World Health Organization

REGIONAL OFFICE FOR Europe

Training curriculum on invasive mosquitoes and (re-)emerging vector-borne diseases in the WHO European Region

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ABSTRACT

The WHO European Region has experienced an increase in the spread of invasive mosquitoes since the 1990s. In particular, *Aedes albopictus* and *Aedes aegypti*, both known vectors of arboviruses such as dengue, chikungunya and Zika virus, have recently spread across parts of the Region. Experts attribute these worrisome developments to a combination of factors, including globalization, increasing international trade and urbanization. The global importance of the arboviruses transmitted by *Aedes* mosquitoes has also increased dramatically, while effective vaccines and medication are mostly lacking (apart from the effective vaccine against yellow fever). This curriculum aims to provide nonspecialists with an understanding of the key issues related to invasive mosquitoes and (re-)emerging vector-borne diseases, and with the analytical skills to improve strategic planning and implementation of activities in their country context.

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The draft version of the curriculum was tested during a five-day training workshop for managerial and technical health staff, held on 28 September–2 October 2015 in Tbilisi, Georgia. After evaluation, the curriculum was revised and updated in October 2016.

Preface

This curriculum aims to provide nonspecialists with an understanding of the key issues related to invasive mosquitoes and (re-)emerging vector-borne diseases, and with the analytical skills to improve strategic planning and implementation of activities in their country context.

Its target audience includes policy-makers and decision-makers as well as programme managers who are, or will be, involved in the planning, implementation and evaluation of strategies to prevent the introduction of and/or control invasive mosquito vectors and vector-borne diseases.

The curriculum does not provide training for specialists on the more technical aspects of mosquito surveillance or control; for this, separate training manuals are available.

The curriculum draws on previous guidelines for dengue control *(1)* and integrated vector management *(2,3)*, guidelines for the surveillance of invasive mosquitoes *(4)* and guidelines for mosquito control *(5)*. It is consistent with the regional Framework for surveillance and control of invasive mosquito vectors and (re-)emerging vector-borne diseases 2014–2020 (2013) *(6)*. All of these documents are recommended reading materials for course participants.

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Introduction

Invasive mosquitoes are those that successfully colonize new countries or territories, potentially causing harmful effects. The WHO European Region has experienced an increase in the spread of invasive mosquitoes since the 1990s *(4,7,8)*. In particular, *Aedes albopictus* and *Aedes aegypti*, both known vectors of arboviruses such as dengue, chikungunya and Zika virus, have recently spread across parts of the Region. Experts attribute these worrisome developments to a combination of factors, including globalization, increasing international trade and urbanization.

Increasing numbers of international passengers arrive in the Region after travelling in countries in which these arboviruses circulate. If the *Aedes* mosquito vectors are present in the area of the Region where an infected person returns, there is a real risk of local transmission of the pathogen.

Globally, the importance of the arboviruses transmitted by *Aedes* mosquitoes has increased dramatically, and effective vaccines and medication are mostly lacking (apart from the effective vaccine against yellow fever). The incidence of dengue has increased 30 fold in the past 50 years *(9)*, and the virus has both expanded its range into new countries and become a greater public health problem within countries. Dengue can lead to a potentially lethal complication called severe dengue, which is a main cause of hospitalization in several countries in South America and Asia.

Dengue was present in countries of southern Europe until the early 1900s, when occasional large epidemics – such as that in 1927–1928 in Greece – occurred *(8)*. The disease disappeared from Europe in the mid-20th century when the local vector *Ae. aegypti* ceased to exist in the Mediterranean area, likely due to a combination of malaria-vector control operations using dichlorodiphenyltrichloroethane (DDT) and the development of water-supply systems *(10)*.

Now that both *Ae. aegypti* and *Ae. albopictus* have (re-)established themselves in the Region, there is a constant risk of dengue outbreaks. Indeed, locally transmitted dengue cases were reported in 2010 in Croatia *(11)*, in 2010, 2013 and 2014 in southern France *(12)*, and in 2012–2013 in Madeira, Portugal *(13,14)*. The outbreak in Madeira resulted in over 2200 cases and had significant implications for the local health system and tourism.

Chikungunya has rapidly expanded its global range within the past decade *(15,16)*. Locally transmitted cases were recorded in 2007 in Italy *(17)* and in 2010 in France *(18)*. Yellow fever, which can also be transmitted by *Aedes* species, has not been recorded in the Region since the 19th century; concern is rising, however, about the recent outbreaks reported from sub-Saharan Africa *(19)* and the unavailability of vaccines.

The global expansion of Zika virus since 2015 is of concern for the Region, particularly because the strain currently spreading in countries without previous evidence of circulation is associated with serious neurological disorders such as Guillain-Barré syndrome and microcephaly *(20,21)*. Madeira and the Black Sea coastal regions of Georgia and the Russian Federation, all with established populations of *Ae. aegypti*, are at high risk for local Zika virus transmission, whereas many countries in the Mediterranean basin, with *Ae. albopictus* populations, are at moderate risk *(22)*.

Considering the public health threat of arboviral diseases to the Region, it is essential that countries develop capacity for preparedness and rapid response in relation to disease outbreaks. This includes early detection of human cases and prevention through vector control *(23)*.

The scope of this curriculum covers all relevant components of the biology and surveillance of invasive mosquitoes, methods of mosquito control and the integrated vector management approach.

Guide for tutors and organizers

This curriculum is presented in a simple format for use by tutors as well as participants of training workshops. It is divided into two modules, one on the surveillance of invasive mosquitoes and one on mosquito control and disease outbreak response. Each module consists of a number of units. Each unit outlines a learning objective, requirements, background, assignment and points for discussion. Unit 1.5 describes a field exercise on sampling techniques.

Each unit's **learning objective** is aimed at guiding both tutor and participants over the course of the unit. **Requirements** are outlined to assist the tutor and organizers in making advance preparations in terms of materials and time needed. The **background** section provides a summary of the subject matter, for presentation by the tutor.

During **assignments** participants break out into groups to discuss the practical implications of the subject matter, particularly in relation to their country context. Groups of 4–8 enable optimal interaction and discussion. Directly after participants have completed an assignment, the tutor should give one or more groups the opportunity to present their outcomes and allow other groups to comment. Any remaining **points for discussion** can be addressed in the plenary session. Table 1 presents an overview of the modules with learning units and time required.

Table 1. Overview of modules with learning units

Module	Unit	Title	Hours needed
1	1.1	Biology of invasive mosquitoes	2–3
	1.2	Identification of invasive mosquitoes	1–2
	1.3	Distribution and spread of invasive mosquitoes	1–2
	1.4	Surveillance of invasive mosquitoes	2–3
	1.5	Field/laboratory exercise on sampling techniques	4–6
	1.6	Monitoring and management of insecticide resistance	1–2
	1.7	Regional networking	1–2
2	2.1	Prevention of introduction (or spread) of invasive mosquitoes	1–3
	2.2	Mosquito control tools	1–3
	2.3	Elimination of colonization foci	1–2
	2.4	Sustainable mosquito control	1–3
	2.5	Lifecycle management of pesticides	1–3
	2.6	Response to disease outbreaks	2–4
	2.7	Policies and intersectoral collaboration	2–4
	2.8	Communication and community participation	1–3

The curriculum was designed for a five-day training workshop (see Annex 1 for a recommended agenda). The selection of units and the time allocated to each could be adjusted to suit the country situation. For example, in countries with established populations of *Ae. aegypti* and *Ae.*

albopictus, Unit 2.1 on prevention of introduction may be of limited use (though it may be applied to areas not yet invaded, or for other species of invasive mosquitoes such as *Ae. japonicus*).

Annex 2 presents a list of recommended reading materials. These can be distributed to participants, for example, as softcopies on a USB flash drive.

Module 1. Surveillance of invasive mosquitoes

Unit 1.1 Biology of invasive mosquitoes

Training objective

Participants learn about key aspects of the biology of invasive mosquitoes, including lifecycle, life traits of main pest and vector species, vectorial capacity, larval ecology and the particularities of invasive mosquito species in order to understand and develop mosquito-surveillance strategies.

Requirements

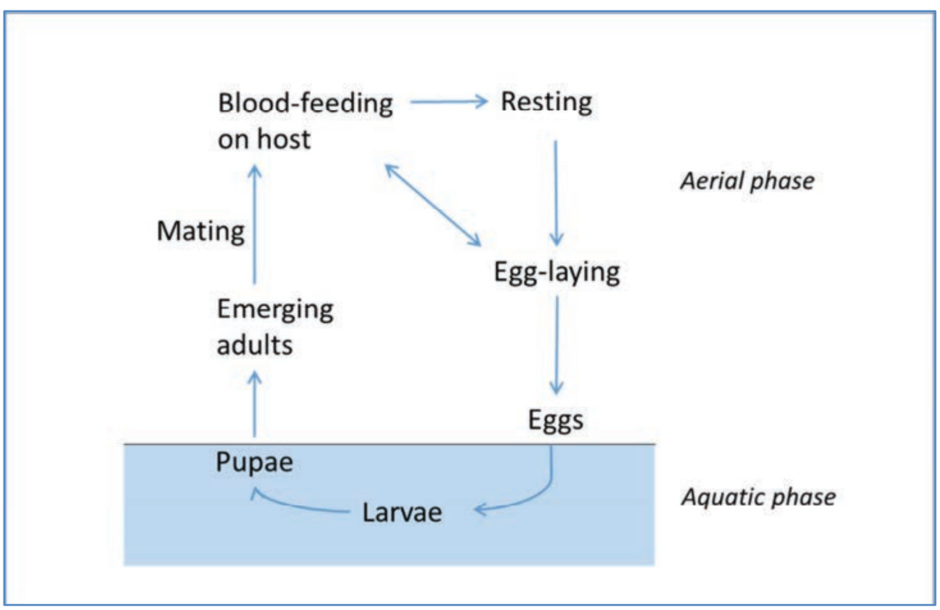
- Information on mosquito fauna from your country – on existing mosquito nuisance and mosquito-borne disease transmission in particular – and on occurrence(s) of invasive mosquito species, if applicable
- Time: 2–3 hours

Background

Mosquitoes belong to the family Culicidae, of which more than 3500 species are currently recognized worldwide. Mosquitoes are ecologically beneficial because of their contribution to biodiversity, food chains and pollination. Only some species threaten human and animal health as vectors of disease.

The mosquito lifecycle is divided into two phases – aerial and aquatic – and comprises several stages, including that of the egg, larvae (4 stages), pupa and adult (Fig. 1).

Fig. 1. Mosquito lifecycle, indicating aerial and aquatic phases



Following emergence and a brief maturation period, adults mate and search for plant fluids such as nectars or decaying fruit to obtain energy. Females also require a blood meal from an animal host (mammals, birds, amphibians, reptiles) to obtain proteins for maturing their eggs. During this blood meal, the female may ingest pathogens from an infectious host. During a subsequent blood meal a few days later, the female may act as a vector (transmitter) of those pathogens – which can include viruses, protozoa, filarial worms or bacteria – to a new host. This phenomenon makes mosquitoes detrimental to human and animal health.

Aedes and *Ochlerotatus* females bite and rest mostly outdoors, whereas *Culex pipiens* (the house mosquito) and most *Anopheles* (the malaria vectors) bite and rest mostly indoors. Females may take several blood meals during their lifespan, which is usually 3–4 weeks depending on weather conditions and predation.

Females can lay eggs on water surfaces (*Anopheles*, *Culex*), on the edge of bodies of water or on wet ground with pockets of water (*Aedes, Ochlerotatus*). Eggs laid on water surfaces generally hatch soon after deposition. The eggs of *Aedes* mosquitoes are laid in small pools of water such as tree holes, discarded containers, bottles, etc. These eggs can remain dormant for up to a year if the water dries up, and subsequently hatch as soon as they come into contact with water again (for example, after rain).

Some genera overwinter as mated females (*Anopheles*, *Culex*) or as eggs that are highly resistant to desiccation and low temperatures (*Aedes, Ochlerotatus*).

From the egg, a larva hatches directly in the water. There, it grows in four stages, or instars, punctuated by periods of moulting. The final larval moult produces the pupa, which subsequently undergoes a final metamorphosis that results in the adult mosquito. In the most favourable conditions of food availability and water temperature (20–25 °C), the aquatic phase is completed in less than a week.

Larvae develop in a wide range of habitats, including temporarily flooded or permanent water bodies, large flooded wetlands, lake and river borders, small ponds and ditches, tree holes, rock pools, springs or artificial pools of water such as containers, cesspits, fountains or rainwater catchment basins. Globally, any water standing for at least a few days can become a mosquito larval breeding site. While some mosquito species are generalists that can develop in natural or artificial breeding sites, others are highly specialized and will only develop in, for example, brackish water or natural plant containers.

Adult *Aedes* mosquitoes usually fly short distances and live, under ideal circumstances of temperature and humidity, for 3–4 weeks. Only female mosquitoes seek blood meals in order to access the protein they need for the development of eggs. Males feed on natural sugar (nectar from flowers, fruits, etc.). After feeding on blood, females rest in dark places both inside and outside of houses. They are then capable of laying 100–150 eggs once every three days. This cycle of blood-feeding and egg-laying continues as long as they are alive.

Invasive mosquito species in Europe belong to the tribe Aedini. They are able to colonize new areas because they are well adapted to human environments. Their eggs can withstand desiccation and are laid in commonly discarded containers (for example, used tyres) found in human communities throughout the world. They feed on a range of hosts and are able to adapt to the subtropical or temperate European climates *(24)*. Among the most invasive species are the

Asian tiger mosquito *Ae. albopictus*, the yellow fever mosquito *Ae. aegypti*, and the Asian bush mosquito *Ae. japonicus (12).*

The vectorial capacity of a mosquito population indicates the risk of pathogen transmission in a specific context, that is, in the presence of local sources of infection, a suitable climate and availability of appropriate hosts. The likelihood of vector-borne infections increases with vector abundance. Transmission may also be possible with low or moderate vector densities if the vector population has a high competence (a high percentage of infectious females).

Assignment

1. In the following list of mosquito breeding sites, indicate those that can be colonized by invasive *Aedes* mosquito species.

   - Marsh
   - Flooded cellar
   - Riverbank
   - Used tyre
   - Flooded meadow
   - Tree hole
   - Flower dish
   - Pond
   - Rainwater barrel
   - Road drain (catch basin)
   - Canal with vegetation
   - Rice field

2. In the following list of mosquito life traits and population parameters, indicate those that are of key importance for assessing the risk of pathogen transmission.

   - Larval longevity
   - Vector competence
   - Adult dispersal
   - Sexual behaviour
   - Adult abundance
   - Sugar meal
   - Adult resting habits
   - Adult host preference
   - Biting rate
   - Adult longevity
   - Preferred location for egg-laying
   - Number of days to deposit eggs after a blood meal (gonotrophic cycle duration)

3. Based on the life traits and population parameters that are of key importance, examine the strengths and weaknesses of each parameter. Make a selection of the parameters that you would survey, and explain your decision.

Points for discussion

- Identify specific information gaps in the selected mosquito population parameters that should be prioritized by research in your country.
- Which data on life traits would you like to get from neighbouring countries to better assess your local context?

Unit 1.2 Identification of invasive mosquitoes

Training objective

Participants learn about the existing methods and tools for identifying invasive mosquito species at their different stages (egg, larva, adult), the skills and training required to do so, and advantages and disadvantages of different methods and tools in order to select those that are most appropriate and to plan collaboration and capacity-building in their country context.

Requirements

- Reference information on mosquito identification
- Information on competences in medical and veterinary entomology and on laboratory capacities in your country
- Time: 1–2 hours

Background

The identification of mosquito species is traditionally based on morphological characteristics. A number of morphological identification keys are available, although these keys are often limited to only some genera and/or certain geographic regions or countries. Experts have recently made efforts to develop identification keys for the complete mosquito fauna of Europe, either as dichotomic keys *(25)* or as computer-aided keys *(26).* These keys depict both larvae and adults. They do not, however, include all recently introduced invasive species; these are addressed in separate keys *(4).*

The morphological identification process requires technical expertise and – even with expertise – is not always successful in accurately identifying a specimen to the species level. Morphological keys for certain life stages are also often lacking. Collecting eggs in ovitraps is the best method for the surveillance of container-inhabiting mosquitoes (which include all invasive *Aedes* mosquitoes). Morphological identification of these eggs, however, is very time-consuming and requires both expertise and special microscopy equipment.

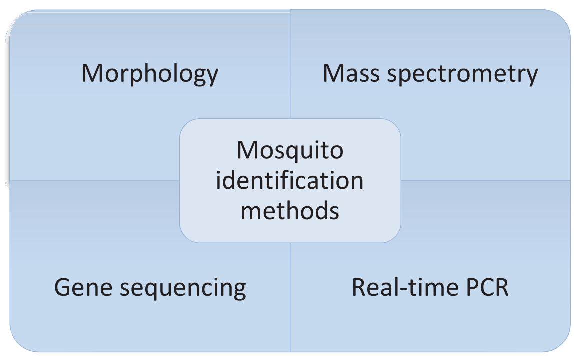
In addition, not all species are well characterized in their egg stage. Female mosquitoes collected via trapping can also lose wing scales or become damaged, thus losing some essential morphological features. Finally, morphological features may not provide enough information to allow for the identification of so-called sibling species within species complexes (for example, *An. maculipennis* complex, *Cx. pipiens* complex). Researchers have therefore developed alternative identification methods (see Fig. 2) to allow for the identification of sibling species. These methods now extend to a wide range of species to optimize the identification process, particularly in routine operations.

Molecular techniques allow for rapid and accurate identification by analysing certain gene sequences or protein profiles. These can also be done by nontaxonomists. These techniques, however, always require a well equipped laboratory and trained personnel, which renders them costly and laborious in large-scale studies and operations. Genetic information (of different loci) is already available for a high number of species. For some groups of species (for example, invasive mosquitoes, malaria vector species complexes), researchers have developed specific real-time polymerase chain reaction (PCR) assays for rapid molecular identification. Finally, protein profiling by mass spectrometry is a method of choice for identifying mosquitoes in their egg, larvae, or adult stages.

Assignment

1. Identify the methods and tools that are currently available for mosquito identification in your country. For each method or tool, indicate the mosquito biological stage(s) to which it applies.
2. For each mosquito identification method presented in Fig. 2, identify the skills and capacities that are required for its use, and suggest procedures to guarantee the highest accuracy of results (for example, double-check with another tool, quality-check with an external partner). Also, give each method an appraisal (use + or – signs) based on its relative usefulness, requirements and cost.
3. Based on this appraisal of strengths and weaknesses, which mosquito identification tools would you select? Explain your decision.

Fig. 2. Main categories of mosquito identification methods



Points for discussion

- Address the requirements for capacity-building (human resources, competencies, equipment, institutional strengthening) to perform accurate mosquito identification at any biological stage in your country.

Unit 1.3 Distribution and spread of invasive mosquitoes

Training objective

Participants learn about the history and current situation of invasive mosquitoes in Europe – including their introduction and spread pathways – and about transmission of pathogens in the European context in order to understand the necessity of surveying and reporting data on the distribution and biology of invasive mosquitoes.

Requirements

- Information on occurrence(s) and spread of invasive mosquitoes in your country
- Information on mosquito-borne disease transmission (if applicable)
- Time: 1–2 hours

Background

Among the two-dozen invasive mosquito species worldwide, container-breeding *Aedes* species are particularly significant. Five such *Aedes* species have recently established themselves in mainland Europe; two of these (*Ae. albopictus* and *Ae. japonicus*) have become widespread and two (*Ae. albopictus* and *Ae. aegypti*) are implicated in pathogen transmission *(23)*.

Ae. albopictus has been spreading and colonizing southern Europe since the 1990s, and is now colonizing more northern locations *(24)*.

Ae. japonicus appears to be better adapted to colder climates and is currently spreading rapidly in central European countries, within a large area from Belgium, the Netherlands and Luxembourg to Hungary.

Ae. aegypti is currently limited to Madeira (Portugal) and some areas along the northeastern Black Sea coast (Georgia, the Russian Federation, northeast Turkey) *(27,28)*. However, because the species was widely established in the Mediterranean basin from the 18th until the mid-20th century, many are concerned about its possible re-establishment in southern Europe. This species has no winter diapause at the egg stage, and therefore is not well adapted to temperate climates. It proliferates under tropical and subtropical climates.

Ae. atropalpus was introduced into Europe on several occasions and successfully established itself in some locations in Italy and the Netherlands. However, control measures have resulted in its elimination and no established population is currently reported.

Ae. koreicus is the most recently reported species (Belgium, Italy, Switzerland), and has shown itself capable of spreading within the region of the southern Alps.

Experts regularly gather and review data on the introduction and spread of invasive mosquitoes in Europe *(7,12)*. Updated distribution maps are available thanks to the European Centre for Disease Prevention and Control (ECDC) VectorNet project *(29)*.

These species can enter a new country or area through the transport of goods containing eggs that can subsequently hatch if they come into contact with water. The global trade in used tyres is the number-one intercontinental spread pathway of mosquitoes; number two is the trade in Lucky Bamboo plants. Once invasive mosquito populations have established themselves and proliferated, eggs are further spread via these pathways. Adults are also frequently carried in vehicles over land.

Ae. albopictus and *Ae. aegypti* are efficient vectors of a number of pathogens that are actively circulating worldwide, including dengue, chikungunya and Zika virus. As a result, local transmission of both dengue and chikungunya is becoming become more and more frequent in the European context *(8)*. *Ae. albopictus* also plays a crucial role in the intensification of filarial worm transmission in animals and thus represents an additional threat to animal health.

Assignment

1. Identify the invasive mosquito species that are present, or are likely to be present, in your country. Indicate for each species whether it has recently invaded or become fully established already.
2. In the following list of all mosquito-borne pathogens, pinpoint those that could be transmitted by the invasive *Aedes* mosquitoes that are or may be present in your country.
   - West Nile virus
   - Chikungunya virus
   - Avian influenza virus
   - *Leporipoxvirus*
   - *Dirofilaria repens*
   - Dengue virus
   - La Crosse virus
   - Usutu virus
   - Cowpox virus
   - Zika virus
   - *Plasmodium falciparum*
   - Japanese encephalitis virus
3. Based on this risk assessment, which mosquito species would you target for control action? Explain your decision.
4. Can the mosquito population be maintained at a low level or eliminated over time in a given locality with available resources?

Points for discussion

- Which data on invasive mosquito species and pathogens would you would like to get from other European countries to better assess the risk in your country?

Unit 1.4 Surveillance of invasive mosquitoes

Training objective

Participants learn about surveillance methods, tools and strategies adapted for invasive mosquitoes in order to develop the capacity for developing a mosquito surveillance plan.

Requirements

- Information on the occurrence of invasive mosquitoes in your country and neighbouring countries
- Information on possible points of entry, for example, highways originating in colonized areas or incoming shipments of used tyres and/or Lucky Bamboo plants (with information on origin, destinations and current practices), international ferry ports, cargo ports and airports
- Time: 2–3 hours

Background

Europe has experienced a considerable increase in the spread of invasive mosquitoes since the late 1990s. These invasive mosquito species may outcompete certain native mosquito species, but the main hazard they present is the threat to both human and animal health. Concern is rising as both vectors and pathogens are increasingly introduced and spread by international travel and trade. Some mosquito-borne diseases are emerging or reappearing after a long absence; others are spreading or intensifying in prevalence. Assessing and managing the risk of transmission of pathogens by mosquito species that have become established within Europe is now a necessity and a priority, in particular for countries where *Ae. aegypti*, *Ae. albopictus* and/or other invasive mosquito species are proliferating *(30)*.

The aim and scope of surveillance must be clearly defined from the outset – many strategic decisions will depend on them. Surveillance may be aimed at (i) early detection of any introduction of invasive mosquito population into a new territory, and survey of its possible establishment and the magnitude of its spread, (ii) assessment of sanitary/disease risks to human health related to invasive mosquitoes or (iii) planning and implementation of control measures and evaluation of their effectiveness.

According to these aims, a mosquito surveillance strategy defines what actions should follow from specific findings, identifies the target invasive mosquito species (one or more), identifies the geographical area and sites to be surveyed, and determines the methods and strategies to be implemented for each category of sites *(4)*.

Surveillance strategies and methods must be adapted to local scenarios. These can fall into three categories: (i) no established invasive mosquito species (with risk of introduction and establishment), (ii) locally established invasive mosquito species (with low risk of spreading into new areas) or (iii) widely established invasive mosquito species (with high risk of spreading into new areas) *(4)*.

The mosquito surveillance plan must do the following:

- define and describe operational issues and options for professionals involved in its implementation;
- describe the diverse procedures for field surveillance;
- determine the methods of identifying mosquito samples; and
- outline the procedures for collecting population parameters in the field, screening for pathogens and determining environmental parameters.

All control measures should be evaluated through a monitoring and evaluation framework with a selection of key indicators. The plan should also include an evaluation of costs and overall efficiency in order to make improvements in the future.

Assignment

1. Identify the possible introduction and spread pathways for invasive mosquitoes in your country and prioritize them for surveillance. Explain your choices.
2. For each of these pathways, as well as for fully established invasive mosquitoes, list the surveillance methods and tools you will apply. Explain your choices.

Points for discussion

- Identify specific gaps in methods and tools that should be prioritized by research and development in your country.

Unit 1.5 Field/laboratory exercise on sampling techniques

Training objective

Participants learn how to (i) select suitable sites collecting invasive mosquitoes, (ii) set up and use a number of sampling techniques and (iii) handle and identify the collected specimens. Note that Annex 3 of the ECDC's *Guidelines for the surveillance of invasive mosquitoes in Europe* (2012) *(4)* provides important background reading material for this unit.

If the training is conducted during a period when invasive mosquito populations are inactive, or at locations where they do not occur or are rarely encountered, this field exercise can still be very useful; even in the absence of mosquitoes, participants will learn about suitable sites for sampling and sampling techniques.

Requirements

- Guides/participants should assemble a wide range of collection materials, including: several dipper samplers, aquatic nets, small plastic trays and plastic cups, transparent jars, pipets, one or more ovitraps and/or gravitraps, mouth aspirators, one or more BG-Sentinel traps and a binocular microscope for identification of specimens.
- Prior to the training, instructors should locate likely breeding or resting sites (for example, gardens, cemeteries, used-tyre dump sites) where there are known populations of invasive mosquitoes. Ideally, these sites will be located within reasonable travelling distance from the workshop venue, and in areas where trapping devices – such as ovitraps and BG-Sentinel traps – will not be easily be found and removed by outsiders.
- If possible, the field exercise should be conducted during a period when invasive mosquitoes are active. The catches can be collected and identified on the day after the traps are set.
- It is best to wear protective clothing when sampling (long trousers, long sleeves) to prevent mosquito bites.
- The exercise will require 4–6 hours in total; half a day for the field exercise, plus half a morning for collecting traps and examining specimens.

Assignment

1. Use dippers to sample for larvae inside open water bodies. Use small scoops and pipets to sample small cryptic breeding sites such as water-containing leaf axils or tree holes. Vases, saucers or artificial containers filled with water are easily emptied into transparent jars to inspect the presence of larvae. Larvae can be transferred by pipet into transparent

containers for transport to the training venue. Make sure to keep the larvae in separate containers according to the type of breeding habitat, and mark the containers accordingly.

2. Ovitraps are an inexpensive and easy method for trapping developing larvae and thus detecting the presence of invasive mosquitoes in an area. Set some traps during the field exercise at the most suitable sites.
3. Sample resting mosquitoes in shelters using aspirators. In vegetation, use sweep nets to catch flying mosquitoes.
4. Examine and discuss the components of special trapping devices, such as the BG-Sentinel trap or any other trap that can be developed locally for collecting adult mosquitoes. Practice setting them up. Traps that use a special chemical lure can be used in combination with CO_2 to increase their effectiveness in attracting mosquitoes.
5. Arrange to collect the ovitraps and BG-Sentinel traps the following day. Examine the catches and keep the specimens for identification.
6. At the training venue, inspect the collected specimens under a binocular dissection microscope. Larvae can be identified at the fourth instar. Smaller larvae should be reared inside a water container until the fourth instar or adult stage.

Points for discussion

- Based on your practical experience, discuss the advantages and disadvantages of each sampling technique with respect to invasive mosquitoes, and the suitability of selected sites with respect to the different trapping/sampling methods.

Unit 1.6 Monitoring and management of insecticide resistance

Training objective

Participants learn about pesticides used for mosquito control, the possible development of resistance in mosquitoes, and ways to survey and manage insecticide resistance in order to prevent and manage insecticide resistance in targeted invasive mosquito populations.

Requirements

- Information on the status of insecticide resistance in invasive mosquito populations from your country, if applicable
- Information on the type and amounts/frequency of pesticides used for mosquito control in your country, if applicable
- Information on laboratory capacities and methods to assess insecticide resistance in your country
- Time: 1–2 hours

Background

Control of *Aedes* vector populations remains the main measure for reducing the risk of transmission of arboviruses. Control methods are chosen according to their efficacy, safety and cost within a given context (see Unit 2.2). Removal of containers in which mosquito larvae develop can be effective; however, this method is not always practical in areas where mosquito larvae habitats are small, dispersed and difficult to find and/or access.

Pesticides, employed as larvicides sprayed on larval habitats, adulticides applied by outdoor space spraying, residual sprays or treated/impregnated materials, are more common control measures. Over the past decade, the use of pyrethroids such as deltamethrin and permethrin has gradually increased as a proportion of total pesticide use for dengue control *(31)*.

Unfortunately, the emergence and development of insecticide resistance in dengue vectors, especially *Ae. aegypti*, present serious operational challenges to vector control programmes. Reports show resistance to all four classes of pesticides (carbamates, organochlorines, organophosphates and pyrethroids) *(32),* and there is growing evidence that this resistance is compromising the success of control interventions, such as those in the Caribbean *(33)*.

Resistance management is crucial to addressing this situation. It aims at preventing or delaying the development of insecticide resistance in a mosquito population while maintaining an effective level of mosquito control. Monitoring changes in the susceptibility of targeted mosquitoes to the pesticides in use should be a routine component of any operational programme. This should be conducted in representative locations, or sentinel sites.

The basic susceptibility test is the standard WHO bioassay in which live mosquitoes or larvae are exposed to a diagnostic dose of a certain pesticide *(34)*[1]. Bioassays are relatively simple to conduct. Biochemical and molecular assays are more technically demanding but can, unlike bioassays, detect low levels of resistance and determine the mechanism of resistance.

Control plans could integrate resistance-management measures *(35)* based on three options:

1. management by moderation, which consists of limiting the chemical selection pressure to preserve the susceptibility genes in the mosquito population through, for example, the use of low pesticide rates, infrequent applications, the use of nonpersistent pesticides and the preservation of refuge areas (unsprayed areas where susceptible populations can be preserved);
2. management by saturation, which consists of overcoming insects' defences through excessive or frequent use of pesticides in order to leave absolutely no survivors; or
3. management by multiple attacks, which consists of combining several independent pesticide-based stresses, each of which exerts selection pressure that is below the level which could lead to resistance (this approach includes the application of chemicals in fine-scale mosaic, in mixtures or, most commonly, in rotation).

Assignment

1. Outline the situation of insecticide resistance in invasive *Aedes* mosquitoes in your country. Highlight gaps in information and capacity for monitoring resistance.

[1] See in particular Annex 4 and 5 of WHO's *Malaria entomology and vector control. Guide for tutors* (2013).

2. For each pesticide or control agent listed below, estimate its relative risk for development of insecticide resistance. Appraise each using + or – signs.
   - Temephos
   - *Bacillus thuringiensis israelensis*
   - DDT
   - *Gambusia* and other predators
   - Permethrin, deltamethrin + piperonyl butoxide
   - Natural pyrethrins
   - Polydimethylsiloxane (silicone film)
   - Deltamethrin
   - Fenitrothion
   - Diflubenzuron
   - *Bacillus sphaericus*
   - Malathion
   - Chlorpyrifos-ethyl

3. In the following list of possible measures, select those that reduce the risk of developing resistance in mosquito populations. Appraise each using + or – signs.
   - Rotate active substances (for example, year 1: deltamethrin; year 2: permethrin)
   - Introduce predators in larval breeding sites (for example, *Gambusia*)
   - Use an active substance that is frequently used in agriculture
   - Reduce the use (in terms of frequency) of pesticides
   - Assess the susceptibility of the targeted mosquito population
   - Combine two active substances (for example, *Bacillus thuringiensis israelensis* and *Bacillus sphaericus*)
   - Reduce the dosage of the active substance
   - Increase dosage of the active substance when efficacy decreases
   - Combine different actions in a mosaic: larvicide, adulticide, source reduction
   - Keep a refuge area (an area free of pesticide spraying) for the mosquito population

Points for discussion

- What would be the optimal strategy for preventing the development of resistance in *Aedes* mosquitoes in your country?

Unit 1.7 Regional networking

Training objective

Participants learn about the importance of regional collaboration and networking linked to the surveillance of invasive mosquito species, and obtain information about potential partner institutions in the Region.

Requirements

- Information on your country's participation (or potential participation) in existing bilateral or regional collaborations and networking related to pest control, medical and veterinary entomology research, native and invasive mosquito surveillance and control
- Time: 1–2 hours

Background

The problem of invasive mosquitoes extends beyond national borders. It requires partnerships between countries to establish harmonized strategies and methods of surveillance and control. As the presence of invasive mosquitoes is relatively new in many countries, however, the awareness and capacity needed to tackle the problem are lagging behind. More than ever, collaboration between countries is critical.

First, regional collaboration and networking plays an important role in filling gaps in national capacities and harmonizing methods of surveillance and control of invasive mosquitoes.

Second, it permits the rapid exchange of information on the status of invasive mosquito populations and the circulation of the pathogens they can transmit. This allows for swift adaptation and reinforcement of surveillance and control.

Third, it aims at updating international and national regulation and recommendations to reduce the risk of passive spread of invasive mosquitoes. To date, no international regulation applies specifically to invasive mosquitoes; the International Health Regulations (IHR) (2005) *(36)*[2] apply to mosquitoes only when they are vectors that constitute a public health risk.

Pan-European networking on invasive mosquito species has been put in place with support from international bodies (the ECDC, the European Food Safety Agency (EFSA) and the WHO Regional Office for Europe) and with assistance from specialized scientific societies (the European Mosquito Control Association, the European Society for Vector Ecology).

ECDC and EFSA fund the VectorNet collaborative network to produce updated vector distribution maps and to support them in their preparedness for vector-borne diseases. They focus in particular on the promotion of partnerships and collaborations between government bodies, research centres, and training and development units concerned with human and animal health. This focus is in line with the One Health approach, which links human, animal and environmental health.

Within these networks, countries can easily identify competent agencies and laboratories and develop regional collaborations. One immediate priority is meeting the demand for a network of reference laboratories to support the identification of mosquito species *(6)*.

Assignment

1. Identify the needs and opportunities for regional collaboration on any aspect of invasive mosquitoes and mosquito-borne diseases that are relevant to your country context. Point out the countries and bodies that should be involved and outline the potential role of each.

[2] See in particular Annex 5 of the IHR (2005).

2. Identify existing cross-border initiatives related to health, agriculture or the environment that could be used for surveillance and control of invasive mosquitoes and mosquito-borne diseases.

Points for discussion

- Discuss possible barriers for establishing regional collaboration and networking on invasive mosquitoes and vector-borne diseases. How could these barriers be overcome?

Module 2. Mosquito control and disease outbreak response

Unit 2.1 Prevention of introduction (and spread) of invasive mosquitoes

This learning unit applies to areas or countries where invasive *Aedes* species have not yet become (firmly) established, or where there is a risk of introduction of additional invasive species.

Training objective

Participants learn to determine the needs, opportunities and feasibility for preventing the introduction of invasive mosquitoes, as applicable to their country context.

Requirements

- Information on incoming shipments of used tyres, Lucky Bamboo plants or other suspected goods carrying invasive mosquitoes (including origin, destination and current practices)
- Time: 1–3 hours

Background

Aedes mosquitoes have the ability to disperse into new countries or areas and then adapt to certain environmental conditions. *Ae. albopictus* is a particularly successful invasive mosquito because its eggs can be transported over long distances with certain goods that can eventually serve as breeding sites. This mechanism of accidental transportation and invasion, aided by international trade, has allowed *Ae. albopictus* to greatly expand its global range.

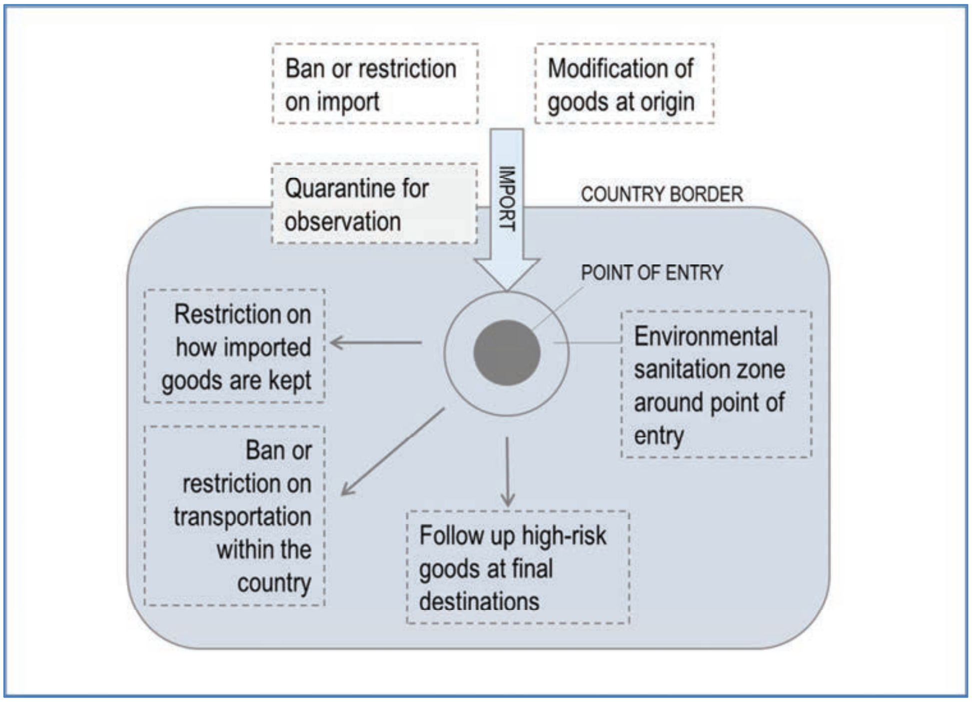
As Module 1 outlined, both *Ae. aegypti* and *Ae. albopictus* have recently invaded parts of the Region and are continuing to colonize new areas and countries *(4)*. Wherever possible, the introduction of these invasive mosquitoes should be prevented. There are several potential strategies and interventions for this (see Fig. 3); the selection process should involve a consideration of the costs and potential benefits of each.

The points of entry into a country deserve special attention. Under the IHR (2005), Member States are obliged to put in place methods and procedures for surveillance and control of vectors and vector breeding reservoirs in and near designated points of entry *(36)*[3]. In addition to designated points of entry, other potential sites for introduction include railway stations and the rest and service areas of motorways that originate in the Mediterranean basin.

Keeping points of entry clear of potential breeding sites for *Aedes* mosquitoes helps to create an inhospitable environment where introduction is most likely. A complicating factor, however, is the potential presence of mosquitoes or their eggs inside freight containers. Freight containers often pass unopened through points of entry and are unpacked only at their final destination. This suggests that high-risk goods should be followed up at their final destination.

[3] See in particular articles 19–21 and Annex 1B of the IHR (2005).

Fig. 3. Potential strategies and interventions to prevent introduction of invasive mosquitoes



One preventative approach is to restrict or ban the importation of high-risk goods. Authorities in California (United States of America), for example, have enacted legislation prohibiting the importation of Lucky Bamboo plants in standing water. Some governments in other regions have imposed legal restrictions on the trade of used tyres into or within the country *(37)*. The financial implications of such measures, however, may not be economically feasible or desirable for some countries. Imported goods could also be quarantined for a fixed period to ascertain that they are free of invasive mosquitoes in any of their life stages *(37)*.

Another preventive approach is to allow importation but impose special restrictions at the point of entry into the country. For example, if used tyres are imported they should be kept under dry conditions to prevent any water from accumulating and creating breeding habitat. As it can be difficult to distinguish between imported and local used tyres, such restrictions should apply to all used tyres. However, these measures require monitoring and enforcement in order to be successful. Spraying used tyres will have a limited effect, as available pesticides do not easily kill the eggs of mosquitoes.

In specific situations, it may be effective to collaborate with companies located at the origin point of traded goods in order to modify shipment conditions and thus reduce the risk of inadvertently transporting viable eggs. Authorities in California have taken this approach, collaborating with companies in China exporting Lucky Bamboo plants to ship them in gel rather than standing water. Nevertheless, data from the Netherlands suggest that the importation of plants in gel cannot adequately prevent the introduction of invasive mosquitoes *(38)*.

Some countries also face the challenge of introduction or spread of invasive mosquitoes from one part of the country to another.

Assignment

1. Identify the designated points of entry to which the IHR (2005) apply in your country. In addition, identify other potential locations for the introduction of invasive mosquitoes using country maps or sketched maps.
2. Briefly describe the situation regarding imported used tyres in your country: the scale at which used tyres are being imported; the tyres' countries of origin, points of entry and final destinations; and the current preventive measures and storage practices (for example, dry storage). Does this pose a risk for introducing invasive mosquitoes? Identify the authorities that can provide the required information, if necessary.
3. Identify the importation of other goods into your country that may harbour the eggs of invasive mosquito species and that require further investigation.
4. For each of the high-risk imported goods that you identified, point out the potential mitigation measures for preventing the introduction of mosquitoes.
5. If your country is facing the introduction or spread of invasive mosquitoes from one part of the country to another, can you propose measures to prevent or delay this?

Points for discussion

- What are the main challenges (for example, technical, operational, financial, legal or institutional) to preventing the introduction of invasive mosquitoes in your country?

Unit 2.2 Mosquito control tools

Training objective

Participants learn about possible tools for mosquito control, including their advantages and disadvantages, in order to select the tools that are most appropriate in their country context.

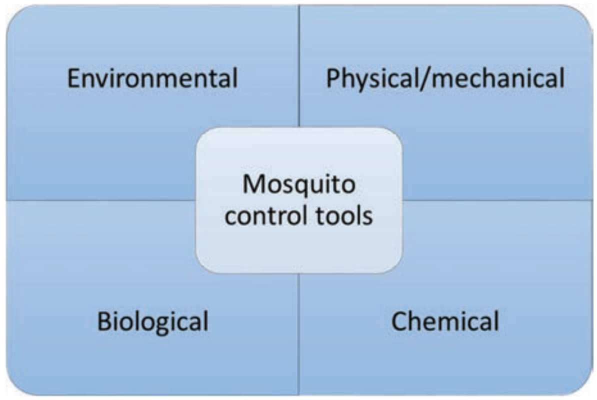
Requirements

- Reference information on each mosquito control tool
- Time: 1–3 hours

Background

Mosquito control is the implementation of all interventions that aim to reduce or eliminate mosquito populations or to reduce human contact with pathogen-transmitting mosquitoes (personal protection). A number of mosquito control tools are available *(5,39).* These tools can be divided into four categories: physical (or mechanical), environmental, biological and chemical (see Fig. 4). The integrated vector management approach recognizes chemical tools as the method of last resort, to be used after all physical, environmental and biological tools have been considered or attempted *(2).*

Fig. 4. Categories of mosquito control tools



To select the most appropriate mosquito control tool or set of tools, it is important to first examine the mosquito lifecycle (see also Module 1). As illustrated in Fig. 1 of Unit 1.1 (page 5), the mosquito lifecycle involves both an aerial and aquatic phase. Adult mosquitoes (aerial) are free-flying, whereas their larvae and pupae (aquatic) live in small water-holding containers. Each mosquito control tool attempts to interrupt this lifecycle at a given point. A combination of tools is normally necessary to substantially reduce mosquito populations.

The aquatic phase can be considered the most vulnerable to control efforts, as larvae are confined to containers that can often be removed, filled or drained with relative ease. The aerial phase can be relatively difficult to control because adult mosquitoes are dispersed in space. *Ae. aegypti*, however, is closely associated with human habitation because of its dependency on human blood and its short flight range. It commonly stays within an individual house or compound. Other *Aedes* species, such as *Ae. albopictus*, can feed on a wider range of hosts (mammals, birds, reptiles) and thus may also live beyond areas of human habitation.

Environmental tools include environmental modification and environmental manipulation. Environmental modification is the permanent removal of breeding sites through draining, filling or covering water bodies. The installation of a reliable piped water supply to households, for example, could be considered an environmental modification because it removes the need for households to keep water tanks in which *Aedes* mosquitoes can breed.

Environmental manipulation creates temporary change within a breeding site. This includes frequent emptying and cleaning (scrubbing) of flower vases, bird baths and water storage containers; collection and disposal of discarded waste and used car tyres; and the management of plants with leaf axils in which *Aedes* mosquitoes can breed.

Physical and mechanical tools include traps, covers for water-storage containers or netting fabric that prevents blood-feeding on humans. Trapping devices to attract and kill egg-laying female mosquitoes (gravitraps) or to trap and kill developing larvae (ovitraps) are largely used for monitoring purposes (See Module 2), but have occasionally been used for mass-killing of dengue vectors *(39–41)*; this requires further study in the European context.

Physical tools also include silicone-based liquids that produce a very thin film on the surface of standing water. This film kills mosquito larvae and pupae by preventing them from breathing at the surface.

Biological tools include microbial pesticides, which have low adverse effects on most non-target organisms, and the conservation or augmentation of predatory organisms (small crustaceans, insects, spiders, small fish) that feed on larvae in water bodies.

Chemical tools include insect growth regulators or conventional chemicals such as larvicides; residual spraying outdoors and/or indoors; topical or spatial repellents; and insecticide-impregnated bednets or curtains. These mosquito control tools are discussed in more detail in separate documents *(5,39)*.

Source reduction, a common term in mosquito control efforts, entails the prevention of *Aedes* mosquitoes from using potential breeding sites. This can involve environmental modification, manipulation and the use of larvicides to change or treat a body of water.

The effectiveness of each tool is determined by several factors. For example, the removal of breeding sites will stop breeding completely, whereas the application of larvicides into breeding sites may not kill all mosquitoes and will have a limited residual period. Effectiveness is also determined by the quality of the intervention, which depends on the degree of coverage of target sites, quality of spray equipment, quality of pesticide, and method and timing of application. Effectiveness of chemical tools also depends on the level of insecticide resistance in targeted mosquito populations (refer to Module 2).

Finally, effectiveness depends on the level of community compliance or participation with the intervention. Mosquito control through source reduction and personal protection rely heavily on the participation of the community, for example, to remove artificial containers in their backyards.

Several criteria should be used when selecting the most appropriate mosquito control tools in a particular country context. The guiding questions in Table 2 can assist decision-makers in this process.

Space spraying (fogging) has been recommended in the past for emergency vector control (to stop an impending outbreak of disease). However, because of lack of evidence on its efficacy in preventing or controlling dengue, space spraying should be used as last resort only *(42)*. In the context of the recent Zika virus epidemic, The WHO Vector Control Advisory Group (VCAG) concluded that outdoor space spraying suppresses *Aedes* populations temporarily, but that indoor space spraying is less effective *(43)*. Indoor spraying is further complicated by the difficulty of providing spray teams with access to indoor spaces, and by the fact that aiming tiny pesticide droplets at mosquitoes during short periods of flight activity is technically demanding. For these reasons, mosquitoes occurring indoors are not usually targeted with this method.

In March 2016, the VCAG reviewed vector control tools in response to the Zika virus outbreak *(43)*. They concluded that existing tools and strategies are effective in reducing the transmission of *Aedes*-borne diseases, including Zika virus, provided that vector control programmes are properly implemented.

The VCAG also reviewed the following five potential vector control tools for Zika virus: (i) control of human pathogens in adult vectors using *Wolbachia* (bacteria that influence mosquitos' susceptibility to the arboviral infection), (ii) control of population levels through the introduction of a genetically manipulated variety (OX513A); (iii) control of population levels through the introduction of large numbers of sterile males (the sterile insect technique); (iv) new vector traps; and (v) attractive toxic sugar baits.

Table 2. Guiding questions for selecting mosquito control tools

	Guiding question
1.	Is the method likely to be efficacious under local circumstances?
2.	Does the mosquito control tool pose any risk to the health of applicators and/or residents?
3.	What are the risks to the environment and non-target organisms?
4.	What are the costs involved (product, protective equipment, training, staff salaries, supervision)?
5.	If pesticides are being used, is there evidence of resistance in mosquito populations?
6.	Will the mosquito control tool likely be acceptable to communities?
7.	Is there a role for communities to participate in implementation?
8.	Is the mosquito control tool in line with current government policies?
9.	Can the mosquito control tool be efficiently implemented within available infrastructure?
10.	How affordable, cost-effective and sustainable is the mosquito control tool likely to be?

After their review, the VCAG recommended the carefully planned pilot deployment (under operational conditions) of *Wolbachia*-based biocontrol and OX513A transgenic mosquitoes, accompanied by independent monitoring and evaluation. The VCAG concluded that more evidence is required before consideration of the pilot deployment of sterile insects, vector traps and attractive toxic sugar baits.

Assignment

1. In the following list of mosquito control tools, estimate for each tool:

   (a) its relative effectiveness in reducing mosquito populations;
   (b) its safety for human health and the environment;
   (c) the risk of development of insecticide resistance;
   (d) the prospect of communities accepting and/or participating in the use of the tool;
   (e) its relative affordability; and
   (f) the available infrastructure and policy support for using it.

   Use + or – signs in Table 3.

2. Based on this appraisal of advantages and disadvantages, which mosquito control tools would you select? Explain your choices.

Points for discussion

- Identify specific information gaps regarding the selected mosquito control tools that should be prioritized by research in your country.

Table 3. Example of a matrix for appraising mosquito control tools

Tool	Criteria					
	Efficacy	Safety	Risk of resistance	Acceptance/ participation	Affordability	Infrastructure/ policy support
Environmental management						
Environmental modification						
Environmental manipulation						
Physical control						
Trapping						
House screening						
Biological control						
Bacterial larvicides						
Use of predators (e.g. fish)						
Chemical control						
Larvicides – insect growth regulators						
Larvicides – conventional chemicals						
Residual spraying						
Space spraying						
Chemical repellents (topical, spatial)						
Insecticide-treated nets/curtains						

Unit 2.3 Elimination of foci of colonization

This learning unit applies to countries or parts of countries where invasive *Aedes* species are not yet (firmly) established, or where there is a risk of colonization of additional invasive species.

Training objective

Participants learn about the use of surveillance data and other available information in order to decide on a locally appropriate strategy for containment of foci of colonization of invasive mosquitoes.

Requirements

- Information about recent elimination operations and their results from your country (or neighbouring country), if applicable
- Time: 1–2 hours

Background

When preventive strategies (see Unit 2.1) cannot stop mosquitoes from accidentally entering the country, introduced mosquitoes may find themselves in a new environment suitable for colonization (for example, with the presence of water containers, suitable hosts for blood meals and mild winters).

Initial colonization may be limited to small areas, or foci, most likely located near the point of introduction. This early stage of colonization, when the exotic population is gradually adapting to the new conditions, presents the most feasible opportunity for eliminating the population.

Elimination of a population is a radical measure, aimed at reducing density to such a low number that any remaining females will not be located by males or will not be able to locate productive breeding sites. This results in local extinction of the population. Without further immigration of mosquitoes from neighbouring populations, the species will be eliminated.

There have been successful cases in the 20th century of elimination or substantial suppression of introduced mosquitoes (including *Aedes* mosquitoes) in large areas. These results were achieved through the wide-scale use of larvicides or through systematic indoor pesticide application in areas where mosquitoes preferred to rest indoors. However, in modern times, the large-scale use of pesticides may no longer be acceptable because of undesirable consequences for non-target organisms, including humans. Similarly, the indoor application of residual pesticides may not be acceptable to householders in modern settings.

The success of elimination efforts depends upon a solid system of mosquito surveillance that provides up-to-date information about the density, spread, breeding preferences and feeding habits of the invasive species (refer to Module 1). A close linkage between the surveillance team and the elimination team is essential.

Only when early detection confirms that the introduced mosquito is confined to a small area should elimination be considered. If mosquitoes are found outside the demarcated foci and local conditions are favourable to their reproduction, it may no longer be feasible to eliminate the species from the area.

As a rule, experts suggest that elimination is only feasible in colonized foci measuring less than 1 km^2. In reality, this figure depends on the species, the risk involved and local environmental conditions. For example, *Ae. aegypti* is a very efficient vector of dengue virus and poses high potential risk to human health; once this mosquito appears in a country, intensified efforts – even at increased cost – are warranted. The 1 km^2 rule may be adjusted as more elimination operations are documented.

Decision-makers must determine whether or not to attempt a full-fledged elimination operation. They will need to consider a number of variables and determine the way forward on a case-by-case basis. By definition, however, a half-hearted effort will result in failure and wastage of resources.

An appropriately swift and comprehensive decision-making process must involve a rapid assessment of the situation. A delay in decision-making for lengthy study or analysis could enable mosquitoes to disperse and establish themselves in new areas; countries should therefore prepare a scenario-based elimination plan well in advance.

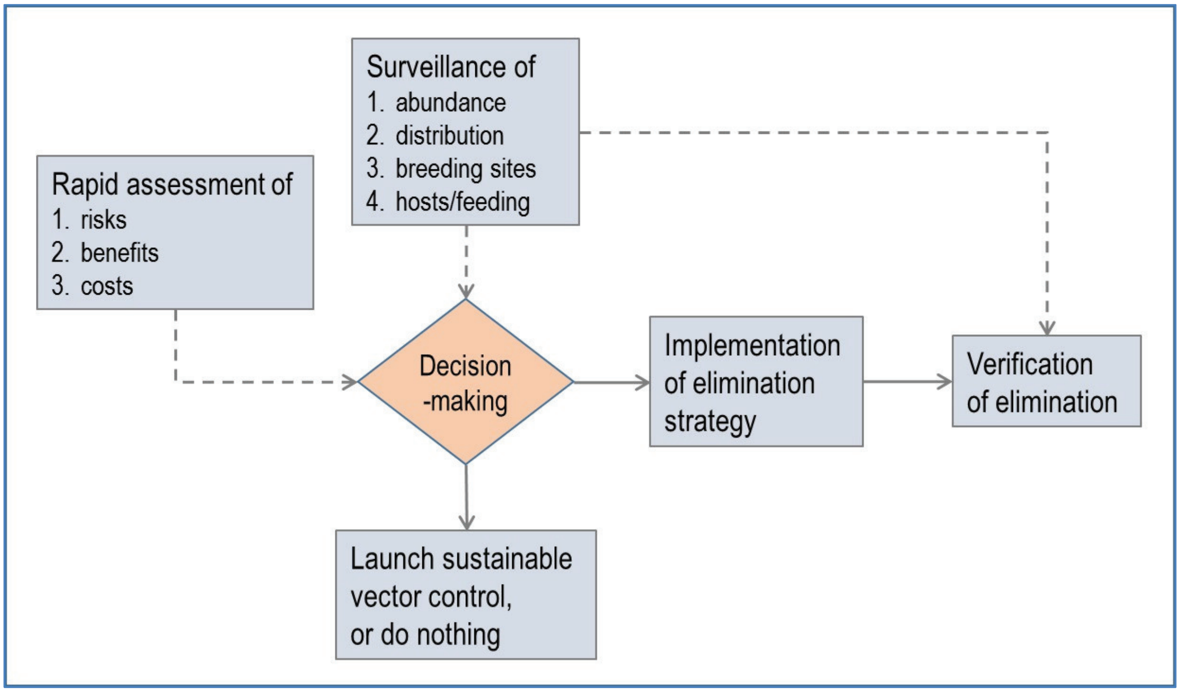
The elimination plan should include the following components (illustrated in Fig. 5):

1. a detailed assessment of the potential risks for human health, animal health and biodiversity associated with each potentially invasive species of mosquito (for example, does the species feed on humans only or on other hosts as well?);
2. a procedure for rapid analysis of costs, with detailed scenarios, and potential benefits of elimination efforts (the benefits of elimination versus the risk of having a firmly established population and threat of disease transmission);
3. a decision-making procedure, with criteria, on whether or not embark on elimination;
4. a plan for intensified surveillance of abundance, distribution, breeding sites and host-feeding, including a direct link with operations;
5. an elimination strategy that includes:
   (a) mapping to demarcate the area targeted for elimination, including data on human habitation, geographic and environmental variables and infrastructure;
   (b) selection of appropriate mosquito control tools (refer to Unit 2.2);
   (c) identification of needs, resources, roles and responsibilities in the elimination operation;
   (d) a plan for informing and involving local authorities and communities; and
   (e) a plan for informing the media, when needed;
6. criteria for verification of the success of elimination; and
7. documentation of the procedure, results and lessons learned to build an evidence base.

An elimination operation will most likely require the intensive use of a combination of mosquito control methods in the demarcated area, including rigorous source-reduction efforts to create inhospitable environments for reproduction as well as the supplementary use of pesticides. When the mosquito population has been reduced to low numbers, luring-and-trapping devices could be useful in killing the last remaining specimens.

Because the elimination of colonized foci is a specialized field with little available experience to draw upon, it is crucial that countries exchange data and experiences with others across the Region to establish a common evidence base.

Fig. 5. Schematic plan for elimination of foci of colonization



If decision-makers opt not to launch an elimination operation, they may then need to determine whether or not to control the mosquito population level to reduce the risk of disease transmission (refer to Unit 2.4) or nuisance and irritation.

Assignment

1. Review available or documented experience with the elimination of invasive mosquito populations in your country. Identify what lessons could be learned from this.
2. Assume the following scenario. Authorities have discovered that *Ae. aegypti*, an efficient dengue vector, has established itself in a town next to the ship harbour. Identify the sequence of actions that must take place. Also identify the different stakeholders (at local, district and/or national levels) that should be involved in each action, and briefly outline their roles.
3. Assume the following scenario. *Ae. albopictus* (or *Ae. aegypti*, as appropriate) has established itself in an area 1 km². As programme manager, you must justify the request for human and financial resources required to eliminate the mosquito population. How would you make the case to decision-makers? What harm, damage or negative consequences could be avoided through an elimination operation, making it worthwhile?

Points for discussion

- Discuss the requirements for capacity-building (human resources, competencies, equipment, institutional strengthening) for the elimination of foci of colonization in your country.

Unit 2.4 Sustainable mosquito control

This learning unit applies to areas or countries where invasive *Ae. albopictus* or *Ae. aegypti* populations are firmly established.

Training objective

Participants learn to analyse the local situation for risk of disease transmission, identify available resources and prepare a strategy for vector control in targeted areas.

Requirements

- Information on entomological surveillance and distribution of invasive mosquitoes
- Information on current and past cases of disease (dengue, chikungunya, Zika virus)
- Outputs from Unit 2.2
- Time: 1–3 hours

Background

In areas or countries where invasive *Aedes* mosquitoes are firmly established, and where elimination of mosquito populations is no longer feasible, the mosquitoes could become vectors of disease. As described previously, this can occur when an infected traveller introduces a disease-causing virus or pathogen into the area that is then transmitted to other people through the bites of mosquitoes.

A high volume of international travel, combined with the global spread and increased outbreaks of dengue, chikungunya and Zika virus in other regions of the world, has resulted in an increase in the number of reported cases of arboviruses among travellers into countries of the Region. This trend is likely to continue and puts countries with established populations of *Ae. aegypti* and *Ae. albopictus* at risk of local disease outbreaks.

Of particular concern are viraemic cases, in which the disease-causing virus circulates for 5–9 days in an infected person's bloodstream. This is the infectious stage of arboviruses such as dengue and chikungunya. Many viraemic cases will not show symptoms of disease and will thus go unnoticed. These asymptomatic cases can nevertheless result in so-called silent transmission of the virus if *Ae. aegypti* or *Ae. albopictus* mosquitoes are present locally.

In this situation, decreasing the density of the established *Aedes* mosquitoes, and preventing human contact with these mosquitoes, will reduce the risk that an accidentally introduced virus will be transmitted from person to person. Because infected travellers can enter a country or area at any time, the emphasis should be on sustainable mosquito control.

Experience from vector-borne disease-endemic countries clearly shows that mosquito control is a key strategy in prevention and control of mosquito-borne diseases *(44)*, particularly those for which effective drugs or vaccines are lacking (dengue, chikungunya, Zika virus). In cases where a human population is vulnerable to an introduced arbovirus, a reduction in both mosquito density and biting intensity will lower the risk of disease transmission.

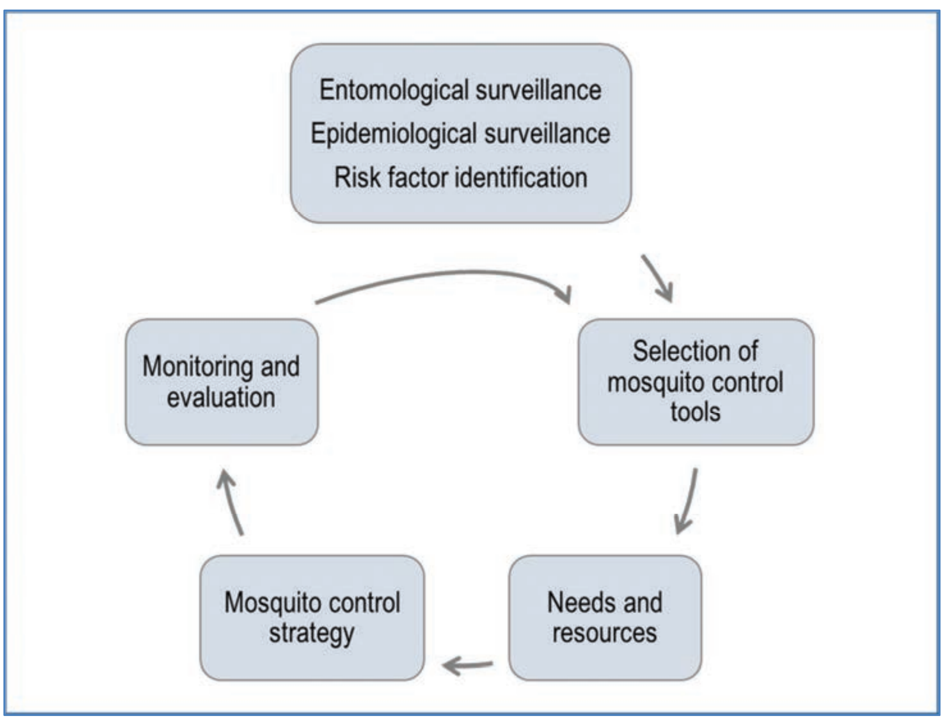
In addition to the threat of disease that they pose, invasive *Aedes* mosquitoes can also become a significant source of nuisance and irritation. In some areas in the Mediterranean basin, for example, *Ae. albopictus* mosquitoes have become so abundant that they are reportedly causing considerable human suffering *(45)*. In these cases, mosquito populations should be controlled to acceptable levels.

The implementation of mosquito control efforts must be carefully planned and based on available evidence and information (see Fig. 6). **Entomological surveillance** should provide timely data on mosquito populations, their seasonal fluctuations and local occurrence. **Epidemiological data** on the locations of current or historical disease cases, and information on identified **local risk factors** (for example, urbanization, suitable breeding sites, tourism or foreign workers), should be used to prioritize localities for mosquito control.

The most appropriate mosquito control **tools** should be selected (refer to Unit 2.2), and the available financial, human and technical resources identified. **Resources** may be available locally in municipalities or villages, or through the involvement of the private sector or communities living in affected areas.

Using available information sources, tools and resources, a team can then prepare a locally appropriate **strategy** for sustainable mosquito control. This strategy could specify activities, materials, criteria and thresholds for mosquito control, as well as the roles and responsibilities of those involved. Routine monitoring and evaluation should support mosquito control efforts by accounting for the resources used, identifying shortcomings and barriers, and measuring the impacts of the operation. This information should be used as feedback to improve future decision-making.

Fig. 6. Suggested decision-making process for sustainable mosquito control



The costs of mosquito control should also be balanced against potential benefits. Costs could be reduced through modifications in the environment that create inhospitable conditions for larval breeding, and by involving local partners and communities in implementing the mosquito control tools.

Assignment

1. Given the abundance and distribution of invasive *Aedes* mosquitoes in your country (or in a selected area within your country), and given the risks of disease transmission and the biting nuisance and irritation caused by these mosquitoes, is it necessary to implement sustainable mosquito control? Outline the key facts and draw your conclusion.
2. Refer to the outcome of your assignment in Unit 2.2. For every mosquito control tool or intervention that you selected, outline an implementation plan that includes:
   (a) when and where to implement;
   (b) how to target;
   (c) which partners, agencies and partners (including local partners) should be involved;
   (d) which should be the responsible agency; and
   (e) who would conduct monitoring and evaluation.

   Use the matrix in Table 4 as guidance.

Table 4. Matrix for mosquito-control planning

	Item	Selected mosquito control tools or interventions			
1.	When to implement (e.g. time of year, frequency)				
2.	Where to implement (e.g. urban centres, high-risk areas)				
3.	Targeting/coverage (e.g. percentage of households)				
4.	Partners in implementation				
5.	Responsible agency				
6.	Agency conducting monitoring and evaluation				

Points for discussion

- Discuss the types of capacities that need to be strengthened for implementing sustainable mosquito control.
- Discuss what measures would be needed in your country to ensure that surveillance activities are properly connected to mosquito control operations.

Unit 2.5 Lifecycle management of pesticides

Training objective

Participants learn about the phases of lifecycle management of pesticides and review their country situation, including weaknesses and opportunities for improvement.

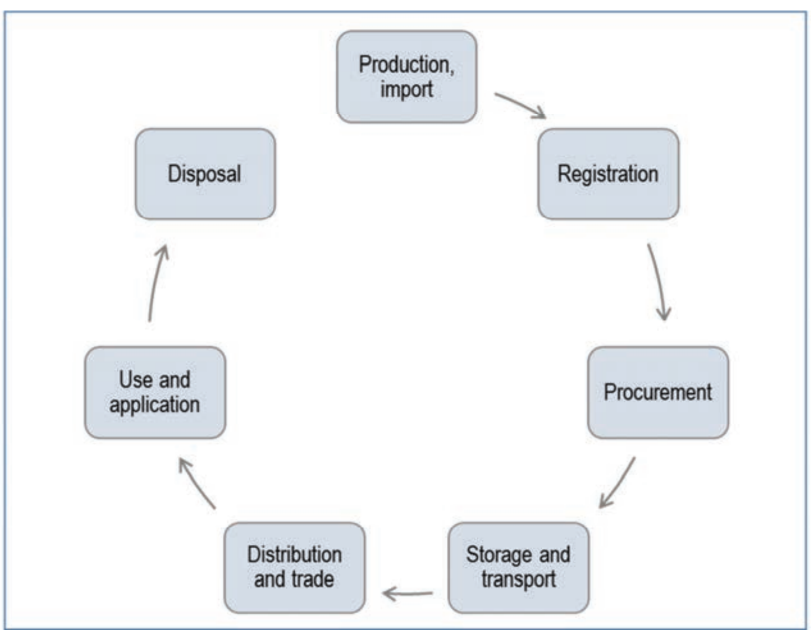
Requirements

- Information on legislation and regulatory control of pesticides for mosquito control in your country
- Time: 1–3 hours

Background

The lifecycle approach to pesticide management refers to the legislation, regulatory control and practices related to all stages of a pesticide's life, from manufacture and import to use and disposal (see Fig. 7). Without good management practices, the effectiveness and safety of pesticides will be compromised and resources will be wasted.

Fig. 7. Lifecycle of pesticides



A globally accepted norm for pesticide management is established in the recently updated International Code of Conduct on Pesticide Management (2014), which addresses both agricultural and public health pesticides *(46).* The Food and Agriculture Organization of the United Nations/WHO Joint Meeting on Pesticide Management monitors the implementation of the Code of Conduct and advises on pesticide regulation and management.

Several international legal instruments, in which many countries participate, are in place to control the use, transboundary movement, international trade and disposal of hazardous pesticides; these have been discussed in separate reports *(47–49).*

Sound management of public health pesticides depends on the existence of appropriate procedures and standards for the stages of the pesticide's lifecycle, particularly related to registration, procurement, storage, transport, distribution, application, disposal, monitoring, quality control, public education and information exchange *(50).*

- **Registration** schemes should control the availability of acceptable public health pesticides. Pesticides should be specified for their intended purposes and labelled properly, and responsible authorities should approve and monitor their purpose, sale and use, and enforce compliance.
- **Procurement** of pesticides, for example, by the agency tasked with mosquito control, should follow an efficient and transparent procedure for obtaining high-quality products at competitive prices for public health purposes. The procurement procedure must be supported by standard guidelines, legal provisions and controls, and should promote after-sales stewardship commitment by the supplier to the end-user level.
- **Storage** and **transport** of pesticides require standards on stock management; record keeping; location, condition and security of stores; and secure transport to and from stores in order to prevent spillage and misuse.
- **Distribution** and **trade** of pesticides should follow regulations on distributor licencing, proper packaging, safe handling and labelling.
- **Pesticide quality control** should involve inspecting whether pesticides that are imported, manufactured or locally traded meet national requirements of labelling, packaging and other specifications. It should also involve taking corrective action against substandard, counterfeit and/or adulterated products.
- **Application** of pesticides should comply with certification standards and include refresher training for spray supervisors and spray operators. Best practices and correct application technology should be adopted, personal protection equipment used, and records kept. Decision-making on selection and judicious use of pesticides must be based on evidence of disease transmission as well as the behaviour, abundance and pesticide-susceptibility of mosquito populations.
- **Disposal** of expired or discarded pesticides, empty containers and other waste should comply with international standards. Countries should also proactively prevent the accumulation of obsolete stock through adequate planning and record-keeping.

If one or more of these key factors is missing, there is a risk of undermining the effectiveness and safety of public health pesticides. Specifically, poor management practices may lead to the distribution of substandard products, unsafe application practices, acceleration of insecticide resistance and accumulation of obsolete pesticides.

Monitoring should ensure that all stakeholders are complying with the regulations on pesticide management. Capacity and infrastructure should also be in place for routine monitoring of spray workers' exposure to pesticides, surveillance and reporting of pesticide poisoning cases and level of insecticide susceptibility in targeted mosquitoes.

Public education on the use of pesticides for public health purposes is essential to creating awareness among the general public about the reasons for pesticide use, best practices of use and compliance, and possible risks of exposure.

Moreover, the exchange of information should ensure the harmonization of decision-making across all components of the pesticide lifecycle. This calls for effective coordination among national stakeholders as well as networking with neighbouring countries and the pesticide industry.

Assignment

1. Describe the registration process for public health pesticides, and agencies involved, in your country.
2. Indicate the responsible agency for each component of the lifecycle of mosquito control pesticides.
3. Identify the existing regulations or standards on the storage, transport, application and disposal of pesticides for use in mosquito control in your country.
4. Identify the problems and gaps that exist at each stage of the pesticide lifecycle (see Fig. 7).

Points for discussion

- Discuss the main priority or set of priorities for improving regulations, guidelines, institutional arrangements or capacity in relation to mosquito control pesticides in your country.

Unit 2.6 Response to disease outbreaks

This learning unit applies to areas or countries where *Ae. albopictus* or *Ae. aegypti* populations are firmly established.

Training objective

Participants learn to identify the essential components of an outbreak response, and about the importance of a preparedness plan.

Requirements

- Information on agencies in your country and their potential involvement in an outbreak response
- Time: 2–4 hours

Background

In areas or countries where invasive *Ae. aegypti* or *Ae. albopictus* mosquitoes are firmly established, dengue, chikungunya or Zika virus could be transmitted locally from person to person. This happens when an infected traveller enters an area where these mosquitoes are present (primary case). Under suitable conditions (for example, in urban conditions with an abundance of mosquito vectors and human hosts) this could result in a local disease outbreak.

Sustainable mosquito control, irrespective of the detection of disease cases, helps prevent the occurrence of outbreaks (refer to Unit 2.4). However, once the first infected case is detected (index case), it will be necessary to step up emergency control action. This starts with an investigation to determine whether the case was locally acquired (indicating that the virus is actively circulating) (see Table 5).

Authorities should be prepared to prevent further infections that can lead to outbreaks, while simultaneously providing supportive care to those who become ill. In the absence of disease outbreaks, or when the intervals between outbreaks are long, programme managers and policy-makers easily overlook preparedness for disease emergencies. The recent emergence of dengue and chikungunya in southern Europe highlights the importance of countries being prepared for outbreaks.

Table 5. Primary and index cases

Case	Description
Primary case	The individual who first brings a disease into a group of people (community, country). The primary case may never be known.
Index case	The patient in an outbreak who is first noticed by the health authorities, and who makes them aware that an outbreak might be emerging *(51)*.

Epidemiology

An outbreak-response preparedness plan should be based on knowledge of the biology of the disease and its transmission. After an infected mosquito passes a virus to a human or animal host through its bite, the virus incubates for 3–10 days (internal incubation time) to produce large amounts of virus in the bloodstream. This viraemic stage lasts 5–9 days, depending on the virus. A viraemic person can develop disease symptoms within days, and these symptoms last for several days. During this viraemic stage the person is infectious, and an *Ae. aegypti* or *Ae. albopictus* mosquito feeding on them will pick up the virus and likewise become infected.

A proportion of infected people will not develop significant disease symptoms, but can still contribute to silent transmission of the virus. Considering intrinsic incubation time and the role of silent transmission, it is difficult to prevent the first wave of local transmission after the virus is introduced by the primary case. The role of an emergency response is, therefore, to prevent a second wave of transmission that spreads beyond those initially infected.

After being ingested by a blood-feeding mosquito, the virus requires 8–12 days of development (extrinsic incubation time) before that mosquito can infect another human. The mosquito remains infected for the remainder of its life, which may be days or a few weeks.

An epidemic will typically start with a rapid rise in the number of new cases until a peak is reached, after which the number of new cases starts to drop. The decline occurs because those who are infected (including those who do not show symptoms) cannot become reinfected. When the vulnerable population necessary to keep transmission spreading is diminishing, the epidemic ends.

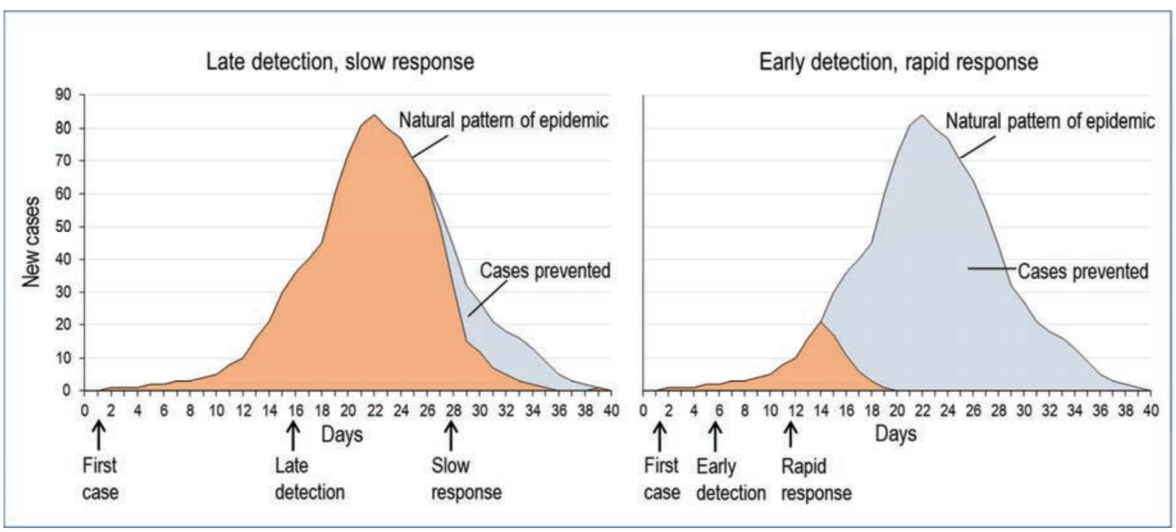
An epidemic will end with or without an emergency response. If the emergency response is started late in the epidemic, especially after its peak, the benefit of the control effort in terms of cases prevented will be rather small. The emergency response will only have a major impact if started at a very early stage – even before the rapid rise in the number of new cases (see Fig. 8).

Disease surveillance

A routine disease-surveillance system for early detection of cases and a mechanism for early warning of an outbreak are both essential to emergency response. This involves the active detection of any suspected cases and their verification through laboratory testing as confirmed cases. Detected cases should result in an immediate warning signal to the outbreak response team.

Detection of a new serotype in an area where an arbovirus was previously reported is cause for special concern because it could cause strong immunological reaction in people that were previously infected.

Fig. 8. Effects of late detection/slow response and early detection/rapid response



The first case is the primary case, which is often unknown.
Source: modified from WHO's *Communication for behavioural impact (COMBI). A toolkit for behavioural and social communication in outbreak response* (2012) *(52).*

Triggers for activation and deactivation

The disease activity level determines the appropriate response action. Where no disease cases have been detected, preventive activities such as routine surveillance and sustainable mosquito control suffice.

Where sporadic cases of disease have been reported, rapid case investigation should determine whether cases were imported or locally acquired. The response action should aim for local elimination of the virus. Infected people should be protected from mosquito bites to stop further spread of the virus. Because mosquitoes in areas visited by the infected person or people could have picked up the virus through a blood meal, these locations (known as case contact points) should be identified and emergency vector control implemented, as appropriate, in an area 100–200 m from each.

Evidence of local transmission is critical because it indicates that transmission (including silent transmission) is ongoing and the virus may have already infected more people (who may still be in the incubation phase, or be asymptomatic). When one or more locally acquired (autochthonous) cases are confirmed, it is time to declare a local outbreak situation.

Once dengue or chikungunya has become endemic, thresholds will need to be set to differentiate between endemic dengue activity and an impending outbreak (for example, by comparing disease activity during the same period over a number of previous years). In this situation, a predicted outbreak requires a larger-scale emergency response with a major public-awareness campaign.

Outbreak response planning

The outbreak response should not be the burden of a single agency or ministry; rather, several agencies and ministries should be actively involved, with one taking the role as coordinator. Experience from other regions indicates that a multisectoral response committee or team should be in place, tasked with the responsibility of being prepared to initiate and coordinate the response to an outbreak. This team could include, for instance, a health coordinator, a clinician, a laboratory technician, a vector control specialist, a water/sanitation specialist, an educator, a local authority and a civil-society representative.

The team should prepare, formally agree and disseminate an outbreak response plan to all participating agencies. The essential steps of outbreak preparedness and response planning are as follows *(1,53)*.

1. Identify a lead coordinating agency.
2. Establish organizational links with other agencies that have direct responsibilities for implementing the plan (for example, dengue response committee).
3. Formalize the outbreak response plan (Fig. 9) that includes:
    (a) enhanced disease surveillance;
    (b) enhanced vector surveillance and emergency vector control;
    (c) management of the health system to deal effectively with an influx of disease cases; and
    (d) a strategy for communication and community mobilization.
4. Define triggers for the activation and deactivation of the plan.

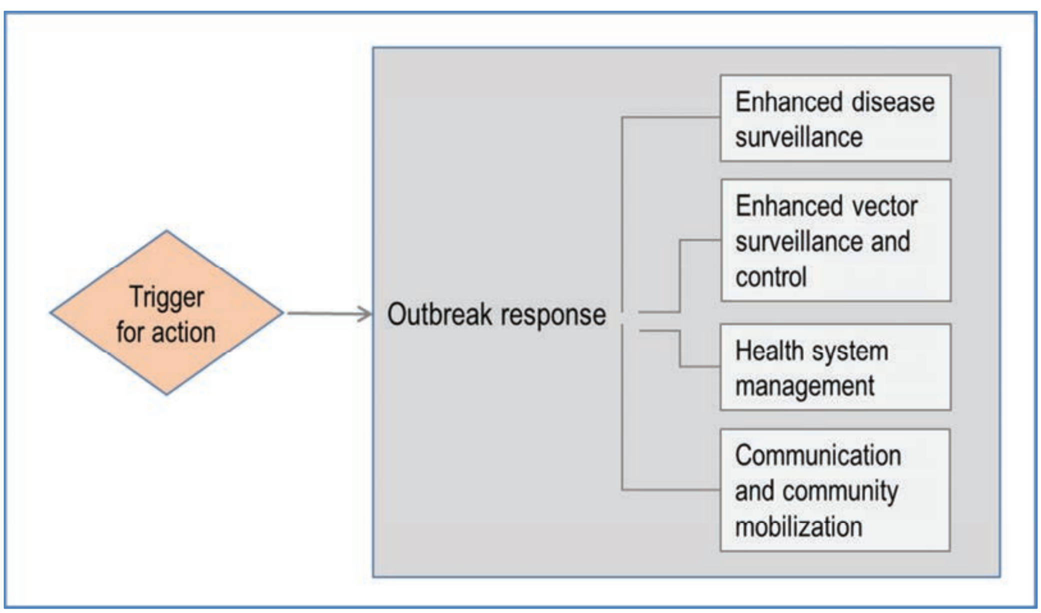
5. Investigate the outbreak.
6. Define the roles and responsibilities of each agency.
7. Conduct multisectoral exercises to discuss and validate the plan.
8. Determine costs and develop human resources.
9. Conduct monitoring and evaluation.

Limited available evidence suggests that elimination of larval habitats with community involvement and the appropriate use of pesticides in and around houses, combined with capacity-building and laboratory support, are crucial for the successful control of dengue outbreaks *(54).*

The team should establish roles, responsibilities and methods for sharing information in as much detail as possible to facilitate a quick and efficient response effort when it is needed. In the event of a suspected outbreak, the team should meet regularly to review the latest data and coordinate the implementation of the response plan. It is critical that plans address human resources development, including emergency training and/or recruitment of staff from other areas. Outbreak investigation is also essential to confirm cases, study entomological parameters and define the extent and spread of the outbreak in time *(55).*

Monitoring and evaluation should provide detailed information on the inputs, implementation process and effects of the response action. After an outbreak, a thorough evaluation of the surveillance and detection of the outbreak, preparedness and management of the outbreak, and control measures should be carried out and documented. This will determine the effectiveness and timeliness of the activities, and identify missed opportunities and needs for policy change *(55).*

Fig. 9. Main components of outbreak response.



Assignment

1. Consider an intrinsic incubation time of five days, a viraemic period of seven days and an extrinsic incubation time of eight days. If the first index case of disease has been detected on day one, after how many days do you expect to see more cases emerging? Give your answer for each of the following two scenarios:
   (a) when the index case is a person who entered the country on the same day (the primary case);
   (b) when the index case is a locally transmitted case (without recent travel history).
2. For your country situation, identify a lead agency and other agencies to be represented in a response team. Propose the roles of each agency.
3. Outline the activities for a response plan in chronological order, from the moment that the first case is detected to the end of the outbreak. For each activity, briefly indicate the actors and their roles, and point out information flows (for example, for data on suspected cases).

Unit 2.7 Policies and intersectoral collaboration

Training objective

Participants learn to identify the role of policy and intersectoral collaboration in the prevention and control of invasive mosquitoes and (re-)emerging vector-borne diseases, and to examine the situation in their country.

Requirements

- Country-specific information on existing policies, legislation and regulatory control in relation to mosquito control, pesticide management and mosquito-borne disease control
- Time: 2–4 hours

Background

Depending on the degree of risk of local transmission and outbreaks of arboviral diseases, countries should raise the issue on their policy agenda, develop or revise appropriate national policies and direct resources to enable effective coordination of prevention, surveillance and control activities.

Examples of effective public policy reform include the development of policies on:

- mosquito surveillance and control;
- environmental sanitation to prevent mosquito breeding;
- construction standards (buildings, drains, etc.) to prevent mosquito breeding;
- used tyres or other high-risk goods (for example, import/export restrictions, conditions for storage, disposal or recycling);
- the inspection of imported goods or private property;

- the registration of pesticides for professional use in mosquito control (at the country level or the level of the European Union);
- pesticide lifecycle management; and/or
- strategic directions for research on invasive mosquitoes or (re-)emerging vector-borne diseases.

Policies are only effective, however, when implemented through appropriate policy instruments, for example, through specific programmes or persuasive measures to create awareness or cooperation, strategic direction for research, or by enacting (and enforcing) laws or regulations.

One specific area for policy development is intersectoral collaboration. Invasive mosquitoes and the diseases they may transmit are not just the health sector's concern. Several other sectors should play a role in the prevention and control of invasive mosquitoes and vector-borne diseases, including the public sectors of transport, tourism, environment, local government, agriculture and trade.

Programmes and actions in each sector can influence conditions for invasion or breeding of mosquitoes, or for the importation, transmission and outbreak of vector-borne diseases. Sectoral programmes could inadvertently create favourable conditions for mosquitoes or disease (for example, through building standards that create breeding sites), or they could work to reduce risks. Analysing and understanding these risks (for example, through multisectoral exercises using the health impact assessment tool *(56)*) is vital to strengthening prevention, surveillance and control within countries.

Control efforts should include the identification of opportunities for leveraging pre-existing resources and structures. For example, professionals already working to find invasive species (for example, insects or plants) in the forestry, natural resources or agriculture sectors could potentially contribute to finding invasive species of mosquitoes as well. Cross-border initiatives related to other sectors (for example, on human or animal disease, or climate change) could also expand to incorporate mosquito control for the prevention of outbreaks.

Assignment

1. Which policies, laws and regulations already exist in your country that support prevention, surveillance and control of invasive mosquitoes and (re-)emerging vector-borne diseases? Consider the examples given above.
2. Identify the main gaps in policies, laws and regulations in your country.
3. For each of the main gaps you identified, propose a solution in the form of a policy instrument. For example, specify a programme, intervention, law, authorized use or restriction needed.
4. Identify opportunities for intersectoral collaboration in the (a) prevention, (b) surveillance and (c) control of invasive mosquitoes and (re-)emerging vector-borne diseases (as appropriate). Which sectors could be involved and what role could they potentially play?

Points for discussion

- Discuss how intersectoral linkages could be initiated, strengthened and/or sustained.

Unit 2.8 Communication and community participation

Training objective

Participants learn to prepare an advocacy plan to increase awareness among senior-level decision-makers and the general public about the need for action against invasive mosquitoes and vector-borne diseases.

Requirements

- Time: 1–3 hours

Background

Invasive mosquitoes and their possible role in local transmission and outbreaks of dengue, chikungunya and Zika virus is a new problem to most countries in the Region. Awareness must be raised in order to gain the necessary support for surveillance, prevention and control at all levels. Communication efforts must focus on two critical audiences: (i) decision-makers and researchers at the senior level and (ii) the general public and affected communities at the field level. Messages can be target specifically towards, for example, students or women who undertake most of the preventative measures in communities.

At the **senior level**, communication efforts should focus on informing governments and institutions about invasive mosquitoes and their role in the transmission of emerging diseases. This is a critical first step that can prompt policy-makers to raise the subject on the policy agenda and allocate the resources required for surveillance, control, communication and research.

Advocacy is needed at the country level, but also at the level of the European Union. This should be firmly based on the available evidence, which includes contemporary surveillance data and risk analysis, as well as the effectiveness of mitigation methods and strategies. Furthermore, communication efforts should inform the research community about the need to strengthen the evidence base on invasive mosquitoes *(57)*.

At the **field level**, affected communities have an important role to play in the surveillance and control of *Ae. aegypti* or *Ae. albopictus*, which are closely associated with humans and tend to inhabit people's houses and backyards. In areas at risk of the introduction of invasive mosquitoes, awareness campaigns should encourage communities to be vigilant and report the appearance of exotic mosquitoes in their area.

In areas where *Ae. aegypti* or *Ae. albopictus* are firmly established, communities also have a major role to play in the sustainable control of mosquito populations by removing breeding sites from their domestic environments. Where there is a risk of transmission of arboviruses, people should also learn to protect themselves against mosquito bites and to seek treatment when the signs and symptoms of disease appear.

Recent studies from other regions indicate that community-based, integrated control of *Ae. aegypti* can reduce vector infestation levels and also have an impact on dengue transmission *(58–60)*. This suggests the need for governments to work in partnership with community-based programmes and nongovernmental organizations.

Surveys conducted prior to outbreaks are vital to identifying the need for attitude or behaviour change and to highlight social, cultural and economic barriers to participation in control efforts. These surveys should inquire into people's knowledge, attitudes and practices regarding mosquito breeding, vector control and vector-borne diseases.

Several tools have helped to create awareness in communities about vector-borne diseases and to encourage behaviour that reduces risk *(3)*. These tools include the mass media; information, education and communication (IEC) activities; and communication for behavioural impact (COMBI).

Mass media platforms can create awareness in the general public, but are unlikely to prompt major changes in people's behaviour. IEC activities address this gap by studying people's needs and perceptions and subsequently motivating attitude and behaviour changes *(61)*. COMBI is another education- and information-based approach aimed at identifying and then achieving one, or several, behavioural changes *(52)*.

This list of tools is not exhaustive, and novel tools or adapted methods for communication and education on invasive mosquitoes and (re-)emerging vector-borne diseases in the European context may be required.

Table 6 presents context-specific strategies for communication. It outlines three possible situations with respect to invasive mosquitoes and gives examples of objectives and methods for audiences at the senior and the community level.

Assignment

1. Prepare a concise rationale for raising invasive mosquitoes and/or (re-)emerging vector-borne diseases on the policy agenda in your country. Address:
   (a) the major (evidence-based) messages that could be advocated to politicians; and
   (b) the desired outcomes of the advocacy actions.
2. Considering the risks of invasive mosquitoes and vector-borne diseases in your country, what should communities do to reduce the risks of invasive mosquitoes or disease transmission?
3. Propose how best to mobilize communities around this issue.

Table 6. Context-specific strategies for communication

	Context/situation	Target audience	Objective of communication	Method of communication
1.	Prevention of introduction of invasive mosquitoes; elimination of foci of colonization	Politicians, policy-makers, researchers	- Political commitment - Policy reform - Research prioritization	- Messages - Case studies
		General public, affected communities	- Compliance with interventions	- Media
2.	Sustainable mosquito control	Politicians, policy-makers, researchers	- Political commitment - Resource allocation - Research prioritization	- Presentation of current results - Case studies
		General public, affected communities	- Compliance with interventions - Behaviour change	- Media - Communication and education strategies
3.	Response to disease outbreaks	Politicians, policy-makers, researchers	- Preparedness - Multisectoral coordination - Plan for outbreak investigation	- Presentation of case studies and scenarios - Multisectoral exercises
		General public, affected communities	- Compliance with interventions - Behaviour change	- Media - Communication and education strategies

Points for discussion

- Discuss the practical aspects of advocacy on invasive mosquitoes in your country context. Determine:
  - (a) who the target audience is;
  - (b) who plays an active role in advocacy;
  - (c) what the best methods of advocacy are; and
  - (d) what information or evidence is still needed to enable good advocacy.

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Annex 1. Recommended training agenda

DAY 1	09:00–10:00	Registration; opening; introduction of participants; training objectives
	10:00–10:30	Biology of invasive mosquitoes (Unit 1.1)
	10:30–10:50	*Coffee break*
	10:50–12:30	Biology of invasive mosquitoes (continued)
	12:30–13:30	*Lunch break*
	13:30–15:30	Identification of invasive mosquitoes (Unit 1.2)
	15:30–15:50	*Coffee break*
	15:50–17:30	Identification of invasive mosquitoes (continued); distribution and spread of invasive mosquitoes (Unit 1.3)
DAY 2	09:00–10:40	Surveillance of invasive mosquitoes (Unit 1.4)
	10:40–11:00	*Coffee break*
	11:00–11:30	Surveillance of invasive mosquitoes (continued)
	11:30–12:30	Prevention of introduction (or spread) of invasive mosquitoes (Unit 2.1)
	12:30–13:30	*Lunch break*
	13:30–17:30	Field/laboratory exercise on sampling techniques (Unit 1.5)
DAY 3	09:00–11:00	Collection of trap; examination of field collected specimens; discussion of sampling methods (Unit 1.5)
	11:00–11:20	*Coffee break*
	11:20–12:30	Mosquito control tools (Unit 2.2)
	12:30–13:30	*Lunch break*
	13:30–14:30	Mosquito control tools (continued)
	14:30–15:40	Elimination of foci of colonization (Unit 2.3)
	15:40–16:00	*Coffee break*
	16:00–17:30	Sustainable mosquito control (Unit 2.4)
DAY 4	09:00–11:00	Response to disease outbreaks (Unit 2.6)
	11:00–11:20	*Coffee break*
	11:20–13:00	Lifecycle management of pesticides (Unit 2.5)
	13:00–14:00	*Lunch break*
	14:00–15:30	Monitoring and management of insecticide resistance (Unit 1.6)
	15:30–15:50	*Coffee break*
	15:50–17:30	Policies and intersectoral collaboration (Unit 2.7)
DAY 5	09:00–10:40	Communication and community participation (Unit 2.8)
	10:40–11:00	*Coffee break*
	11:00–12:00	Regional networking (Unit 1.7)
	12:00–13:00	Evaluation and closing of the training
	13:00–14:00	*Lunch break*

Annex 2. Recommended handout materials

Surveillance and identification

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Control methods and strategies

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Handbook for integrated vector management. Geneva: World Health Organization; 2012 (http://whqlibdoc.who.int/publications/2012/9789241502801_eng.pdf, accessed 22 November 2016).

Policy

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Zika strategic response plan, revised for July 2016–December 2017. Geneva: World Health Organization; 2016 (http://apps.who.int/iris/bitstream/10665/246091/1/WHO-ZIKV-SRF-16.3-eng.pdf, accessed 22 November 2016).

The WHO Regional Office for Europe

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Training curriculum on invasive mosquitoes and (re-)emerging vector-borne diseases in the WHO European Region

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