Unit, the participants should be able to:

- know the role and objectives of vector control in malaria prevention and control
- describe vector control options, their expected impacts, their advantages and their limitations
- identify operational issues likely to influence vector control planning and implementation
- demonstrate a technical understanding of the main vector control measures

This learning unit serves as an introduction to malaria vector control. A considerable amount of time has been allocated to the learning unit, as extensive discussions, demonstrations and practical are required to provide sound technical knowledge and some skills of the various vector control options.. You will give presentations based on the materials in the *Learner's Guide*.

Note: Make sure the learners study the reading at the end of the learning unit before coming to class. This reading and any other materials you can provide on control methods is required in order to complete this learning unit effectively.

Equipment and support

Presentation equipment and materials are needed in this section, including the relevant videos on spraying techniques if available. The demonstration and discussion of materials and equipment should be done before Exercise 6.3 if possible.

Indoor residual spraying

You will need compression sprayers, buckets measuring cylinders (1 litre capacity), a training wall for spraying, and one charge of a residual insecticide. A well-trained vector control technician should demonstrate the parts and operations of a spray pump, preparation of insecticide solutions, and spraying techniques.

Insecticide treated nets

Bed nets, insecticides for bed net treatment, treating basins, measuring cylinders (l litre capacity and 10 ml capacity) are required for demonstration and practical.

Larvicides

You should have at least one type of biological control agent, and one chemical larvicides. Demonstrate application methods and dosage calculations.

Learning and teaching methods

Exercise 6.1

Had out the malaria vector life cycle at the end of this learning unit to the learners and have them complete the exercise.

Solution: A possible solution is given at the end of the learning unit.

Exercise 6.2.

Solution: Aspects of the vector (and components of vectorial capacity) expected to be affected by different types of vector control methods.

Method	Larval density (m)	Adult density (m)	Adult survival (p)	Human biting habit (a)
Larval control				
Source reduction	+	+	-	-
Larvivorous fish	+	+	-	-
Larviciding	+	+	-	-
Reducing man-vector contact				
Insecticide-treated mosquito nets and other materials	-	+/-	+/-	+
Improved housing	-	-	-	+
Repellents and Mosquito coils	-	-	-	+
Adult mosquito control				
Insecticide-treated mosquito nets and other materials	-	+/-	+/-	+/-
Indoor residual spraying	-	+	+	+
Space spraying	-	+	-	-

+ reduction expected
- no effect
+/- effect doubtful or conditional on other factors

Exercise 6.3

The advantages and limitations of malaria vector control can be presented in different ways. Examples are given below.

1. Reduce human-vector contact

Approach	Advantages	Limitations
Environmental Management • Improve housing, screening, windows, closed eves	• Long lasting effective and efficient • Low maintenance	• Large initial cost • Periodic maintenance
Chemical Control • Nets & insecticide impregnated nets • Repellents	• Community based • Effective	• Vector biting behaviour outside houses decreases effectiveness • Can not be use by people who are allergic to the product used • Success or failure depends on the participation of the people at risk • Short duration of repellents
Biological Control	Not applicable	

2. Reduce vector density

Approach	Advantages	Limitations
Environmental Management • Eliminate or modify breeding sites	• Long lasting effective and efficient • Low maintenance • Community based	• Large initial cost • Potential negative effect on the environment • Periodic maintenance
Chemical Control • Space spraying • Larviciding	• Effective in some circumstances • Larvicides are easy to apply • Larviciding can be community based	• Short duration • Need specialized personnel for space spraying • Risk of contamination of environment • Potential effects against other species • Breeding sites may be extensive and dispersed
Biological Control • Larvicides	• Effective in some circumstances • Community based • Little environmental impact	• Breeding sites may be extensive and dispersed

3. Increase adult vector mortality

Approach	Advantages	Limitations
Environmental Management	Not applicable	
Chemical Control • Indoor residual spray • Community-based impregnated nets	• Effective if vector bites inside and rests on walls • Very effective if used correctly • Low environmental impact	• High cost • Requires periodic application • Inadequate sprayable surfaces • Need well-trained personnel for spraying • Success or failure depends on the participation of the people at risk • Can not be use by people who are allergic to the product used • Success depends on the relationship between the activity of the vector and humans
Biological Control	Not applicable	

Exercise 6.4

Make sure the working groups use the reading at the end of the learning unit as a guide to this exercise. They will need to include their plan, outcomes anticipated, and advantages and limitations of their implementation strategy. Ask the following question to close this exercise and lead into the next section on integrated control.

i) What if it does not work as planned?
ii) What would you do?

Exercise 6.5

Some points needs to be taken into account when considering the efficacy of IRS. First of all, this is a tool for interrupting or severely suppressing malaria transmission. IRS is not necessarily the best tool when other aims are targeted, e.g. restriction of morbidity and prevention of mortality. Therefore, the objectives of malaria control should be clearly specified. Secondly, the degree of perfection of operation is crucial. The coverage of the structures should be no less than about 90%, which may be a difficult task for cost and operational reasons. Work in small groups and answer the following.

a) Partial spraying may be counterproductive: e.g. by spraying of cattle sheds and not fully covering residence dwellings. Because spraying of cattle sheds may divert mosquitoes toward the human dwellings, if the insecticide used has a repellent action which in turn could increase the transmission.

b) Apart from the high refusal rate, a problem is exophily and outdoor transmission that diminish efficacy of IRS.

c) Exophily and outdoor transmission diminish the efficiency of IRS.

d) False! The aim of IRS is to reduce mosquitoes' longevity below the length of the period of sporogony. That is why the method is efficacious even when mosquitoes are not killed instantly.

e) False, IRS protects the mosquito population from becoming infected by eliminating those specimens that attack humans **after** they have fed. If infected mosquitoes are already around, they can occasionally infect people in the sprayed houses, but, if IRS was done before the transmission season, no infected mosquitoes will be around.

f) False, the number of people protected can not be equal the number of inhabitants of sprayed houses. An "all or nothing" principle is the principle behind IRS. In the e.g. of 50% of coverage, the degree of protection will be close to zero, since the level of coverage is much less than the desired threshold of 90%. On the other hand, if coverage is sufficiently high, people in a few unsprayed houses are also protected.

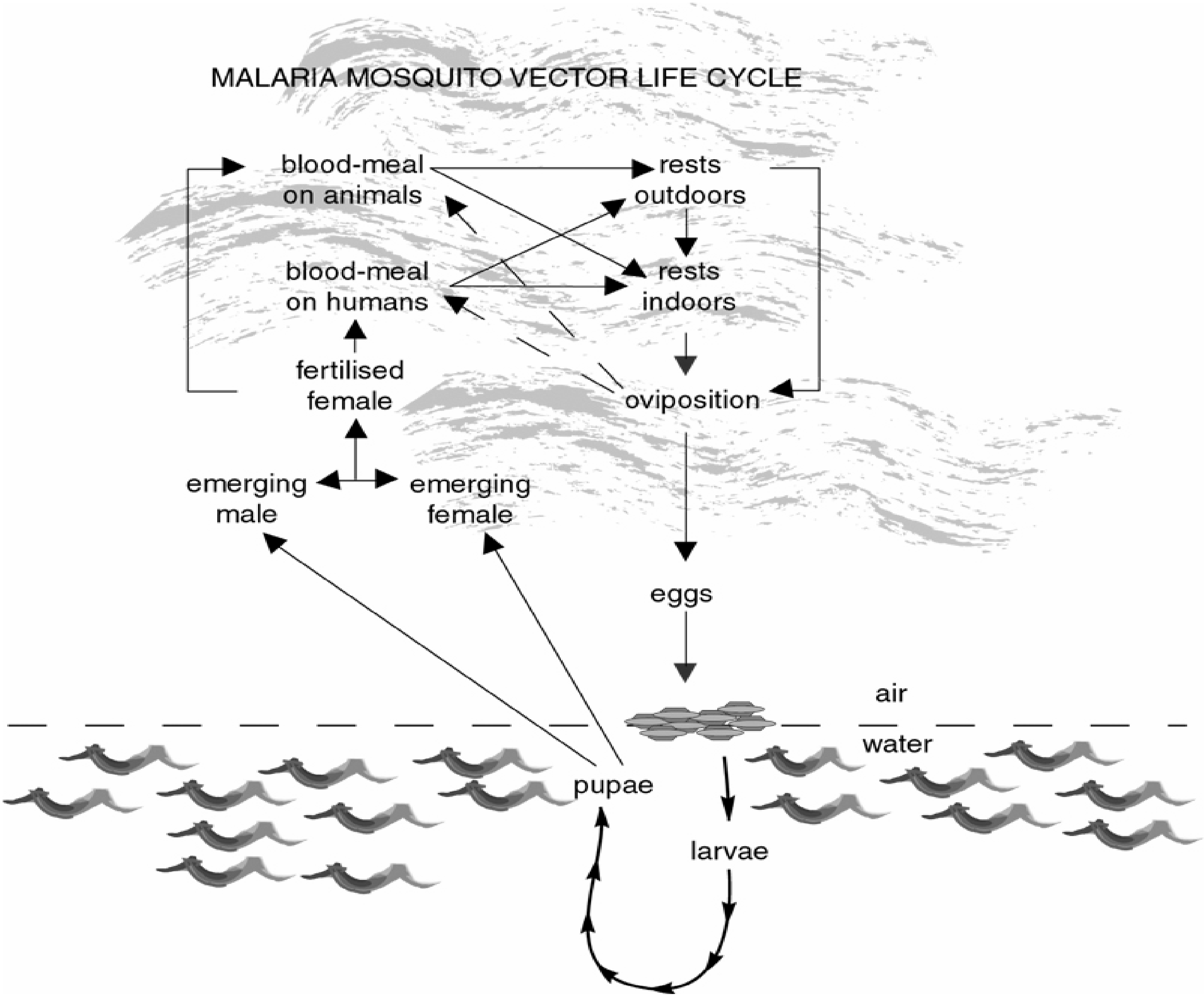
g) In case of epidemics or complex emergencies, the priority for IRS are temporary dwellings, shacks etc. where migrants importing infection tend to live.

Guidelines for assessment

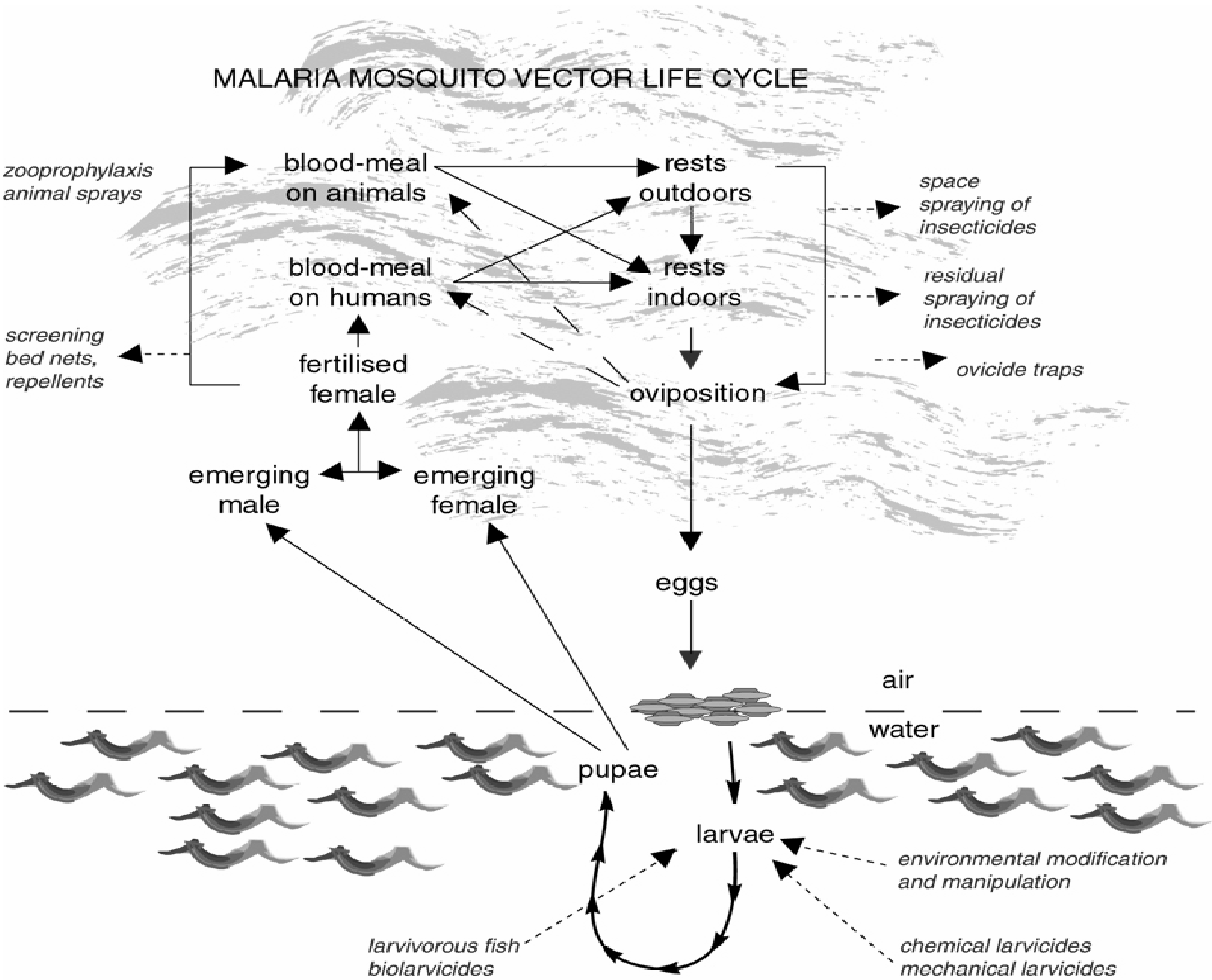
The groups should be able to demonstrate understanding of the basic skills required in vector control.

By the end of the session, you should ask participants at random some of the important roles of vector control in malaria control programmes and issues to be considered during implementation of vector control, in order to assess their level of understanding. Discuss the safety, maintenance and operational issues related to the demonstration of vector control methods.

Figure. Malaria vector life cycle



Solution: Malaria vector life cycle with control measures



Learning Unit 7

Malaria stratification and vector control

Learning objectives

By the end of this Unit the learner should be able to:

- Describe the epidemiological characteristics of the six major malaria strata
- Select effective vector control options according to the local epidemiological characteristics and strata of malaria

The main objective of this unit is to acquaint learners with malaria stratification and the appropriate vector control options for each stratum. Learners are expected to understand important characteristics of the various eco-epidemiological types of malaria and how to select appropriate vector control methods that maximize the benefits of protection.

Equipment and support

You should provide flip charts for group discussions.

Teaching and learning methods

Presentation

Your presentation should cover the six major malaria epidemiological strata. The learners should have a good understanding of these strata. During your presentation you can as the learners questions concerning the types of malaria in their area of work. For example,

1. Using Table 7.1 ask the learners if their malaria programme classifies endemicity based on spleen and parasite rates.

2. What type of malaria is most prevalent where they work or in their country?

3. Is there an area where there is urban malaria? If so what are the vectors? How do you distinguish between urban and periurban malaria?

The learners should be aware that the classification of areas as epidemic-prone or endemic malaria is not always straightforward when transmission is of moderate intensity (e.g. meso- versus hyper-endemic or hyper- versus holo-endemic malaria).

Cover the following points in your presentation:

1. **Unstable malaria**. Main entomological and environmental features of unstable malaria have to be discussed. The instructor should ask how these factors determine the distribution of infection and diseases among the population. Learners may discuss a broad stratification of Africa into endemic and epidemic strata.
    - Which group of the population is more affected?
    - What is the immune status of the population?
    - Who needs special attention? What vector control options are most effective?

2. **Stable malaria**. Learners should be asked to discuss in groups what important features distinguish endemic malaria from the epidemic type based on the points raised when discussing unstable type of malaria.

3. **Urban malaria.** The need to treat urban malaria as a separate stratum and the peculiar features of urban malaria should be discussed. How some control measures implemented in rural areas of similar endemicity are difficult to apply in urban settings, the significance of an island of low transmission (observed in urban) surrounded by highly endemic rural and periurban communities need to be stressed.

4. **Complex emergency situations**. The importance of paying special treatment and attention to this stratum and how vector control measures need to modified to meet the requirements of these strata should be discussed in detail.

Group discussions followed by group presentations and plenary discussion. There are two exercises to be done in group discussion.

Exercise 7.1

The learners should form three working groups and answer the following questions related to the epidemiological strata of malaria**.**

1. What are the consequences of the entomological and environmental factors on the prevalence of parasite, immune response of the population, age distribution of infection, illness and death due to unstable malaria? Stable malaria? Compare and contrast the differences.

2. State the characteristics of stable malaria that can limit the impact of large-scale vector control measures such as residual spraying of houses

3. Which mechanisms do you think are affecting vector density in urban settings?

Possible solutions

1. In unstable/epidemic-prone areas, parasite prevalence is normally very low and only increases during transmission. Due to short transmission and/or low level of transmission, immunity to the disease is generally very low or absent. All age groups are affected by malarial disease and mortality.

2. In stable-malaria areas, parasite prevalence is very high with little seasonal fluctuation. Due to the intense transmission, immunity to the disease is generally very high in the adult population. Only children below 5 years are affected by malarial disease and mortality.

3. Factors that may affect vector density in urban settings include limited breeding sites as the result of development or construction of buildings and streets, and pollution of water bodies that might be unfavorable for some vectors.

Exercise 7.2

You should select two to six of the epidemiological strata for each working group. The aim is for the learners to select the vector control options that they thinks are feasible for each stratum. Each group should list the results on a flip chart and the reason for their selection. They will then present their results in plenary.

Possible solutions: Vector control options in different epidemiological strata

1. Vector Control options in unstable malarious areas

Almost any vector control measure appropriately applied to specific situations of unstable malaria areas will have an impact in reducing the risk of malaria. The main objective of vector intervention in such low endemicity areas is reducing the degree of transmission. For example reducing the entomological inoculation rate (EIR) from one per year, which is common in such areas, to 0.5 per year will have a considerable impact on prevalence of infection, disease and death due to malaria. Individual protection methods could also have a considerable impact when applied properly and accepted by the public. The choice of appropriate vector control measure in such areas is therefore dependent on vector behaviour, cost, and other socio-economic factors. In areas where malaria is unstable **vector control is an indispensable tool** to protect the population from the risk of malaria epidemics.

Residual house spraying is the most widely used and highly effective technique to prevent or reduce the negative impact of epidemics. In such areas houses or shelters are sprayed with insecticides with residual life of 3 to 12 months. For maximum killing effect insecticides with low irritant effect are preferred. However, chemicals with repellent property should also provide a reasonable degree of protection by driving the mosquitoes to the hostile outdoor environment, thereby lowering mosquito survival and parasite development.

Individual protection with insecticide-treated materials and other repellents can also be highly effective. ITN have been proved to reduce illness and death due to malaria significantly in low transmission areas. However, it is important to make sure that there is sufficient awareness and acceptability in the community before choosing ITN over other vector intervention methods. One important drawback of ITN in low transmission areas is the fact that the low nuisance effect of mosquitoes for a longer part of the year may affect the appropriate use and acceptability of bed nets (“Why bother using nets if mosquitoes are not a big nuisance?”).

Larviciding and source reduction are effective if breeding sites are limited and well known. It is also a better alternative where highly exophilic vectors are involved and where there are significant cultural or other objections to indoor house spraying.

As stated earlier some areas in this stratum are of very low endemicity. Therefore routine vector control operations such as residual house spraying and larval control measures can be expensive and may not be recommended in such areas. Promoting the use of personal protection such as ITN is important, and monitoring key indicators of malaria epidemics and preparedness to prevent such epidemics is also crucial. Malaria outbreaks occurring in such areas can be very serious because of the very low level of immunity in the population. Residual house spraying is the most effective option in preventing epidemics and/or for a faster effect when responding to epidemics in such situations.

2. Vector control options in areas with stable malaria

As discussed earlier stable malaria type is characterized by intensive transmission potential well beyond what is needed to saturate the prevalence of infection in a community. In other words even if we could manage to bring down the intensity of transmission several times below its initial level, this may have little or no effect on prevalence of the infection or on associated morbidity and mortality. Moreover, vector intervention operations intended to bring down transmission to such a considerable extent are going to be very expensive. The main objective of vector control in stable malaria situations must focus on providing effective personal protection for the most susceptible age groups against vector contact rather than aiming at reducing the potential for transmission at the community level.

ITN are currently the most effective and practical vector control option in areas where malaria is highly endemic. Recourse to ITNs has been effective in significantly reducing child mortality in The Gambia and several other African countries where transmission occurs all the year round or is seasonally intensified. The mechanism by which ITNs reduce child mortality is not clearly known: reductions in child mortality occur without a significant lowering of the prevalence of infection. It is speculated that by decreasing the number of infective bites and thus of super-infections, ITNs lower the risk of severe malaria, thereby reducing mortality. Another less plausible explanation is the irritating effect of pyrethroids affects mosquito-feeding time an lower the rate of sporozoite inoculation.

Consensus on the impact of ITN in highly endemic areas is that this is the most effective and practical option for vector control. Unless such programs are sustainable, however, protection during early childhood may prevent the development of protective immunity and lead to higher mortality during late childhood or adult age. In addition to their protective role, ITN may nevertheless allow the development of an immune response, though at a slower pace; in that case, ITN users would not be at much higher risk than non-users at a later age. Studies are under way to clarify this point.

3. Vector control options in urban settings

Because fewer open spaces are available, vector-breeding sites in the urban environment are usually very limited and clearly defined. Therefore:

Vector control in urban area must focus on environmental measures directed at eliminating breeding sites through community participation.

- Larviciding is important where other environmental remedies are not applicable.
- Personal protection in the form of screening houses is often applicable in urban settings and is effective.
- Promoting the use of ITN is also advisable. ITN are more acceptable than residual spraying in urban areas and also probably more affordable to the population than in rural communities. The nuisance effect of urban culicine mosquitoes can also make bed nets more acceptable in urban areas.

4. Vector control in development projects

- Selection of suitable housing sites for the labour force and adequate protective measures such as screening of houses must be considered in the planning of projects.
- Environmental disturbances that favour vector breeding must be avoided and precautionary measures must be included in the design of the projects.
- Use of ITNs must be encouraged.
- Residual house spraying must also be used depending on the housing conditions, cost, and other epidemiological factors.

Policies and legislation must incorporate some of the above precaution measures in the planning of development projects.

5. Vector control options for nomadic populations

- The most practical option for protection against mosquito biting for nomadic population is provision of ITN. Long-lasting nets may be useful to overcome the problem of re-treatment.

- Application of insecticides with long residual life (e.g. pyrethroids) to the inner surface of the movable mats and tents of the nomads could also provide protection against malaria risk.
- Nomads must be trained on the use of their cattle as a shield against mosquito biting by strategically placing them between mosquito breeding and their settlement sites.

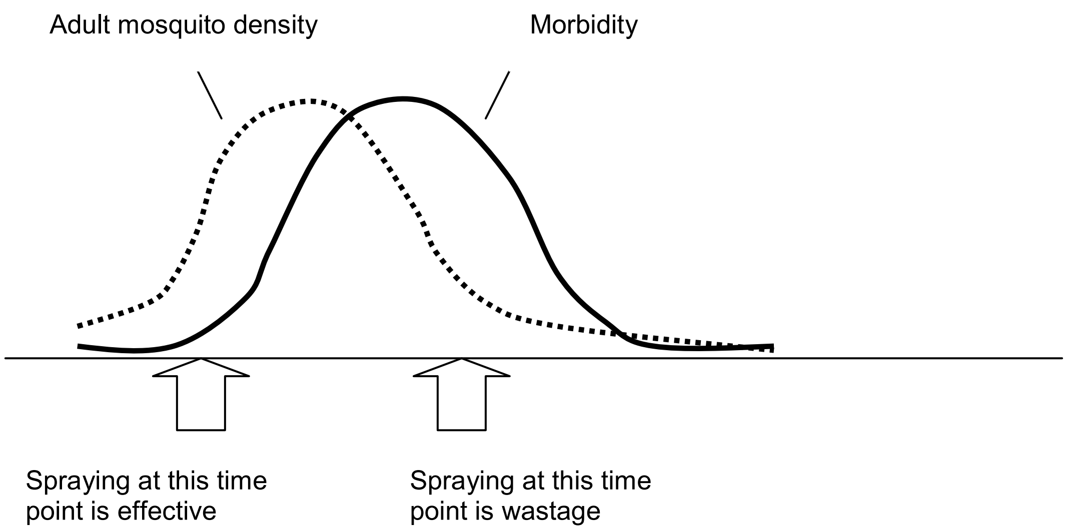
6. Vector control options in complex emergency situations

The choice of vector intervention will depend on local factors such as the type of shelter available, human habits, vector behaviour, and malaria endemicity.

- Residual house spraying is useful in acute and chronic emergencies if displaced populations inhabit regular housing, vectors are indoor resting and there is good organization.
- Where canvas tents are issued, spraying of inner surfaces with a residual pyrethroid will give long protection against malaria vectors and it is a better alternative to ITN in the acute phase. Treatment of blankets or outer sheets with permethrin is a promising option for refugees sleeping under plastic sheeting or other makeshift materials. This new approach is ideal in short, acute emergencies because blankets are always distributed and treatment with permethrin will give protection in all types of shelter.
- In the post-emergency phase increased use of residual spraying or shift to ITN is recommended depending on the housing, cost and other epidemiological factors. The chronic phase is the time to introduce cost recovery mechanism as refugees and internally displaced persons become more self-sufficient and some are able and willing to pay for ITN. We must also consider the conditions facing refugees and internally displaced people when they return home after the conflict. This is probably the stage where ITN have greatest potential.

Discussion

To close this learning unit you should summarize the relationships between epidemiological strata and vector control. You should also present the graph below and explain why the **timing** of vector control in relationship to epidemiological indicators is so important.



Finally, propose the following query to see if the learners consider it is true or false.

> *Even a large effort (e.g. by applying residual spraying to reduce transmission) may have very little impact on prevalence of infection due to high vectorial capacity or basic reproduction rate of malaria in stable conditions.*

Lead a vivid discussion on this aspect of vector control.

Learning Unit 8

Management of malaria vector control programmes

Learning Objectives

By the end of this Unit the learner should be able to:

- strengthen and direct surveillance and information management systems to provide support for decision-making for vector control
- develop the capacity to address the technical, operational, managerial, and policy aspects that are necessary to ensure efficient and effective functioning and cost-effectiveness of vector control
- establish a vector control monitoring system and select the indicators needed to monitor and evaluate vector and malaria control
- incorporate operational research in malaria vector control programmes

Equipment and support

Only presentation equipment and materials are needed in this section.

Learning and teaching methods

Lecture presentation and group work followed by plenary discussion will be used. In small groups, participants should be able to work out the two exercises in this learning unit.

Exercise 8.1
Possible solution:

Table 8.1 Operational and entomological indicators to be monitored

Vector control	Operational	Entomological
Larval control	▪ Amount of insecticide used ▪ Coverage (e.g. proportion of potential breeding sites eliminated in relation to the total operational area; surface area of water in which larvicide has been plied) ▪ Timing and frequency of applications ▪ Cost	▪ Larval density ▪ Adult vector density ▪ Larval insecticide susceptibility
Control of man-vector contact	▪ Amount of insecticide used ▪ Dosage ▪ Frequency of net treatments ▪ Coverage: (e.g.) number and proportion of households with at least one ITN in use; number and proportion of number of houses which are mosquito proofed ▪ Cost	▪ Human biting rates ▪ Human blood indices ▪ Adult vector density ▪ Parous rates ▪ Sporozoite rates ▪ Adult insecticide susceptibility
Adult mosquito control	▪ Amount of insecticide used ▪ Dosage (e.g. mg a.i./m^2) ▪ Coverage (e.g. number and proportion of houses sprayed with residual insecticides) ▪ Cost	▪ Human biting rates ▪ Human blood indices ▪ Adult vector density ▪ Parous rates ▪ Sporozoite rates ▪ Adult insecticide susceptibility

Exercise 8.2
Possible solution:

Selected indicators for monitoring the impact of vector control on malaria incidence (modified from WHO Technical Report Series 857).

Vector control method	Target population	Outcome indicator
Indoor residual spraying	- Number of people in the area sprayed - Number of people in houses sprayed	- Percentage reduction in disease incidence in target area or group - Infant parasite index in endemic areas -Percentage reduction in disease mortality
Impregnated mosquito nets	- Number of people in area of bednet use - Number of people living in houses in which nets are used - Number of people using bednets	- Percentage reduction in disease incidence in target area or groups - Percentage reduction in disease morality Percent reduction in all caused mortality (malaria)
Larviciding	- Number of people in the in the operational area	- Percentage reduction in disease incidence

Guidelines for assessment

Participants should understand the concepts of management of malaria vector control, especially in relation to programme planning, monitoring and evaluation, and issues relating to cost-effectiveness of control options. They should be able to do the exercises on indicators for vector control and malaria.