Pacific Public Health Surveillance Network

Manual for Surveillance and Control of Aedes Vectors in the Pacific

Prepared by the Pacific Community
and the World Health Organization
Division of Pacific Technical Support

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Pacific Community
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Authors and contributors

Manual for surveillance and control of Aedes *vectors in the Pacific* was prepared by the Pacific Community (SPC) and the WHO Division of Pacific Technical Support (WHO-DPS) in consultation with country and territory representatives beginning in May 2019. The initial draft was produced by Tanya Russell (James Cook University, Australia) and technical input was provided by: Hervé Bossin (Institut Louis Malardé, French Polynesia), Nicolas Pocquet (Institut Pasteur, New Caledonia), Geoff Wilson (World Mosquito Program, Fiji), Angela Merianos (WHO-DPS, Fiji), Tessa Knox (WHO, Vanuatu), Matthew Shortus (WHO, Laos), Salanieta Saketa (SPC, Fiji), Jocelyn Cabarles and Onofre (Jojo) Merilles (SPC, New Caledonia).

Consultation, technical input and data was provided by the following country and territory representatives: Maru Enua Jerome Miro (Cook Islands), Tangata Vaeau (Cook Islands), Vakaruru Cavuilati (Fiji), Vineshwaran Rama (Fiji), Rosanna Yoon Rabago (Guam), Teanibuaka Tabunga (Kiribati), Vincent Scotty (Nauru), Florie Cheilan (New Caledonia), Sylvia Tmodrang (Palau), Melinda Susapu (Papua New Guinea), Paulo Penita Seuseu (Samoa), Cynthia Angela Joshua (Solomon Islands), Nathan Junior Kama (Solomon Islands), Charles Butafa (Solomon Islands), Lekon Tagavi (Vanuatu), Andy Manu (Niue), Sela Fa'u (Tonga), Moses Pretrick (Federated States of Micronesia), Aileen Benavente (Northern Mariana Islands).

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Abbreviations

AGO	Autocidal gravid ovitraps
BI	Breteau index
Bti	*Bacillus thuringiensis israelensis*
Bs	*Bacillus sphaericus*
CDC	Centers for Disease Control and Prevention
CHIKV	Chikungunya virus
CI	Container index
DEET	N,N-Diethyl-meta-toluamide
DT	Tablet for direct application
EC	Emulsifiable concentrate
EI	Emergence inhibition
EVS	Encephalitis Vector Survey
EWARS	Early Warning and Response System
GAT	Gravid *Aedes* traps
GR	Granule
GVCR	WHO *Global Vector Control Response 2017–2030*
HI	House index
HLC	Human landing catches
IEC	Information, education and communication
IHR	International Health Regulations
IGR	Insect growth regulators
IIT	Incompatible Insect Treatment
IRAC	Insecticide resistance action committee
IRM	Insecticide resistance management
T-IRS	Targeted indoor Residual Spraying for *Aedes*
ITNs	Insecticide-treated bed nets
LC	Lethal concentrations
LSM	Larval source management
MMF	Monomolecular film
MR	Matrix release
NGO	Non-government organisation
T-ORS	Targeted outdoor Residual Spraying for *Aedes*
PAHO	Pan-American Health Organization
PBO	Piperonyl butoxide
PCR	Polymerase chain reaction
PICTs	Pacific Island countries and territories
PoE	Points of Entry
PPE	Personal Protective Equipment
PPHSN	Pacific Public Health Surveillance Network
PQ	Prequalified
PRVBD	Pacific Regional Vector Borne Diseases (project)
QC	Quality control
RNA	Ribonucleic acid
RR	Resistance ratio
SC	Suspension concentrate
SIT	Sterile insect technique
SOCO	Single overarching communication outcome
SPC	the Pacific Community
ULV	Ultra-low volume
UV	Ultraviolet
VBDCP	Vector-borne disease control programme
VCAG	Vector Control Advisory Group
WG	Water-dispersible granules
WHO	World Health Organization
WP	Wettable powder
WPR	WHO Western Pacific Region

Glossary

Arbovirus	A group of viruses which are transmitted to humans by arthropods such as mosquitoes or ticks.
Area	Areas include locations or regions (provinces, islands, health zones, cities) defined in accordance with geographic relevance to vector surveillance and control operations, not necessarily based on administrative boundaries (WHO 2015b) (see Box 1).
Bionomics	Vector bionomics is the study of the ecology and behaviour of organisms in their natural habitat and their adaptation to their surroundings.
Contact location	Other premises where the infected individual had spent significant quantities of time within the past 14 days (e.g. schools or workplaces) (Vazquez-Prokopec et al. 2017a).
Importation risk	Risk or potential influx of arboviruses via infected individuals or infected *Aedes* species mosquitoes. *Note: "Infected individuals" includes residents infected while visiting endemic areas as well as infected immigrants.*
Infectivity	Ability of a given arbovirus to establish an infection in an *Aedes* mosquito and continue to replicate until the mosquito has virus in its salivary glands.
Insecticide resistance	Ability of mosquitoes to survive exposure to a standard dose of insecticide; this ability may be the result of physiological or behavioural adaptation.
Monitoring and evaluation	Monitoring is a process of gathering and using data on programme implementation with the aim of ensuring that programmes are proceeding satisfactorily, and making adjustments if necessary. The monitoring process often uses administrative data to track inputs, processes and outputs, although it can also consider programme outcomes and impacts. Evaluation is a more comprehensive assessment of a programme; it is normally undertaken at discrete points in time and is focused on the longer term outcomes and impacts of programmes. The overall goal of monitoring and evaluation is to improve programme effectiveness, efficiency and equity.
Surveillance	Systematic collection, analysis and interpretation of disease-specific data and use in planning, implementing and evaluating public health practice.

Source: Adapted from (WHO 2016c)

Summary

In recent times the Pacific has been experiencing unprecedented concurrent outbreaks of dengue, chikungunya and Zika virus infections that are spread by *Aedes* mosquito vectors. These have placed a heavy toll on many of the already fragile health systems and, if not contained, the epidemic waves will have local economic and social repercussions aside from direct effects on morbidity and mortality and pose risk for further spread to other countries and territories.

Zika virus infection which was considered a mild disease, was declared a Public Health Emergency of International Concern in early 2016 due to associated neurological complications causing congenital anomalies in infected pregnant women that was first documented in French Polynesia and later in other regions of the world.

Although epidemiological surveillance of these arboviral infections have improved in the Pacific region over the past decade this is not the case for vector surveillance and control. Vector control capacity in many Pacific Island countries and territories (PICTs) is limited and insufficient. Currently there are no ongoing entomological surveillance systems targeting *Aedes* vectors in many PICTs except for New Caledonia, French Polynesia and Fiji. The vector data for other PICTs is from outdated surveys or from recent ad hoc surveys.

The *Manual on Surveillance and Control of* Aedes *Vectors in the Pacific* was developed with the goal of strengthening vector surveillance and control capacities and capabilities in the region. The manual provides guidance for all PICTs to use in their efforts to prevent and control arboviral infections and should be contextualised for individual country and territory situations.

The manual is aligned to requirements of vector surveillance under the International Health Regulations (IHR 2005), Asia Pacific strategy for emerging diseases and public health emergencies (APSED III) and the Global Vector Control Response 2017–2030.

The intended target audience is for managers and operational staff responsible for planning, implementing and monitoring and evaluating national vector control programmes and also for collaborating and implementing partners. A multi-sectoral approach to vector surveillance and control is encouraged, as various sectors such as ports of entry and municipalities have very important roles to play.

SPC and the WHO Division of Pacific Technical Support together with other Pacific Public Health Surveillance Network (PPHSN) technical partners will ensure that the aim and objectives of the manual are achieved through a well-defined entomology capacity building programme that targets both operational staff and managers of vector control programmes and is adequately financed and resourced.

1 Introduction

1.1 Background

Mosquitoes can transmit pathogens like viruses and parasites that infect millions of people globally. Mosquitoes of the *Aedes* genus can transmit viruses that cause dengue, Zika and chikungunya disease. Such arthropod- or insect-borne viruses are termed "arboviruses". Outbreaks of arboviruses have increased in frequency, scale and impact in Pacific Island countries and territories (PICTs) (Roth et al. 2014), with almost all PICTs having now reported outbreaks of dengue. Between August 2014 and June 2019, the *Pacific Syndromic Surveillance System/EWARS* recorded 36,270 notifications of dengue-like illness[a] with 73 alerts (33% of total disease alerts). Furthermore, the geographic distribution of the *Aedes* mosquitoes is expanding with current global distribution for *Ae. aegypti* and *Ae. albopictus* the widest ever recorded (Kraemer et al. 2015).

Vector control interventions have one of the highest returns on investment in public health (WHO 2017a). Effective *Aedes* vector control programmes will reduce the frequency and severity of outbreaks of dengue, chikungunya and Zika. However, there are a number of constraints that limit the implementation of effective vector control. These include unplanned urbanisation; inadequate planning and programme management; limited human, financial and infrastructural capacity; and lack of political will. This *Manual* is intended as a reference guide for surveillance and control of *Aedes* vectors appropriate to the various contexts of PICTs. A list of additional manuals and guidance documents is provided in Annex 1 List of relevant guidance by topic area.

1.2 Aim and objectives

The overall aim of this *Manual* is to provide an easy-to-follow manual and information to guide PICTs to prevent and control *Aedes*-borne diseases. The emphasis is on informed planning and implementation of vector surveillance and control enabled by strengthened capacities and capabilities. The scope of the *Manual* is limited to *Aedes*-transmitted arboviruses of key importance to PICTs, namely dengue, Zika and chikungunya. However, the principles of vector surveillance and control apply for lymphatic filariasis where the vector(s) belong to the *Aedes* genus and inhabit similar habitats or exhibit similar behaviours to the *Aedes* species that transmit arboviruses.

The specific objectives of the *Manual* are:

- to guide planning and implementation of surveillance for *Aedes* arbovirus vectors;
- to guide technical decisions on the appropriate choice(s) and sustainable implementation of vector control options for the management of vectors to prevent, contain or respond to arbovirus transmission;
- to enable vector control programme activities to be supported by best practice quality control and monitoring, plus effective communication and community engagement.

1.3 Target audience

This *Manual* has been developed primarily for managers and operational staff responsible for planning, implementing, monitoring and evaluation of *Aedes* vector surveillance and control, as well as implementing, collaborating and community partners.

1.4 Vector surveillance and control in policy context

Strategic guidance to countries, territories and development partners to strengthen vector control is provided by the WHO Global Vector Control Response 2017–2030 (GVCR) and the WHO *Regional Action Plan for Dengue Prevention and Control in the Western Pacific (2016)*. These high-level strategies advocate for comprehensive vector control programmes, which are supported by increased technical capacity, improved infrastructure, strengthened monitoring and surveillance systems, and greater community mobilisation.

[a] Only 14 PICTs are currently using the dengue-like illness indicator; hence the relatively low number of notifications.

1.5 A comprehensive vector control programme

Each PICT should have a unit/department responsible for vector-borne disease control. The GVCR advocates for greater integration between programmes that may address different vector-borne diseases, and outlines the foundational elements and the pillars underpinning effective and locally adapted sustainable vector control systems.

Pillars:

- strengthen inter- and intra-sectoral action and collaboration;
- engage and mobilise communities;
- enhance vector surveillance, and monitoring and evaluation of interventions; and
- scale up and integrate tools and approaches.

Foundational elements:

- enhance vector control capacity and capability; and
- increase basic and applied research, and innovation.

1.6 International Health Regulations (2005) and global public health security

The International Health Regulations (2005) or "IHR (2005)" are an international law which helps countries work together to save lives and livelihoods affected by the international spread of diseases and other health risks (WHO 2005c). They entered into force on 15 June 2007 and are binding on 196 countries across the globe, including all WHO Member States (and all PICTs).

The IHR (2005) aim to prevent, protect against, control and respond to the international spread of disease while avoiding unnecessary interference with international traffic and trade. They establish a set of rules to support the global outbreak alert and response system and require countries to improve international surveillance and reporting mechanisms for public health events and to strengthen their national surveillance and response capacities. They support reductions in the risk of disease spread at international airports, ports and ground crossings, including those spread by vectors.

The IHR are supported by a handbook for *Vector Surveillance and Control at Ports, Airports, and Ground Crossings* (WHO 2016b). The handbook provides technical advice and standardised procedures for developing a comprehensive programme for systematic monitoring of disease vectors and integrated vector control at points of entry (PoE). The handbook also serves as a reference for port health officers, regulators, port operators, and other competent authorities in charge of implementing the IHR (2005). This *Manual* provides more specific guidance for PICTs to conduct vector surveillance in line with IHR (2005).

1.7 Healthy Islands

Healthy Islands is an ideal envisioned in 1995 that has served as a unifying theme to guide health development and health promotion in the Pacific (WHO 2005b). The vision of Healthy Islands is a reflection of the values driving development in the Pacific, and each country or territory should adapt policies and practices to its own specific situations. Central to the Healthy Islands concept is its sense of ownership and uniqueness to the Pacific.

Healthy Islands are places where:

- children are nurtured in body and mind;
- environments invite learning and leisure;
- people work and age with dignity;
- ecological balance is a source of pride; and
- the ocean which sustains us is protected.

1.8 Intra- and inter-sector collaboration

Reduction of disease burden through vector control is a shared responsibility of all members of society. This will maximise efficiencies, have greater impact than isolated, uncoordinated activities and harness diverse capital (WHO 2017a).

1.8.1 Within the health sector

The health sector has a main coordinating role in the prevention and control of arboviral diseases. Health sector units or agencies that have a role are: the vector-borne disease control programme at national and provincial levels, as well as its surveillance system which may be part of the general health information system; health centres and hospitals; public health laboratories; health promotion boards; and agencies responsible for early warning and risk assessment. In some countries or territories, the responsibilities and capacities of the vector-borne disease programme have been shifted from the national programme level to the provincial/local health system as this is an appropriate level at which dengue should be detected, managed and controlled.

Coordination between these bodies is of utmost importance in the fight against arboviral diseases. Importantly, hospital staff should be alerted of a possible outbreak to be prepared for diagnosis, case management and triage. Furthermore, active surveillance and rapid response will require coordination of expertise at the national and provincial/local levels.

1.8.2 Between sectors

A challenge for health authorities is how to actively engage other sectors as partners in the prevention and control of dengue (e.g. other ministries and authorities, development partners, and the private sector). An engagement strategy could be through inter-ministerial agreement, formal agreement between departments and agencies, and a multi-sectoral committee with a mandate and budget for dengue. The action response teams would have representation from several sectors, and be tasked with mobilising, organising and implementing the emergency response actions in close liaison with the dengue surveillance unit (WHO 2017a).

2 *Aedes* vectors and disease transmission in the Pacific

2.1 Mosquito life cycle

The life cycle of mosquitoes comprises four stages. The adult is the flying stage. The adult female mosquito takes a blood meal about every two or three days. The blood provides nutrients to develop a batch of eggs, which are usually laid before another blood meal is taken.

Aedes mosquitoes lay eggs on the inner side of water containers, just above the water line. Note that some species, including *Ae. aegypti*, often skip-oviposit. This means they lay eggs from a single batch in a variety of containers. *Aedes* eggs undergo embryonation and are resistant to drying so that they remain viable for many months. After the eggs become wet (usually during a rain event), the eggs hatch and the mosquito larvae come out (Figure 1). The young mosquitoes (called larvae) live in water and look like small wriggling worms. The small larva emerging from the egg is called the first instar; at regular intervals it sheds its skin and second, third and fourth instar larvae appear (each slightly larger in size). Finally, the fourth instar develops into a pupa which changes into an adult mosquito that can fly. The entire immature stage lasts about 8 to 10 days.

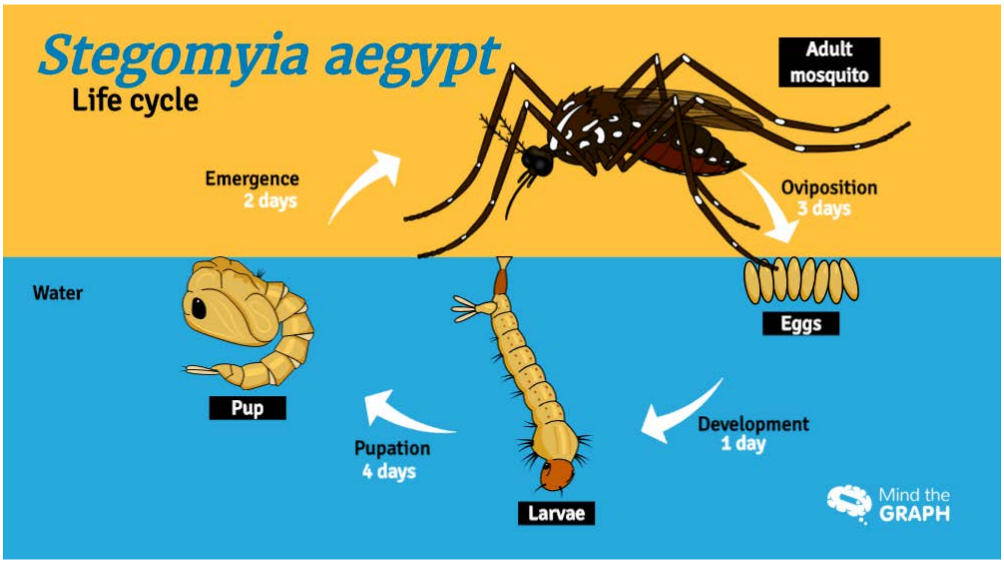


Figure 1: Life cycle of a mosquito.
Source: https://mindthegraph.com/profile/mindthegraph2/infographic-105214#/

2.2 Transmission of arboviruses

Dengue, chikungunya and Zika viruses are passed from human to human by the bite of an infective female mosquito. When the mosquito is taking a blood meal from a viraemic person, it ingests the virus. The mosquito does not immediately become infective (i.e. able to transmit the virus and infect other human hosts), because it takes around 7–14 days for the virus to replicate and disseminate throughout the mosquito body; this is called the "extrinsic incubation period". This is a very important factor which explains why only older mosquitoes (>7 days) contribute to virus transmission. Once infective, the mosquito remains so for the rest of its life, which is usually between 15 and 30 days. The vector transmits the virus to other humans when it emits saliva before and during blood feeding.

2.3 Mosquito behaviour and distribution

To mount an effective vector control programme, it is essential to know which mosquito species are being targeted (Table 1). This is because species may differ in habits and behaviours (Table 2), and vector control programmes need to be adjusted accordingly. *Aedes aegypti* is the most efficient species at spreading arboviruses. However, what makes the Pacific region unique, is that arbovirus transmission can also be maintained by *Aedes albopictus, Aedes polynesiensis* and *Aedes hensilli,* which is an important consideration when planning vector control strategies. There are additional *Aedes* species present in the region and, while not all are known vectors of arboviruses, some have regional importance (e.g. *Aedes rotumae*).

Table 1: Known distribution of *Aedes* vectors in the Pacific, as of 2019

Country or territory	*Ae. aegypti*	*Ae. albopictus*	*Ae. polynesiensis*	*Ae. hensilli*
American Samoa	Present		Present	
Australia, Queensland[1]	Present	Present		
Cook Islands	Present		Present	
Fiji	Present	Present	Present	
French Polynesia	Present		Present	
Guam		Present		
Kiribati	Present	Present		
Marshall Islands	Present	Present		
Micronesia (Shinichi 2014) [2]	Present	Present		Present
Nauru	Present			
New Caledonia	Present			
New Zealand				
Niue	Present		Present	
Northern Mariana Islands		Present		
Palau	Present	Present		Present
Papua New Guinea	Present	Present		
Pitcairn Islands	Present		Present	
Samoa	Present	Present	Present	
Solomon Islands	Present	Present		
Tokelau	Present		Present	
Tonga	Present	Present	Present	
Tuvalu	Present		Present	
Vanuatu	Present	Present	Present	

Sources: (Guillaumot et al. 2012, Kraemer et al. 2015). Information updated by Ministry of Health staff (refer to list of country or territory representatives in Authors and contributors section).

[1] In Queensland, *Ae. aegypti* are found as far south as Rockhampton, and *Ae. albopictus* are restricted to the Torres Strait Islands.

[2] In Micronesia, the vectors present in each state are Yap: *Ae. hensilli;* Chuuk: *Ae. albopictus* and *Ae. hensilli;* Pohnpei: *Ae. albopictus;* Kosrae: *Ae. aegypti* and *Ae. albopictus*.

Table 2: Bionomics of *Aedes* vectors common in the Pacific

Bionomic parameter	*Aedes aegypti*	*Aedes albopictus*	*Aedes polynesiensis*	*Aedes hensilli*
Larval habitats	Inhabits artificial containers (e.g. tanks and others for water storage, tyres, pot-plant bases, buckets, discards or those typically found around or inside homes) (Christophers 1960). Can utilise natural sites (e.g. bromeliads)	Inhabits a broad range, from natural sites (e.g. bamboo stumps, bromeliads, coconuts and tree holes) to artificial containers (Hawley 1988, Bonizzoni et al. 2013)	Cryptic natural and artificial containers such as tree holes, crab burrows, and coconuts (Bonnet and Chapman 1958)	Inhabits artificial containers (e.g. cans and buckets) and natural sites (e.g. coconut shells) (Shinichi 2013, Ledermann et al. 2014)
Peak feeding times	Feeds during daylight hours, usually more active in the early morning or late afternoon (crepuscular)	Feeds during daylight hours, usually more active in the early morning or late afternoon (crepuscular)	Feeds during daylight hours, usually more active in the early morning or late afternoon (crepuscular)	Feeds during daylight hours, usually more active in the early morning or late afternoon (crepuscular)
Preferred host species	Only feeds on humans	Will opportunistically feed on humans and other animals	Will opportunistically feed on humans and other animals	Feeds on humans and monkeys
Preferred feeding location	Tends to feed more commonly indoors	Tends to feed more commonly outdoors	Typically feeds outdoors (Russell et al. 2005)	Outdoors or indoors
Preferred resting sites	Rests indoors in dark shady areas below 1.5 m in height (Scott and Takken 2012)	Rests outdoors on vegetation and also indoors (Paupy et al. 2009)	Generally rests outdoors on vegetation	Outdoors on vegetation
Flight range	Limited flight dispersal – usually only 50–100 m (Liew and Curtis 2004, Harrington et al. 2005)	Average flight range is 50–200 m (Marini et al. 2010)	Limited flight dispersal, usually only 50–100 m (Hapairai et al. 2013)	

Source: *Aedes hensilli:* Grayson Brown, pers. comm.

3 Operational priorities for vector surveillance and control

The strength and rigour of *Aedes* vector surveillance and control programmes must be strengthened through PICs to incorporate both proactive and reactive approaches. Interventions should be evidence-based, targeted and guided by entomological and epidemiological data. Importantly, where insecticidal products are to be applied these should be WHO prequalified and their selection based on local *Aedes* vector insecticide susceptibility (WHO 2016a, Roiz et al. 2018).

Conducting routine vector surveillance and control activities is of utmost importance. Routine activities must be maintained even in the absence of arbovirus transmission. Data from routine vector surveillance is used to guide sustained proactive vector control and in the event of an outbreak can provide information used to mount the most effective response. However, routine surveillance data are generally not useful for predicting arboviral outbreaks (as local transmission risk in most PICs is strongly dependent on virus importation). Routine vector control activities ultimately aim to reduce vector densities and subsequently the risk of arbovirus outbreaks. This chapter categorises transmission scenarios, classifies the risk of arbovirus outbreaks, and links both to priority vector surveillance and control responses in the absence and presence of cases.

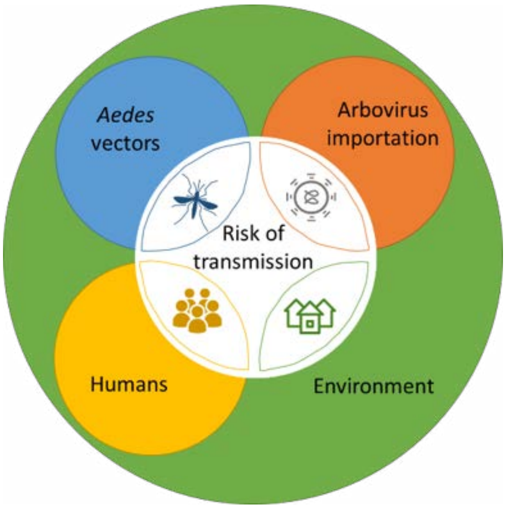


Figure 2: Transmission can occur when there is overlap of vectors, viruses and humans; environment directly affects each of these factors and therefore heavily influences transmission dynamics

3.1 Risk of arbovirus outbreaks

Arbovirus transmission occurs when arboviruses, a competent vector population, and a susceptible human population coexist in a receptive environment (Figure 2). Transmission risk varies geographically and over time. For instance, within a single country or territory there may be an area (i.e. suburb, city or island) with endemic ongoing transmission, another area with one or two cases, and an absence of transmission across the remainder of the country or territory. Transmission also varies over time, and can occur throughout the year in some areas or sporadically in other areas. This is highly dependent on the rate of importation of viruses. Some regions of the Pacific experience the majority of outbreaks during the warm and rainy season, which is generally from October to March in the northern Pacific and from November to April in the southern Pacific.

Each country or territory should assess the risk of outbreaks (Table 3). The scale of risk stratification can be at subnational level (provinces, islands, health zones, cities, suburbs within cities, villages) depending on the geographic or administrative divisions of relevance to vector control operations. Transmission risk is dynamic, necessitating frequent review to ensure risk classifications remain relevant and informative.

Table 3: Classification of the risk of arbovirus outbreak

Risk component [1]	General criteria for risk classification of subnational areas [2]		
	Low	Moderate	High
Vectors	No competent vector species present [3] but there is a risk of vector introduction and establishment	Occurrence of at least one competent vector species [3]	Occurrence of at least one competent vector species [3]
Humans	A mostly sero-positive immune population [4]	A sero-naïve population [4]	A large sero-naïve population [4] and high population density
Arboviruses	No circulating virus and minimal influx of travellers [5] from high or moderate risk areas	No circulating virus and minimal influx of travellers [5] from high-risk areas	Circulating virus or regular influx of travellers [5] from areas with ongoing transmission

Note: It is assumed that there are no areas of the Pacific that have no risk of arbovirus transmission.

[1] For a given area, different components may have different classifications. A pragmatic decision should be made, such as to base the overall classification on the average.

[2] Areas include locations or regions (islands, health zones, cities, villages, suburbs) defined with geographic relevance to vector control operations, not administrative boundaries (WHO 2015b).

[3] Includes *Ae. aegypti*, *Ae. albopictus*, *Ae. polynesiensis* and *Ae. hensilli*, or other locally important species.

[4] Refers to anticipated sero-prevalence of the human population to the virus or viral serotype(s) most likely to be introduced into the area due to circulation in surrounding areas/countries; determination is based on the timing and extent of historical transmission and the age distribution of the population to give a broad estimate of sero-naïve populations.

[5] Travellers include visitors and returnee residents who may travel for seasonal work or study.

Arbovirus outbreaks (for further detail see PPHSN Pacific Outbreak Manual)

An outbreak is an unexpected increase in the number of cases of an illness. It is when the number of actual cases is more than the number of expected cases in a specific population in a specific period of time.

Understanding the epidemic curve of a dengue outbreak is essential to mounting an effective response. Most importantly, vector control needs to be implemented as early as possible after detection of cases. If the emergency response is started late in the epidemic, especially after the peak of the epidemic, the benefit of the control effort in preventing cases will be minimised. Vector control targets the mosquito population, and the peak in mosquito densities occurs before the peak in human cases is observed. Although outbreak alert indicators do exist, the means to deploy them in early warning systems is often lacking. It is essential to improve monitoring and evaluation systems and to use operational tools such as the Early Warning and Response System (EWARS) for Dengue Outbreaks (WHO and The Special Programme for Research and Training in Tropical Diseases 2017)

3.2 Transmission scenarios

Five transmission scenarios have been defined to guide prioritisation of vector surveillance and control actions:

1. no confirmed (or suspected) arbovirus cases in area
2. non-endemic areas with an outbreak (≥1 case where there are usually no cases)
   a. isolated cases (usually 1 or 2) in the area
   b. multiple locally acquired cases throughout the area
3. endemic transmission: continuous transmission throughout the year, either as isolated cases or widespread throughout the area
   a. does not exceed the threshold for an outbreak
   b. exceeds the threshold for an outbreak.

The transmission scenarios define the number and distribution of suspected or confirmed cases, which inform the appropriate vector surveillance and control activities. For isolated cases (e.g. as for setting 2a), it is essential to determine if cases are imported or locally acquired. A case investigation needs to include a travel history and entomological assessment. Regarding the definitions of outbreak thresholds, these will need to be adjusted to suit the local conditions (WHO and The Pacific Community 2016).

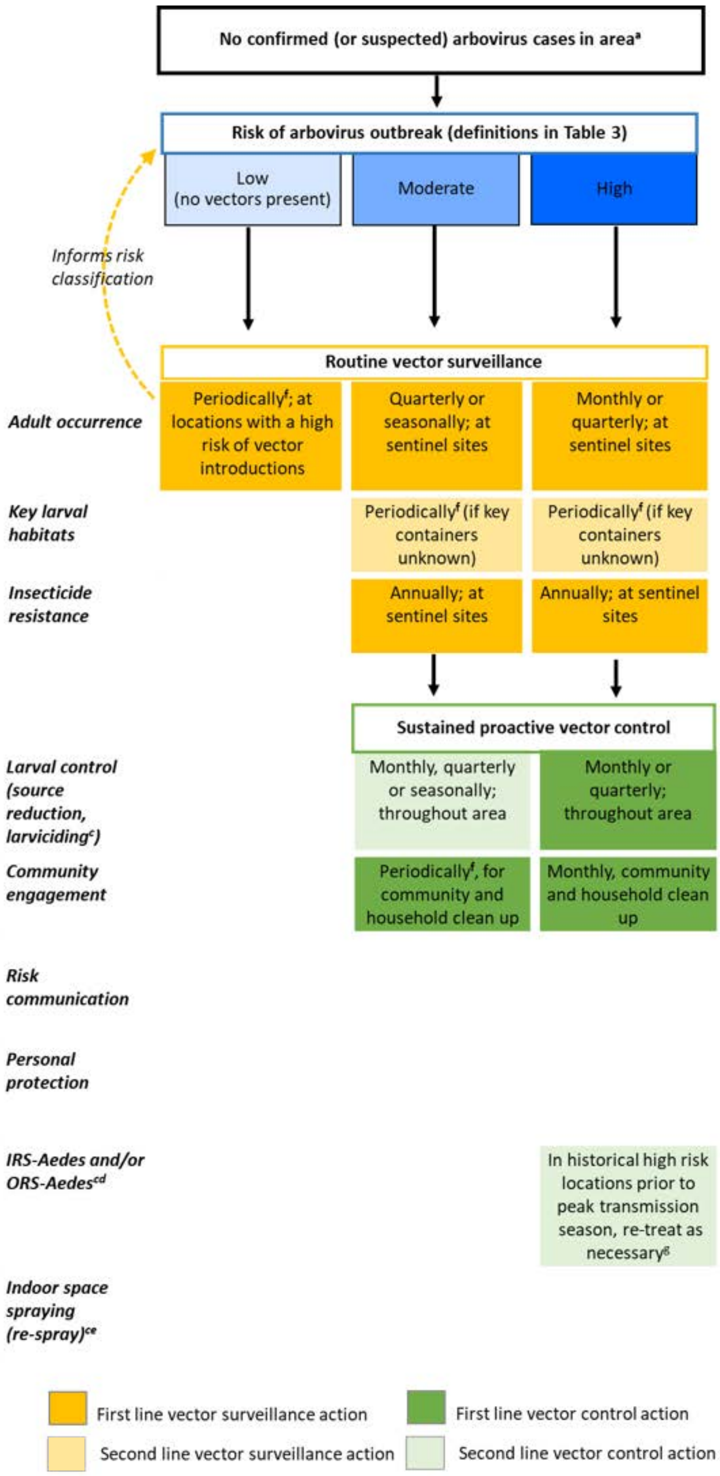
Box 1: Terminology used to define geographic places

Country	A geographical area encompassing a nation that is a distinct entity in political geography
Province	The largest subnational administrative division within a country
Area/zone	Areas include locations and regions (iskands, zones, cities, village, suburb) with relevance to vector control operations
Location/premises	The buildings and associated places that together form an entity, for example, hospitals, household, school, factory
Structures and outdoor places	The indoor and outdoor areas of each location, and have relevance to the deployment of vector control

The flowcharts below provide a simple example of how the risk of arbovirus outbreaks and transmission scenarios can be used to define vector surveillance and control activities. Other documents are available that provide more detailed guidance (e.g. PAHO Technical document for the implementation of interventions based on generic operational scenarios for *Aedes aegypti* control). However, the definitions of scenarios presented herein have been based on settings in the Pacific region, where arbovirus transmission is sporadic and is highly dependent on importation, with detection of a single case often used as the trigger for an outbreak response. In most PICTs, urban centres are generally small, human and mosquito population movement is limited due to islands, and therefore containment is more feasible than for larger urban centres of many dengue-prone areas of Asia and the Americas. Countries and territories are encouraged to adapt these flowcharts to their individual settings and scenarios, and to review them regularly (e.g. annually) and update as required.

3.3 Considering risk of an outbreak and transmission scenarios to guide action

An example of the ways in which the risk of an outbreak and transmission scenarios can prioritise vector surveillance and control is presented in the following figures. Figure 3 defines the actions in the absence of arbovirus cases. Detection of any single arbovirus case should trigger a switch to Figure 4 actions, though some routine actions will be maintained.



a The minimum size of an area is determined by availability of reliable disaggregated disease surveillance data and feasibility for decisions on vector control implementation. The area is not necessarily based on administrative boundaries

b Outbreak thresholds should be adjusted to suit the local conditions by each country or territory (WHO and The Pacific Community 2016)

c Use insecticide class to which there is no known resistance in local *Aedes* vectors, see Section 5.7.2

d Frequency of re-spraying will depend on the residual efficacy of the formulation and application type as well as other factors such as the surface type

e Indoor space spraying should be done at least once per week for a minimum of four weeks when there is an outbreak (Gunning et al. 2018)

f Generally means 2 or fewer times per year, depending on need

g If surveillance system is sensitive enough to identify clusters in a timely manner, can use as a response measure

h Distance from cases for focal activities will depend on the environment and vectors (e.g. 100–200 m radius)

i With suspected or confirmed *Aedes*-transmitted arbovirus infections

Figure 3: Flowchart showing the operational priorities for vector surveillance and control based on risk of arbovirus outbreak (as outlined in Table 3).

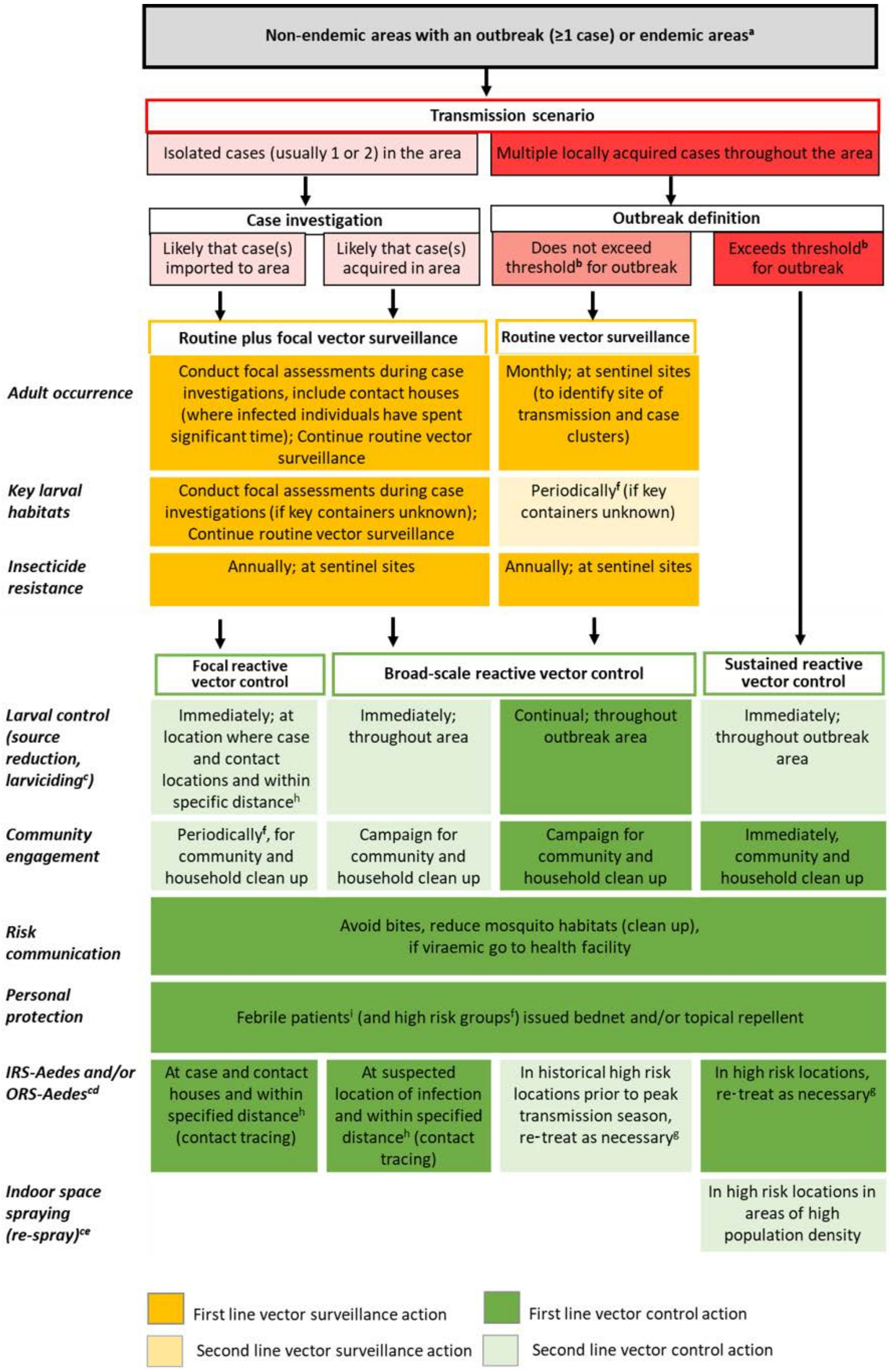


Figure 4: Flowchart showing operational priorities for vector surveillance and control actions based on transmission scenarios in which at least one arbovirus case been detected

Refer to footnotes for Figure 3

3.4 Priorities for vector surveillance

The purpose of routine vector surveillance is to inform programmatic decisions for effective vector control operations. **Routine surveillance activities should ideally be conducted before, during and after outbreaks. Additional entomological investigations will be required as part of case investigations during outbreaks.** However, in PICTs there are often limited staff available for routine activities, especially during outbreaks. This makes it even more important to define prioritised actions in non-outbreak and outbreak situations.

Key entomological indicators and the frequency of surveys will depend on the risk of arbovirus outbreaks (Table 4). Routine vector surveillance should be conducted at representative sentinel sites (see Section 4.3). The sampling effort, including the number of sampling sites and frequency of sampling, depends on the characteristics of the area being surveyed (i.e. larger cities compared with smaller villages), the risk of arbovirus outbreak and available capacity and funding.

Table 4: Vector surveillance by priority according to risk of arbovirus outbreak

(for indicator definitions see Table 10; for classifying risk of arbovirus outbreak see Table 3)

● High priority; ○ moderate priority; - low priority or not relevant

	Routine surveillance by risk classification			Case investigation	Points of Entry	Preferred traps
Indicator	Low	Moderate	High			
Adult vector composition and behaviour						
Adult occurrence	●	●	●	●	●	A, C, D, F
Density	-	-	○	-	-	A, C, E
Human biting rate	-	-	-	-	-	D
Biting time	-	-	-	-	-	D
Biting location	-	-	-	-	-	D
Resting location	-	-	○	-	-	C
Vector insecticide resistance						
Resistance frequency	-	●	●	-	○	G, H
Resistance intensity	-	-	○	-	-	G, H
Immature vector aquatic habitats						
Habitat availability	-	○	○	●	●	H
Key larval habitats	-	○	●	●	○	H
Pupal productivity	-	-	○	-	-	H
House index (HI)	-	-	-	-	-	H
Container index (CI)	-	-	-	-	-	H
Breteau index (BI)	-	-	-	-	-	H

Note:

- The following indicators were excluded due to the difficulty of accurate measurement: adult infection rates and resistance mechanisms.

- Trapping techniques: A. BG-sentinel traps; B. Gravid Aedes traps; C. Resting collections; D. Sweep net collections; E. CO2 baited light traps; F. Ovitraps; G. Immature sampling. For more detail see Section 4.3.

- Resistance frequency is the proportion of adult female vectors surviving exposure to insecticide, while resistance status is the classification of the vector population as confirmed resistant, possibly resistant or susceptible based on the results of the frequency testing.

3.4.1 Prioritising adult surveys over immature surveys

Aedes surveillance efforts have historically focused on assessments of larval and pupal stages due to difficulties with sampling adult *Aedes* that are generally present in low numbers. However, the density of adult *Aedes* mosquitoes is more closely linked to dengue incidence than larval or pupal indices (Scott and Morrison 2010, Bowman et al. 2014). As such, ***the focus of routine surveillance should be on adult Aedes vector surveys.***

That said, an understanding of key larval containers of the local *Aedes* vectors is useful to guide interventions that target aquatic mosquito stages, such as larval source reduction. Not all water containers are equal, and some will produce many more *Aedes* adults than others. Key containers are likely to vary between PICTs and within areas of a country or territory, due to the different settings and local *Aedes* vectors. Therefore, key containers should be periodically assessed to ensure there is a clear picture for each country or territory.

3.4.2 Routine vector surveillance

Routine vector surveillance involves collecting standardised information, for which the minimum level is detailed in Table 5.

Table 5: Suggested traps, sites and sampling frequency to monitor the highest priority vector surveillance indicators.

Indicator	Trap choices [a]	Sampling sites	Sampling frequency
High risk of arbovirus outbreak			
Adult occurrence	BG-Sentinel trap Resting collections Ovitraps Sweep net collections	Sentinel sites (select representative sampling sites throughout the area)	Monthly or quarterly
Resistance frequency	Ovitraps Larval and pupal surveys	Sentinel sites	At least once a year (outside outbreak times)
Key larval habitats	Larval and pupal surveys	Sentinel sites (systematic searches of each premises within the defined area)	At least once or twice a year
Moderate risk of arbovirus outbreak			
Adult occurrence	BG-Sentinel trap Resting collections Ovitraps Sweep net collections	Sentinel sites (select representative sampling sites throughout the area)	Quarterly or seasonally
Resistance frequency and status	Ovitraps Larval and pupal surveys	Sentinel sites	At least once a year (outside outbreak times)
Low risk of arbovirus outbreak			
Adult occurrence	BG-Sentinel trap Ovitraps Sweep net collections	Sentinel sites (select premises or geographic hotspots at a high risk of vector introduction, see Section 4.3)	Once or twice a year, can be seasonal. For presence or absence, less frequent sampling with a large number of replicates might suffice

[a] Programmes can be built on the use of one of these trap types for each indicator

Vector introductions in low risk areas: Routine vector surveillance in low risk areas aims to rapidly detect introduced *Aedes* vector species. When an incursion of an *Aedes* vector species is detected, spot checks should be initiated to determine the distribution of the species, as well as the aquatic habitats and insecticide resistance profile to inform the vector control response. Additionally, upon detection of an exotic species, the routine surveillance programme should be immediately revised to that appropriate for an area with a moderate or high risk of arbovirus outbreaks, and the decision should be made as to whether to mount an emergency response. When detecting presence or absence in low risk areas, less frequent sampling with a large number of replicates might suffice. Note that this recommended sampling frequency differs from when detecting the presence or absence in high-risk PoEs, where regular sampling is required.

3.4.3 Vector surveillance during outbreaks (case investigations)

Vector surveillance in an outbreak situation depends on the transmission scenario. Vector information can provide an indication of the risk of onwards transmission, although surveillance activities should not detract from core vector control activities to contain or prevent arbovirus transmission. The minimum level of vector surveillance to be collected during outbreaks is detailed in Table 6.

Table 6: Suggested traps, sites and sampling frequency for vector surveillance activities during case investigations.

Indicator	Trap choices [a]	Sampling sites	Sampling frequency
Case investigation			
Adult occurrence	BG-Sentinel trap Resting collections Sweep net collections	Initial case houses or contact location [b]	Immediately
Habitat availability	Larval and pupal surveys	Initial case houses or contact location [b]	Immediately
Key larval habitats	Larval and pupal surveys	initial case houses or contact location [b]	Immediately

[a] Programmes can be built on the use of one of these trap types for each indicator

[b] Contact location is defined as other premises where the infected individual has spent significant quantities of time within the previous 14 days (e.g. schools/workplace)

Vector surveillance during widespread outbreaks: During widespread outbreaks, routine vector surveillance may be de-prioritised in preference to vector control activities, especially where there are limited human, financial or other resources. Note that the vector control response in outbreak situations depends on an established routine vector surveillance system to inform decisions. This refers to the activities conducted as a part of a routine entomological vector surveillance programme, and not the monitoring and evaluation of the vector control activities.

For guidance regarding the epidemiological component of a case investigation, see the PPHSN Pacific Outbreak Manual.

3.5 Priorities for vector control based on transmission scenarios

3.5.1 Proactive vector control

Sustainable proactive vector control is conducted in areas when there is no confirmed (or suspected) arboviral cases, but there is a moderate or high risk of an arbovirus outbreak. Sustained reductions in vector densities will reduce both the occurrence (frequency) and severity (scale) of outbreaks. However, proactive vector control should not depend on heavy use of insecticides, as this will increase selection pressure for insecticide resistance.

Proactive vector control should be considered an opportunity to implement insecticide resistance management; as insecticides with different modes of action are available, further larval control through source reduction can minimise a heavy reliance on insecticide use.

Proactive vector control in the absence of transmission should include the following components.

- ***Regular source reduction*** (Section 5.1.1): Implementing year-round source reduction to reduce or eliminate larval habitats for vectors to prevent or minimise mosquito biting densities with strong community engagement. Source reduction activities must be tailored to the vector species present in the area, and use knowledge of their key larval habitats. In high-risk areas this is a first line action, while in moderate areas this is a second line action.

- ***Community engagement*** (Section 7): Disseminating contextualised, locally appropriate information and education materials about *Aedes* vectors and personal protection measures, as well as working in partnership with communities to reduce vector aquatic habitats. Community engagement is a first line action in both high and moderate risk areas.

- ***Pre-emptive Targeted-Indoor Residual Spraying (T-IRS)*** (Section 5.2): In areas with a high risk of an outbreak, and there is a clear seasonality to the outbreaks (usually dengue), pre-emptive T-IRS can be deployed to hotspots or other high-risk areas prior to the peak transmission season. Note that this is a second line vector control action for high-risk areas.

3.5.2 Reactive vector control

Vector control during outbreaks aims to ***rapidly reduce the density of adult mosquitoes before they complete the extrinsic incubation period (typically 8–12 days) and can transmit virus.*** If a single imported case is detected, a focal and rapid response is required to prevent further spread. If transmission is already widespread, then interventions should be carefully selected and prioritised for the areas with highest transmission (identified through epidemiological surveillance). Reactive control of *Aedes* vectors responds to information detected through passive surveillance of suspected or confirmed cases at health facilities. Response times need to be fast and within the extrinsic incubation period. Rapid response is limited by the fact that the majority of arboviral cases are asymptomatic and unreported, with delays between health facility detection and reporting to vector control authorities.

Reactive vector control should include the following activities (Figure 3):

- ***Targeted indoor residual spraying (T-IRS) or targeted outdoor residual spraying (T-ORS)*** (Sections 5.2 and 5.3): T-IRS and/or T-ORS is the first line priority when isolated cases (usually one or two) have been detected in an area. When responding to isolated cases, the residual spraying activities use information from the case investigation to focus T-IRS or T-ORS activities to the case and contact location or suspected place of infection, and within a specified distance (considering the flight range of the vector, e.g. 100–150 m radius). Where there are multiple locally acquired cases spread throughout the area, T-IRS or T-ORS is conducted at high-risk locations and repeated as necessary. It is important to understand if the local vectors prefer to rest indoors or outdoors to ensure that the residual sprays are targeted to where the majority of the vectors are resting. The generally preferred resting sites of the primary vectors are listed in Table 2.

- ***Personal protection*** (Section 5.4): In all scenarios, febrile patients should be issued with a long-lasting insecticidal mosquito net or topical repellent.

- ***Risk communication*** (Section 8): In situations where cases have been locally acquired, it is imperative to inform the community of the situation, ensuring that the context-appropriate messages inform actions to avoid mosquito bites, reduce mosquito habitats and go to the health clinic if febrile. Community stakeholders should be engaged in the development of these messages and the dissemination strategies to enhance their effectiveness.

- ***Source reduction*** (Section 5.1.1): In situations where multiple locally acquired cases are detected throughout the area, work with communities to organise area/community clean-up campaigns targeting key larval containers for disposal or destruction, including large junk objects that accumulate water (broken washing machines, refrigerators, toilets) in houses and public areas. Note that when a rapid vector control response is necessary, this is a second line activity.

- ***Larviciding*** (Section 5.1.2): For responsive vector control, VBDCP-led larval source management is the second line of defence. This involves identifying, treating, modifying, or removing mosquito-producing containers. Containers that cannot be emptied or modified should be treated with a long-lasting larvicide.

- ***Indoor space spraying*** (Section 5.5): When there are multiple locally acquired cases throughout the area, and the threshold for an outbreak has been exceeded, indoor space spraying can be used. The application needs to be repeated once a week for at least 4 weeks. This is only for situations where the vectors rest indoors (based on local routine surveillance data).

- ***Coordination:*** During an outbreak, larger geographic areas need to be protected, and implementation of adult and larval control measures must be coordinated. The VBDCP staff may conduct house visits in teams of up to 3–4 people with clearly defined roles and responsibilities.

3.6 Prioritising data for decision-making

Evidence-based decision-making at national and subnational levels requires ***entomological, epidemiological and intervention data.*** These data should be used to stratify transmission risk, to plan vector control, to guide vector and epidemiological surveillance, to respond rapidly to introduced cases or outbreaks, and to assess the impact of interventions (WHO 2017a). Routine vector surveillance activities are to be undertaken with the express purpose of informing programmatic decisions for appropriate proactive or reactive vector control (Table 7).

Other data from outside the health sector should also be used when informative, including data on weather, urban planning, housing, water, sanitation and agricultural insecticide use. Monitoring of human demographic and socio-economic changes is also imperative given the association of vector-borne diseases with societal factors such as disaster or climate-induced displacement, unplanned urbanisation and migration (WHO 2017a).

Linking data from different sources can be supported through a single, flexible data storage system to collate, validate, analyse and present aggregate statistical data. Timely data entry and sharing is critical, especially as the effectiveness of reactive vector control is dependent on early detection and data communication between health providers, vector control officers and the community. Hence, a close link between those responsible for dengue epidemiological surveillance and vector control is essential to share data on the number of new cases, the locations and population groups most affected, and the trends observed.

Table 7: Examples of the decisions that should be made using information from routine vector surveillance programmes

Core vector surveillance indicator	Decisions that can be made using the information	Examples
Adult occurrence	Assessing the risk of arbovirus transmission	Areas where at least one competent vector species occurs would be classified as having a high or moderate risk of transmission, after also considering information about the human, arbovirus and environmental factors
Adult occurrence	Local adaptation of vector control activities	Vector control activities should be tailored to the local *Aedes* vector species
Insecticide resistance profile	Insecticide choice	It is important to select insecticides to which local *Aedes* vector species are susceptible. This is relevant for larviciding, targeted residual spraying, space spraying and ITNs
Key larval habitats	Optimisation of larval control and community awareness and education messages	Effective source reduction of key larval habitats is entirely dependent on high levels of community participation; thus it is essential that communities are engaged and informed about key larval habitats
Resting habits	Whether to use T-IRS or T-ORS	The application of residual sprays should be targeted to the location/s where the local *Aedes* vectors tend to rest

3.7 Points of Entry

The priorities for vector surveillance and control at points of entry are presented in Figure 5.

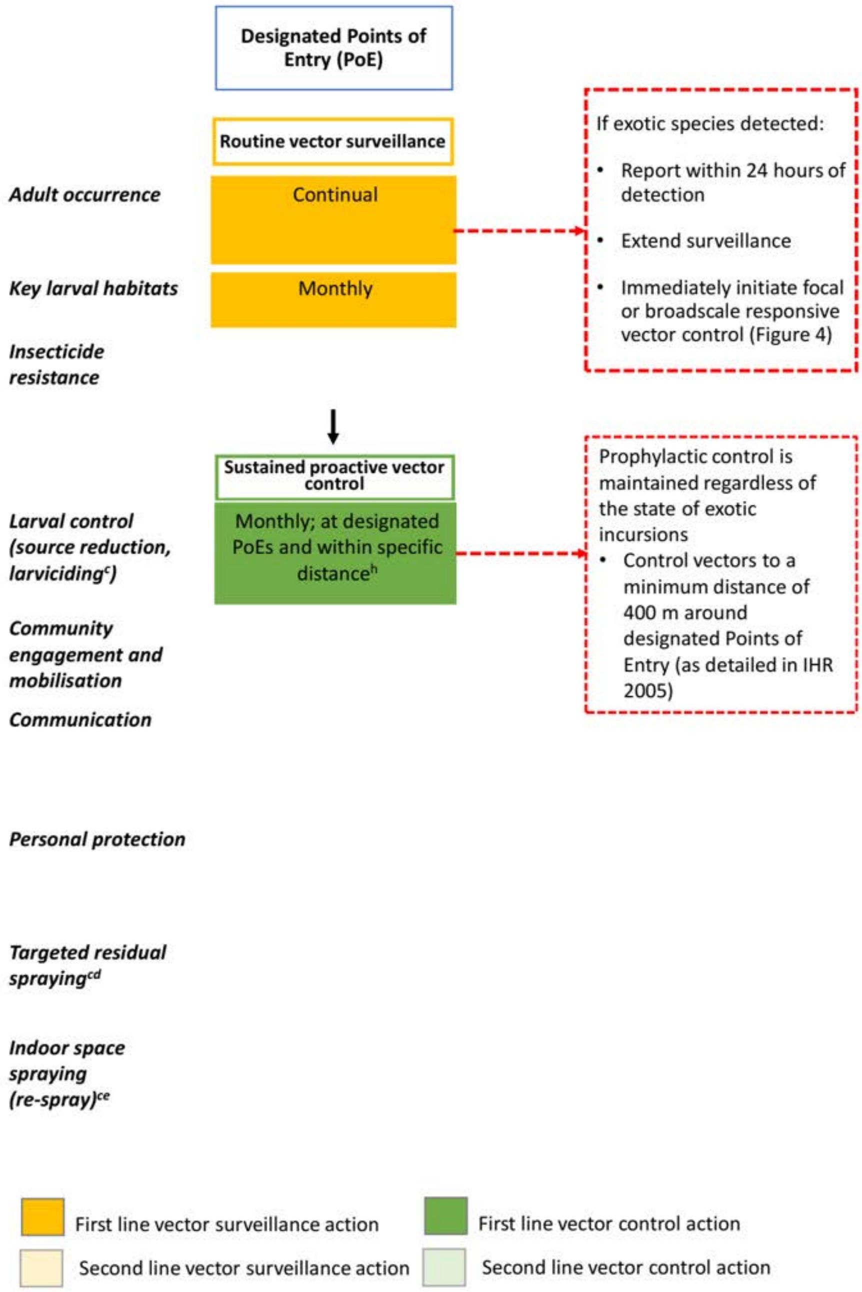


Figure 5: Vector surveillance and control at points of entry

[c] Use insecticide class to which there is no known resistance in local *Aedes* vectors

[d] Frequency of re-spraying will depend on the residual efficacy of the formulation and application type as well as other factors such as the surface type

[e] Re-spraying should usually be done at least once per week for a minimum of four weeks

[h] Distance from cases for focal activities will depend on the environment and vectors (e.g. 100–200 m radius)

3.7.1 Vector surveillance in points of entry

The primary purpose of vector surveillance at designated points of entry (PoE) is to monitor mosquito species presence to detect and respond to the introduction of exotic species. When an incursion of an *Aedes* vector species is detected, spot checks should be initiated to determine the distribution and spread of the species away from the PoE, as well as the aquatic habitats and insecticide resistance profile to inform an urgent vector control response. Any new *Aedes* incursions should be assumed to be pyrethroid resistant, as resistant populations are now present throughout the Pacific (Table 12). The minimum level of vector surveillance to be collected at PoEs is detailed in Table 8.

Table 8: Suggested traps, sites and sampling frequency for vector surveillance activities at points of entry

Indicator	Preferred traps	Sampling sites	Sampling frequency
Point of entry			
Adult occurrence	BG-Sentinel trap Ovitraps	Systematically at and around (400 m) each PoE	Continual
Habitat availability	Larval and pupal surveys	Systematically at and around (400 m) each PoE	Monthly
Key larval habitats	Larval and pupal surveys	Systematically at and around (400 m) each PoE	Monthly

3.7.2 Vector control at points of entry

Under the IHR obligations, designated PoEs are to be maintained free of insects, vermin and risk of transmission, and thus vector control activities aim to control *Aedes* vectors to a minimum distance of 400 m around each PoE. Vector control should be ongoing and prioritise larval source reduction and larviciding (see Section 5.1). These prophylactic vector control operations are ongoing, regardless of the status of exotic *Aedes* incursions. Further information is provided in the handbook for Vector surveillance and control at ports, airports, and ground crossings (WHO 2016) (WHO 2016b).

Inter-sector engagement: Vector surveillance and control at PoE should engage PoE agency partners to support the programme.

4 *Aedes* vector surveillance

Vector surveillance involves the regular and systematic collection, analysis and interpretation of entomological data for health risk assessment, and for planning, implementing, monitoring, and evaluating vector control (WHO 2018b). Importantly, surveillance data should be standardised, of high quality and used for decision-making.

4.1 Types of surveys

There are four types of entomological surveys: routine surveys, baseline surveys, spot checks and focus investigations (Table 9). Operational research provides more detailed evaluations of entomology and vector control and are usually conducted in collaboration with partner institutes, including national research or academic institutions; operational research is not discussed in this *Manual* (WHO 2018b).

Table 9: The description and purpose of different types of entomological surveys

Type of survey	When to use	Type of site	Description	Purpose
Routine survey	Continual	Sentinel	Regular long-term observations (usually monthly, quarterly or annually) in fixed locations	To identify changes in vector species occurrence, susceptibility to insecticides and key larval habitats, which will inform best practice vector control
Focus investigation	As part of a case investigation	Case and contact locations, and surrounding houses	Short-term reactive investigations in areas of new, persistent or resurgent arbovirus transmission	Investigations are conducted around identified cases or foci of transmission to inform reactive vector control operations
Baseline survey	When planning vector control activities	Sentinel or focus	Time-limited surveys used to gather baseline data	The baseline data is used for planning vector control measures and may also help identify appropriate sentinel sites for routine surveys
Spot check	To answer a specific question	Targeted site	Ad hoc assessments carried out in selected locations as a supplement to routine observations	Spot checks are designed to address specific problems, for example to assess the quality of implementation of an intervention or a potential increase in the risk of transmission

4.2 Entomological indices

Defining key entomological indices (Table 10) is essential for ensuring that vector surveillance data inform vector control decisions.

Table 10: Entomological surveillance indicators

Indicator	Outcome(s)	Calculation or explanation
Adult vector composition and behaviour		
Adult occurrence	Presence of *Aedes* vectors within an area	The presence of *Aedes* vectors recorded within a specified area and time frame
Density	Number of adult female vectors collected, per sampling method per area	The relative abundance of each species as a proportion of the total number of vectors collected, within a specified area and time
Human biting rate	Number of female vectors that attempt to feed per person	Number of female vectors collected that attempted to feed per total number of collection efforts (e.g. with sweep net collections)
Biting time	Number of female vectors that attempt to feed or are freshly blood-fed, per person per unit time	As for "human biting rate" but reported for individual time increments Numbers are compared by period to identify peak biting times

Indicator	Outcome(s)	Calculation or explanation
Biting location	Proportion of attempted bites or successful blood-feeds by adult and female vectors indoors and outdoors, per unit time	Simultaneous sampling indoors and outdoors to indicate endophagy and exophagy Endophagy index = number of *Aedes* vectors biting indoors/[number biting indoors + number biting outdoors]
Resting location (indoor resting density)	Proportion of adult female vectors collected resting indoors (and outdoors in structures sampled), usually per person per hour	Simultaneous resting collections indoors and outdoors for an indication of endophily and exophily Endophily index = number of *Aedes* vectors collected resting indoors (indoor resting density)/[number resting indoors + number resting outdoors]
Vector insecticide resistance		
Resistance frequency	Proportion of adult female vectors alive after exposure to insecticide (i.e. survival rate)	Susceptibility testing with a discriminating or diagnostic concentration The results of the frequency testing can be used to classify the vector population as confirmed resistant, possibly resistant or susceptible
Resistance intensity	Classification of adult female vector populations as having high, moderate or low resistance	Susceptibility testing with different intensity concentrations of insecticide The proportion of female vectors alive after exposure is calculated prior to classifying the level of resistance
Immature vector presence and density		
Habitat availability	Number of key larval habitats in an area	Count of potential larval containers by categories in a defined area
Key larval habitats	The types of containers that are disproportionally responsible for producing adult *Aedes*	Proportion of key larval habitats positive for *Aedes* larvae, expressed per area, per house or per container type
Pupal productivity	The number of pupae present in aquatic habitats by area and container category	The density of pupae produced from each category of habitat within a defined area (WHO 2011a) Identifying the most productive containers is used for targeting larval control measures (units are pupae per container type)
House index (HI)	Percentage of houses with at least one positive container	$HI = \left(\frac{\text{Infested houses}}{\text{Houses inspected}}\right) \times 100$
Container index (CI)	Percentage of all containers with water that are larvae positive	$CI = \left(\frac{\text{Containers positive}}{\text{Containers inspected}}\right) \times 100$
Breteau index (BI)	Number of positive containers per 100 houses	$BI = \left(\frac{\text{Containers positive}}{\text{Houses inspected}}\right) \times 100$

Based on Table 8 from (WHO 2018b)

4.3 Sentinel sites

Sentinel sampling involves regular (monthly or quarterly) trapping at ***fixed sites***, usually stratified across the area. The selection of surveillances sites is important, and selection of areas or properties that are more likely to yield useful data and are geographically isolated from each other is suggested. High-risk premises are those that have frequent contact with viraemic patients, provide large numbers of mosquito larval habitats or represent an opportunity for large numbers of people to be infected.

Potential high/medium risk premises are listed below:

- traditionally constructed households (lacking insect screens or with gardens providing large amounts of shade and potential containers)
- guest houses
- hospitals
- tyre dealers
- wrecking yards
- plant nurseries
- schools
- markets
- rubbish dumps.

Geographical hot spots for potential virus transmission are listed below:

- older or poorly maintained areas of town with a high density of traditional housing (especially with a history of high *Aedes* densities)
- areas that have previously supported dengue and arbovirus activity
- industrial areas (especially those with tyre yards and wreckers)
- areas with a high proportion of key larval containers.

4.4 Common mosquito sampling methods and analytical techniques

A range of different methods exists for sampling and analysing the different life stages (eggs, larvae, pupae, adults) of *Aedes* vectors. Each methodology has limitations, and integrating more than one technique is recommended, depending on the question.

Table 11: Sampling methods and analytical techniques for Aedes surveillance

Aedes sampling methods
Adult sampling
• BG-Sentinel traps • Gravid Aedes traps • Resting collections • Sweep net collections • CO_2 baited light traps
Egg sampling
• Ovitraps
Immature sampling
• Larval and pupal surveys
Vector analysis techniques
Species identification
• Morphological identification keys
Vector insecticide resistance
• Susceptibility assay with discriminating concentration (1×) of insecticide • Susceptibility assay with intensity concentrations (1×, 5×, 10×) of insecticide

4.4.1 BG-Sentinel trap

Overview

The BG-Sentinel trap uses attractive visual cues that can be combined with olfactory lures (e.g. CO_2, BG-Lure®) (Maciel-de-Freitas et al. 2006, Williams et al. 2006, Ball and Ritchie 2010) to increase collections. The trap is essentially a collapsible, container with a white lid and a black entrance funnel in the middle. Inside, there is a small electrical fan that sucks air through the trap and draws any approaching mosquitoes into a catch bag. The BG-Sentinel trap requires a large 12 V battery or mains power for operation.

Photo source: https://www.bg-sentinel.com/

Figure 6: The BG-Sentinel: Biogents mosquito trap for researchers.

Key features of the trap are listed below:

Target stages	**Entomological surveillance indicators**
• collects adults of both sexes and all physiological states.	• *Aedes* vector adult occurrence • adult vector density.
Advantages	**Disadvantages**
• collapsible and lightweight • effective at capturing *Aedes* adult mosquitoes • not labour intensive.	• needs a 12 V or DC energy source • expensive traps and batteries • samples degrade after a couple of days • indiscriminate, so catches many insects requiring separation in the laboratory.
Deployment • placed in a sheltered location away from direct sunlight, wind, and rain • can be placed indoors and outdoors • placed at ground level • data are the total no. of adults per sampling effort (by species and sex).	
Sample period • can be deployed for up to one week, depending on the specimen condition and power supply used – if a battery is used, the deployment time will be shorter as it uses ~10–11 Ah/day.	
Further information • manufacturer: Biogents • user manual: https://eu.biogents.com/wp-content/uploads/BG-Sentinel-2-Manual-EN-web.pdf • instructional videos: https://www.bg-sentinel.com/en/use.html	

4.4.2 Gravid Aedes traps

Overview

Gravid *Aedes* traps (GAT) and autocidal gravid ovitraps (AGO) use similar principles of attraction to ovitraps. They attract females seeking a site for egg laying, as they contain water infused with organic matter such as hay and are modified to capture the gravid (egg-carrying) females. These traps use either funnels (Eiras et al. 2014), sticky boards (Chadee and Ritchie 2010), adulticides (Mackay et al. 2013) or a thin film of oil (Heringer et al. 2016) to prevent captured mosquitoes from escaping.

Photo source: Kyran Staunton

Figure 7: Left: BioCare® autocidal gravid ovitrap (AGO); Right: Biogents gravid Aedes trap (BG-GAT).

Key features of the trap are listed below:

<table>
<tr><td>Target physiological states
gravid female Aedes.</td><td>Entomological surveillance indicators
Aedes vector species occurrence
adult vector density</td></tr>
<tr><td>Advantages
cheap and simple to operate
no electricity required
no CO_2 required
effective for collecting virus-positive mosquitoes (gravid females will have taken at least one blood meal).</td><td>Disadvantages
relatively low catch rates as only target gravid females
if a sticky surface is used, it can damage the samples
if left too long, fungus will begin to grow on mosquito samples
if the organic infusion is too rich, they will attract Culex and other flies.</td></tr>
<tr><td colspan="2">Deployment
the organic infusion in combination with the black colour attracts mosquitoes, so it needs to be positioned where it is readily visible, but protected from rain (i.e. not hidden in bushes)
placed at ground level
data are the total no. of females per sampling effort (by species).</td></tr>
<tr><td colspan="2">Sample period
deployed for 5–7 days.
no more than a week at a time to prevent eggs from trapped gravid females developing to adults.</td></tr>
<tr><td colspan="2">Further information
manufacturer: Biogents
user manual: https://eu.biogents.com/wp-content/uploads/BG-GAT-manual-web.pdf
instructional video: https://eu.biogents.com/bg-gat/#1510135224840-4f68d395-5d31
can be home-made.</td></tr>
</table>

4.4.3 Resting collections

Overview

Resting collections involve the systematic searching of potential resting sites, usually with the aid of a flashlight. Adult mosquitoes are captured using mouth- or battery-powered aspirators or handheld nets (WHO 2016f). Backpack aspirators powered by rechargeable 12-V batteries are an efficient means of collecting resting adult mosquitoes in and around human habitation. A recommended backpack aspirator is the "Prokopack", which is light and economical (Vazquez-Prokopec et al. 2009, Koyoc-Cardeña et al. 2019).

Photo source: Gonzalo Vazquez Prokopec

Figure 8: Battery powered backpack aspirator.

Key features of the aspirator are listed below:

<table>
<tr><td>Target stages
adults of both sexes and in all physiological states.</td><td>Entomological surveillance indicators
adult occurrence
adult vector density (calculation units are per house or per hour of effort)
resting location.</td></tr>
<tr><td>Advantages
provides information about adult resting habits, which informs effective targeted residual spraying
has been calibrated (Koyoc-Cardeña et al. 2019).</td><td>Disadvantages
labour intensive and requires trained personnel
variable efficacy as it is often difficult to locate resting mosquitoes
requires sampling of large numbers of houses in short periods of time (e.g. 100–200 houses per neighbourhood)
difficult to standardise (especially outdoors) due to the wide variety of resting sites.</td></tr>
<tr><td colspan="2">Deployment
depends on target species
Ae. aegypti typically rest indoors, especially in bedrooms and dark places such as clothes closets and other hidden sites, usually under 1.5 m in height
Ae. albopictus and Ae. polynesiensis often rest in vegetation and natural harbourage sites close to households
remember the local vector population may not primarily rest in the "typical" sites due to behavioural changes
artificial resting structures (e.g. wooden boxes, fibre pots and other containers) may be used to try to increase resting catches (Silver 2008)
data are the total no. of adults per sampling effort (by species and sex).</td></tr>
<tr><td colspan="2">Sample period
collection period in each house should be fixed (e.g. 10 minutes per house)
collections should preferably take place early in the morning.</td></tr>
<tr><td colspan="2">Further information
For more details, see (Silver 2008).</td></tr>
</table>

4.4.4 Sweep net collections

Overview

Human landing catches (HLC) consist of collectors sitting or standing and catching any mosquitoes that are attracted to them. For *Aedes* collections, the mosquitoes should be captured with a sweep net.

Photo source: Kyran Staunton

Figure 9: Conducting sweep net catches while wearing protective clothing and repellent. A white mat is placed on the ground to increase visibility.

Key features of sweep net collection are listed below:

Target physiological states	**Entomological surveillance indicators**
• host-seeking female mosquitoes • males will readily be caught.	• *Aedes* vector species occurrence • adult vector density • biting time • biting location.
Advantages	**Disadvantages**
• provides a direct estimate of the host-seeking mosquito population • is one of the only tools that can effectively estimate biting times and locations.	• labour intensive • risk of field staff becoming infected, especially in areas with ongoing arbovirus transmission; risk is reduced by using sweep nets to catch mosquitoes before they feed • results depend on the collectors' skills and on the attraction a person exerts on mosquitoes.
Deployment • sampling for day-biting mosquitoes should occur in shaded environments • collectors can wear protective clothing and repellent to minimise exposure to mosquito bites • data are the total no. of adults per sampling effort (by species and sex).	
Sample period • for standard comparisons, a fixed sampling duration is recommended (e.g. 15 minutes per hour) • sweep net catches should be conducted during times of peak mosquito activity. Alternatively, catches can be conducted across a standardised 12 h or 24 h period to assess when peak biting activity occurs.	
Further information • For more details see (WHO 2013c)	

4.4.6 CO_2 baited light traps

Overview

Light traps baited with CO_2 are used less frequently than other traps, for targeting *Aedes* species. They use CO_2 as the primary attractant (from dry ice or a gas tank). The suction fan runs using a battery or a power supply, and can be used with or without a light source.

Common CO_2 baited light traps include the Centers for Disease Control and Prevention (CDC)-trap and the Encephalitis Vector Survey (EVS) trap.

Photo source: Scott Ritchie

Figure 11: Left: CDC light trap. Right: EVS trap. In both images dry ice (a source of CO_2) has been placed into the black tin.

Key features of the CO_2 baited light trap are listed below:

Target stages • host-seeking female mosquitoes.	**Entomological surveillance indicators** • *Aedes* vector species occurrence • adult vector density.
Advantages • simple, light and portable.	**Disadvantages** • requires a source of CO_2 and battery • less efficient than BG-Sentinel traps • the fan can damage mosquito samples.
Deployment • sampling for day-biting mosquitoes should occur in shaded environments • traps should be placed with the entrance about 50 cm above ground level when targeting *Aedes* species • data are the total no. of females per sampling effort (by species).	
Sample period • 12 to 24 h when using dry ice • can extend for multiple weeks if using a CO_2 tank and regulator.	

4.4.7 Ovitraps

Overview

An ovitrap is a small black, cylindrical container holding water and a substrate (this is often a small piece of wood such as a tongue depressor) on which eggs can be laid. The ovitrap acts as an ideal egg-laying (oviposition) site for the female *Aedes* mosquito (Fay and Eliason 1966, Silver 2008).

Figure 12: Left: Ovitrap made from a black bucket with a white egg strip. Middle: Another type of egg strip made from a tongue depressor wrapped in brown paper towel. Right: an ovitrap in the field.

Photo source: Left: Kyran Staunton, Middle: Guam operational manual. Right: Scott Ritchie

Key features of the ovitrap are listed below:

<table>
<tr><td>Target stage
• eggs (laid by gravid females).</td><td>Entomological surveillance indicators
• Aedes vector species occurrence
• resistance frequency
• resistance status
• resistance intensity.</td></tr>
<tr><td>Advantages
• inexpensive and easily deployed
• can collect eggs to produce for insecticide resistance bioassays.</td><td>Disadvantages
• interpret data with caution because ovitraps compete with naturally occurring oviposition habitats, e.g. oviposition indices may be skewed after source reduction campaigns when gravid females find fewer suitable habitats and lay a larger proportion of eggs in the ovitraps, confounding the evaluation of control efforts (Focks and WHO TDR 2003)
• egg counting, hatching and species identification require laboratory space and trained staff.</td></tr>
<tr><td colspan="2">Deployment
• position ovitraps in favourable sites for Aedes mosquitoes, usually sites that are secluded, shaded, low to the ground, near vegetation and protected from rain and animal disturbance
• position indoors or outdoors
• wedge small ovitraps between structures, such as bricks, to prevent falling over
• do not place near spider webs or inside very thick vegetation
• enhanced by adding a hay infusion (Reiter et al. 1991)
• a small number of ovitraps is usually enough to determine vector presence
• data collected are the total no. of eggs per trap or the total no. of traps that are infested with eggs (Roiz et al. 2018).</td></tr>
<tr><td colspan="2">Sample period
• No more than a week at a time to prevent them from producing adults.</td></tr>
<tr><td colspan="2">Further information
• Can be home-made.</td></tr>
</table>

4.4.8 Larval and pupal surveys

Overview

Larval surveys can be used to assess the types of immature habitats in an area, while pupal surveys can assess the productivity of each container type. Knowing the key larval habitats is important for focusing larval source management efforts.

Photo source: Tanya Russell

Figure 13: Conducting a larval survey

Key features of the survey are listed below:

<table>
<tr><td>Target stages
• larvae (3rd–4th instars) and/or pupae.</td><td>Entomological surveillance indicators
• Aedes vector species occurrence
• resistance frequency
• resistance status
• resistance intensity
• habitat availability
• key larval habitats
• pupal productivity (WHO 2011a)
• house index (HI)
• container index (CI)
• Breteau index (BI).</td></tr>
<tr><td>Advantages
• economical
• a source for F1 material for insecticide resistance bioassays.</td><td>Disadvantages
• poor indicator of adult production (WHO 2016f)
• labour intensive
• need strong identification skills if more than one Aedes species present in an area
• cryptic habitats not surveyed so indices are underestimated.</td></tr>
<tr><td colspan="2">Deployment
• systematically search each premises
• immature surveys should favour areas near human habitation and high risk for Aedes-borne viruses, and any habitat of any size that holds water should be carefully inspected
• defining key containers requires quantifying the number of larvae in positive containers, and analysing by container type (WHO 2016f)
• rear immature specimens to adults in the laboratory for identification
• large containers e.g. 200 L drum or rainwater tank, use a dipper or net
• small containers: empty the entire contents into a tray and pick out the immature stages with a pipette
• discarded car tyres: use a small net or a 30 ml pipette
• tree holes and leaf axils: pipette out the contents with a 30 ml pipette – may need to add water to the holes to flush out larvae in the debris at the bottom
• crab holes: pump out with a pump with a long hose attached
• funnel traps: can be used in sites with poor access, such as wells (Kay et al. 1992)
• useful to georeference survey sites
• data are the total number of larvae and pupae per site or dipping effort. Larvae can be recorded by early or late instars. Alternatively, presence or absence at each site can be recorded.
• Note: Disturbed larvae dive to the bottom and may take some time before returning to the surface.</td></tr>
</table>

4.5 Mosquito identification

After mosquito specimens have been collected, they need to be identified to species using morphological keys. Operational staff should be trained to easily distinguish between male and female mosquitoes, as well as the different genera and species.

The vector *Ae. aegypti* is easily distinguished with simple magnification. The species *Ae. albopictus* and *Ae. polynesiensis* are also morphologically identifiable, but noting that they are both members of the *Ae. scutellaris* group, and need to be distinguished from any other *Ae. scutellaris* species. Older mosquitoes may have lost part of the scales, and are thus more difficult to identify.

Morphological keys for the common mosquitoes are detailed in Annex 2. Mosquito identification keys.

4.6 Insecticide resistance

Insecticide resistance is the ability of mosquitoes to survive exposure to a standard dose of insecticide; this ability may be the result of physiological changes including increased enzyme levels to break down insecticides (WHO 2016e). Large-scale and intensive use of insecticides in *Aedes* control increases the selection pressure on vector populations to develop insecticide resistance. Although resistant individuals will be rare initially, the repeated use of the insecticide will allow these mosquitoes to contribute more offspring to the next generation than individuals that lack the resistance trait. This results in the selection of resistance within the population.

The development of insecticide resistance in *Aedes* vectors is a potential threat to the sustained effectiveness of insecticidal vector control interventions. Resistance to all four classes of insecticide commonly used in vector control has been recorded for *Ae. aegypti* (Moyes et al. 2017). Resistance to the organophosphate temephos is reducing the effectiveness of larviciding interventions in several countries (Ranson et al. 2010). Resistance to pyrethroids has also become widespread in countries where these insecticides are used in space spraying operations (Moyes et al. 2017).

Insecticide resistance monitoring in field populations of *Aedes* is required to determine the levels, mechanisms and geographical distribution of resistance in order to select appropriate insecticides for vector control. Evidence-based decisions will ensure that effective insecticides are selected and used. Further information on resistance management is provided in Section 5.7.

The process and considerations for monitoring are outlined in the *Test procedures for insecticide resistance monitoring in malaria vector mosquitoes. Second edition (2016).* While this guidance was developed for *Anopheles*, the procedures are similar for *Aedes* vectors with some changes in insecticide concentrations or exposure times. The *Test procedures* include full details on the methods and considerations and are summarised in Annex 3 Overview of the process and outcomes for insecticide resistance monitoring for mosquitoes.

Table 12: Distribution of insecticide susceptibility of *Aedes* vectors in the Pacific since 2010

● Confirmed resistance for at least one site; ▲ Possible resistance for at least one site;
■ Susceptibility for all sites tested; ◆ Not tested since 2010; - species not recently detected

Species	*Ae. aegypti*			Ae. albopictus		
Insecticide class	Pyrethroids	Organophosphates	Carbamates	Pyrethroids	Organophosphates	Carbamates
American Samoa				-	-	-
Australia, Queensland (Endersby-Harshman et al. 2017)	■	◆	◆	◆	◆	◆
Cook Islands	◆	◆	◆	-	-	-
Fiji	●	●	◆	◆	◆	◆
French Polynesia	●	◆	◆	-	-	-
Guam	-	-	-	■	■	◆
Kiribati	●	■	◆	◆	◆	◆
Marshall Islands	■	◆	◆	■	■	◆
Micronesia (FSM)	■	◆	◆	■	■	◆
Nauru	◆	◆	◆	-	-	-
New Caledonia (Dusfour et al. 2015)	●	▲	◆	-	-	-
New Zealand	-	-	-	-	-	-
Niue	◆	◆	◆	-	-	-
Northern Mariana Islands	-	-	-	◆	◆	◆
Palau	▲	■	●	■	▲	●
Papua New Guinea (Demok et al. 2019)	●	■	●	■	■	■
Pitcairn Islands	◆	◆	◆	-	-	-
Samoa	●	■	◆	-	-	-
Solomon Islands	▲	◆	◆	▲	◆	◆
Tokelau	◆	◆	◆	-	-	-
Tonga						
Tuvalu				-	-	-
Vanuatu	●	▲	◆	●	◆	◆
Wallis and Futuna	■	◆	◆	-	-	-

Sources: Information shared by ministry of health staff of respective countries and territories (refer to list of country and territory representatives in the Authors and contributors section). Additional information shared by Matt Shortus (Samoa, Kiribati); Grayson Brown (Guam, Marshall Islands).

4.6.1 Mosquitoes for testing

Mosquito collections

For adult resistance bioassays, the following should be collected, in preferential order:

- ideal: adult female mosquitoes derived from field-collected larvae or eggs
- second option: F1 progeny of wild-caught adult female mosquitoes
- not recommended: wild-caught adult female mosquitoes (because the specimens are of unknown age, and this is important because age can influence test results).

For larval resistance bioassays, the following should be collected:

- ideal: larvae derived from field-collected eggs, or field-collected larval specimens.

Target sex and physiological state for bioassays

- adult females aged 3–5 days that are non-blood-fed and starved of sugar for 6 hours
- for larval bioassays, use 3rd or 4th instar larvae.

4.6.2 Types of phenotypic bioassays

WHO standard bioassay

The basic test, the standard WHO bioassay, uses a standard test kit with filter papers. Filter papers are treated with the "discriminating concentration", which is twice the lethal dose estimated to kill 100% of susceptible mosquitoes. The discriminating concentration has been determined experimentally for each insecticide (Table 13) (WHO 2016e).

In the standard WHO bioassay, exposure time is usually 1 hour. This is followed by a 24-h holding period. A control using filter paper with carrier oil only is required for comparison with the insecticide plus carrier oil filter papers. High mortality in the control treatment indicates that mosquitoes died from causes other than the insecticide. After the holding period, if less than 98% of the mosquitoes have died, this is an indication of resistance.

Supplies

All supplies for WHO insecticide susceptibility tests are manufactured, supplied and dispatched by the University Sains Malaysia (USM), Penang, Malaysia (http://www.inreskit.usm.my/). Standard kits are available for testing susceptibility of adult mosquitoes (to adulticides) and larval mosquitoes (to larvicides).

Table 13: Discriminating concentrations and exposure time of insecticides used for *Aedes* mosquitoes in phenotypic bioassays

Insecticide class	Insecticide	Discriminating concentrations	Exposure period (hours)
Pyrethroids	Cyfluthrin	0.15 % [a]	1
	Deltamethrin	0.05 % [a]	1
	Lambda-cyhalothrin	0.03 %	1
	Permethrin	0.25 %	1
	Etofenprox	0.50 % [a]	1
	Alpha-cypermethrin	0.03 % [a]	1
Organophosphate	Fenitrothion	1.00 %	1
	Malathion	0.80 %	1
	Pirimiphos-methyl	0.21 % [a]	1

[a] Tentative

CDC bottle bioassay

The CDC bottle bioassay is flexible in that various concentrations of an insecticide can be evaluated, including the insecticides in use in the study area. This bioassay measures the time it takes for an insecticide to kill the adult mosquito. The CDC bottle bioassay is increasingly being used. The advantages of bioassays are that they are relatively simple to use, and they provide quick results on mortality cause.

4.6.3 Resistance frequency and status

Overview

- Resistance frequency is the proportion of adult female vectors that are alive after exposure to a discriminating concentration of insecticide in standard bioassays.
- Resistance status is the classification of adult female vector populations confirmed as resistant, possibly resistant or susceptible (Table 14).

Table 14: Interpretation of the results of phenotypic bioassays to define resistance status

Mortality	Interpretation
98–100 %	Susceptible
90–97 %	Possible resistance
<90 %	Resistant

4.6.4 Resistance intensity using 5× and 10× intensity concentrations

Overview

- Resistance intensity is the classification of adult female vector populations as having high, moderate or low resistance (Table 15). Exposure at the higher concentrations will yield information on the intensity of resistance, which can be defined as the "strength" of a resistance phenotype.
- It is suggested that resistance at 5× and especially at 10× the discriminating concentration may indicate or predict operational control failure and highlight a particularly urgent need to develop an appropriate resistance management strategy (WHO 2016e).

Table 15: Interpretation of the results of resistance intensity bioassays

Mortality	Concentration	Interpretation
<98 %	10× discriminating dose	High intensity resistance
≥98% <98%	10× discriminating dose 5× discriminating dose	Moderate intensity resistance
≥98% ≥98% <98%	10× discriminating dose 5× discriminating dose 1× discriminating dose	Low intensity resistance

4.6.5 Bioassays for larvicides, including biological larvicides

Larval bioassays, where larvae (of known age or instar) are exposed for 24 h or 48 h to treated water, are used to assess resistance (WHO 2005a, 2016d). Two approaches can be used: determining dose–response values or tests against a discriminating concentration. In both cases, each treatment should be replicated four or more times, and compared with an equal number of controls that are set up simultaneously in dechlorinated tap water (with any organic solvents added).

Determining dose–response values

Larvae are exposed to a wide range of insecticide concentrations to test the activity range of the insecticide. After determining the mortality of larvae in this range of concentrations, a narrower range of concentrations is used to determine the LC50 and LC90 values. The same procedure is carried out with a susceptible strain that is kept in an insectary colony.

Lethal concentrations (LC) that result in 50%, 90% and 99.9% mortality (LC50, LC90, LC99.9 values) are calculated from a log dosage-probit mortality regression line using computer software programs. The resistance ratio (RR) is the ratio produced when the LC50 value of the field-collected strain is divided by the LC50 value of a susceptible strain. When RR is <5 the field population is considered susceptible, when RR is between 5 and 10 the mosquitoes are considered to have moderate resistance, and when RR is >10 the mosquitoes are highly resistant.

Tests against a discriminating concentration

Alternatively, a rapid assessment of the resistance status of a field population can be attained by assessing mortality against the discriminating dose. ***The discriminating concentration for temephos has been established as 0.012 mg/L.***

When necessary, the discriminating concentration can be calculated using the results of bioassays run against a susceptible strain. The discriminating concentration is calculated as twice the LC99.9 value of the susceptible strain that is kept in an insectary colony. When interpreting the results, the same classifications apply, as per discriminating concentration bioassays with adults. Mortality of 98–100% indicates susceptibility, 90–97% is possible resistance and <90% is confirmed resistance.

4.6.6 Bioassays with insect growth regulators (IGRs)

Insect growth regulators (IGRs) have a delayed action on treated larvae. Juvenile hormone analogues interfere with the transformation of late instar larvae to pupae and then to adult. Chitin synthesis inhibitors inhibit cuticle formation and affect all instars and immature stages of the mosquito.

In IGR tests, mortality is assessed every 2 or 3 days until adult emergence, or mortality in immature stages. An accurate initial count of larvae is essential because of the cannibalistic or scavenging behaviour of larvae during the long exposure period. Larvae should be provided with a small amount of food every 2 days. The effect of IGRs on mosquito larvae is expressed in terms of the percentage of larvae that do not develop into successfully emerging adults, termed adult emergence inhibition (IE%). The bioassays are conducted in the same manner as the dose–response bioassays for larvicides, as outlined above (section 4.6.5).

5 *Aedes* vector control interventions

Well implemented vector control programmes using proven tools and strategies are effective in reducing the transmission of *Aedes*-borne diseases (WHO 2017c).

The key vector control interventions for *Aedes* include:

- **larval control including source reduction and larviciding;**
- **Targeted indoor residual spraying (referred to as T-IRS** throughout this document to distinguish from IRS for other vectors); [Delete: and in line with terminology used by PAHO (Pan American Health Organization 2019)]
- **Targeted outdoor residual spraying** (referred to as T-ORS throughout this document);
- **personal protection measures;**
- **indoor space spraying.**

All decisions on vector control should be based on adequate knowledge about the historic and current disease situation, risks of transmission, and evidence for the effectiveness of vector control interventions.

Selection of insecticide product

When selecting an insecticide product, the following criteria should be considered:

- registration, procurement procedures and availability in the country or territory
- WHO recommendation and specification for the product
- quality of the insecticide product, based on data of quality control testing
- evidence on effectiveness and residual activity of the product in the field
- cost of the product and its application
- acceptability by the community and available data on safety to humans
- status of resistance of the vector to the insecticide, based on phenotypic bioassays
- potential impacts on the environment and non-target organisms
- special requirements regarding life-cycle management of the product (e.g. shelf life, disposal).

For WHO prequalified vector control products see: http://www.who.int/pq-vector-control/prequalified-lists/en/

5.1 Larval control including source reduction and larviciding

Source reduction should be the primary strategy used for larval control. The larvae of *Aedes* vectors utilise artificial and natural habitats in close proximity with human settlements, making it relatively practical to reduce vectors through community participation. Where larval habitats cannot be addressed through source reduction, it is appropriate to apply larvicides. The deployment of source reduction versus larviciding depends on the specific habitat/s being targeted and in practice these tools are complementary and to be used in an integrated manner (Table 10). The challenge is managing the nexus between source reduction and larviciding operations to ensure that habitats are not missed or treated by both programmes.

Table 16: Container categories and appropriate actions for *Aedes* larval control

Container category	Examples	Volume	Source reduction							Larvicide		Biological
			Remove and/or destroy	Move or invert	Fill in	Unblock	Empty periodically	Scrub periodically	Seal with lid or cover openings	Focal application	Perifocal application	Predatory fish or copepods
Large artificial receptacles	Tanks	>200 L							**X**	X		X
Medium artificial receptacles	Plastic and metal drums	50 - 200L					**X**	**X**	**X**	X		X
Small artificial receptacles	Plastic buckets, used paint containers	<100L	X	X								
Small discards	Glass and plastic bottles and jars, tin cans	<10L	X									
Rain gutters	Intact but blocked, damaged	variable	X[a]			X				X		
Septic tanks	Unsealed	variable			X	X			X	X		
Crab burrows		<5L									X	
Solid waste	Old boats, old cars	variable	X	X							X	
Tyres	New or used	<5L	X	X							X[b]	
Tarpaulines	Tarpaulins, plastic wrapping films	<5L	X	X								
Construction equipment	Concrete mixer, tipper, side walls	variable		X			X					
Puddles		variable			X						X	
Ornamental containers	Flower or cuttings vases, other ornaments	<1L					X	X				
Coconuts	Cut coconuts and husks	<1L	X	X							X[b]	
Treeholes		<1L			X						X	
Other cryptic sites		variable									X	

[a] If damaged
[b] If concentrated in piles
Adapted from WHO (2009)

5.1.1 Source reduction including physical modification

Overview

Source reduction is the removal, destruction, covering or emptying of water habitats to reduce the sources of mosquitoes (WHO 2009). Such actions should be the mainstay of any *Aedes* vector control programme. The key to success is a strong community outreach programme, with the goal of 70% to 80% participation. Education on the biology of the mosquito, its ecology, and environmental management measures is of utmost importance to engage communities and prevent vector proliferation (refer to Section 7 Community engagement).

Advantages

Source reduction is:

- economical and can provide sustainable reductions in mosquito densities.

Disadvantages

Source reduction has some disadvantages.

- Not all aquatic habitats can be modified or removed to minimise larval production.
- Efficacy is dependent on the operators and community understanding the key aquatic habitats that produce the majority of adult mosquitoes (i.e. "key containers").
- It is reliant on strong community participation.

Deployment (for further detail see (WHO 2016b))

Piped water supply: Where reliable piped water is provided there is generally a reduction in the storage of water in containers. This helps to reduce *Aedes* breeding and thus helps reduce the risk of arbovirus transmission.

Mosquito-proofing of essential water containers: Where water containers are needed for water storage, measures should be taken by communities to prevent vector breeding. This could be by tight mesh or sealed lids.

Clean and scrub: Water storage containers can also be regularly emptied and scrubbed to remove eggs sticking to the inner surface. Flower vases, ceremonial vases, potted plant saucers, bird baths and ant traps are also amenable to weekly cleaning and scrubbing to remove eggs of *Aedes* mosquitoes. Using bleach is an effective method to kill eggs.

Emptying and turning: Unused containers, such as buckets and boats, can easily accumulate rain water when not in use and should therefore be kept in a sheltered space or turned upside-down.

Filling and managing: Certain *natural* habitats can accumulate water for more than 7 days and provide ample organic material (e.g. decomposing leaves), enabling mosquito development. Examples are tree holes, plant axils and rock pools. Environmental management measures that can be taken in these habitats include filling tree holes with cement or sand, avoiding the presence of plants with plant axils, such as bromeliads, around people's houses, and filling rock pools with sand and stones.

Waste disposal: An increasing problem in many urban settings is the disposal of plastic and tin waste in people's yards, or along the streets, allowing breeding of *Aedes*, especially during the rainy season. A combination of raising community awareness and education, clean-up campaigns, and garbage collection services can reduce small containers, empty bottles, cans, plastic bags, etc. This can also enable market creation in recycling or reuse of plastic or rubber items.

Solid waste management: Solid or bulk waste (e.g. discarded refrigerators, disused boats) can provide larger volumes of standing water and produce substantial numbers of *Aedes* or other vectors throughout the rainy season. Used car tyres allow accumulation of water and provide a dark surface favoured for egg laying. Bulk waste should be collected and properly disposed of or recycled, with community participation by municipality services and civil society organisations. Used tyres should be stored in a sheltered area to avoid exposure to rain, or be recycled or shredded for landfill.

House design/maintenance: Maintenance and certain adaptations of houses and other structures can help prevent larval breeding or adult mosquito entry/residence. House screening and air conditioning reduces entry and presence of *Aedes* vectors indoors. Houses can be designed without the use of gutters to avoid stagnant water when gutters block, or good maintenance of gutters, drains and ant barriers can also avoid blockages. *Aedes* vectors can also breed inside underground structures and water collection containers, such as utility vaults, septic tanks and wells. These water bodies can be covered with sealed lids. In places that are not easy to reach, expanded polystyrene beads could be used to prevent larval development.

5.1.2 Larviciding

Overview

Larviciding is the regular application of chemical or biological agents to aquatic mosquito habitats. The use of larvicides is *supplementary* to source reduction, aiming to kill larvae in water bodies that cannot be drained, filled or otherwise modified. There is limited evidence for the effectiveness of larviciding, largely because larviciding has rarely been studied as an intervention on its own, with evidence primarily coming from studies where it is used in combination with source reduction or space spraying (Erlanger et al. 2008, Bowman et al. 2016).

Advantages

Larviciding has

- a wide range of active ingredients (potential for resistance management)
- minimal environmental impact.

Disadvantages

Larvicides have some disadvantages.

- Residual efficacy depends on formulation; some formulations have a relatively short period of effectiveness after application.

Larvicides

Table 17: The WHO prequalified compounds available for larviciding

Insecticide compounds	Insecticide class or mode of action	Formulation type	Dosage (mg/L)	ADI (mg/kg bw)	Use in drinking water[a]
Bacillus thuringiensis israelensis	Bacterial larvicide	WG, GR	1–5	–	Suitable
Bacillus thuringiensis israelensis + Bacillus sphaericus	Bacterial larvicide	GR		–	Formulation is not suitable
Spinosad	Spinosyns	DT, EC, GR, SC	0.1–0.5	0–0.2	Suitable
Diflubenzuron	Chitin synthesis inhibitor	DT, GR, WP	0.02–0.25	0–0.02	Suitable
Novaluron	Chitin synthesis inhibitor	EC	0.01– 0.05	0–0.01	Suitable
Pyriproxyfen	Juvenile hormone mimic	GR, MR	0.01	0–0.1	Suitable
Polydimethylsiloxane	Synthetic polymer	MMF		0–0.8	Formulation is not suitable
Pirimiphos-methyl	Organophosphate	EC	1	0–0.3	***Not recommended***
Temephos	Organophosphate	EC, GR	1	0.023	Suitable[b]

Source: See up-to-date listing on WHO prequalified website. Accessed: 7 Nov 2019

Abbreviations: DT = tablet for direct application; EC = emulsifiable concentrate; GR = granule; MMF = monomolecular film; MR = matrix release; SC = suspension concentrate; WG = water-dispersible granules; WP = wettable powder;

ADI = acceptable daily intake; bw = body weight

[a] When applied at the recommended dosage rate.

[b] Consider using alternative sources of water for small children and bottle-fed infants for a period after application. However, exceeding the acceptable daily intake will not necessarily result in adverse effects.

Bacterial insecticides. These insecticides are based on bacterial species that produce specific crystal proteins during sporulation. These proteins are toxic to mosquito larvae when ingested, and have no undue impacts on other groups of insects, fish, mammals or humans. The products include *Bacillus thuringiensis israelensis (Bti), Bacillus sphaericus (Bs)* and spinosad. Spinosad is a new biorational insecticide that consists of two neurotoxins extracted during fermentation of the bacterium *Saccharopolyspora spinose*. Spinosad is not as specific as *Bti*, but is non-toxic to vertebrates and has demonstrated a relatively long activity period when applied to vehicle tyres (Marina et al. 2012). Dosages can be adjusted to provide residual efficacy in small containers (Ritchie et al. 2010).

Insect growth regulators (IGRs). IGRs are a special group of insecticides that prevent mosquito larvae from developing into adults. There are two types of insect growth regulators: juvenile hormone mimics (which prevent the development of larvae or pupae into the next stage) and chitin synthesis inhibitors (which inhibit cuticle formation). The main disadvantage of the use of IGRs is their high purchase cost. Residual formulations such as pellets and briquets are available.

Monomolecular film (MMF). This unique liquid works by forming a very thin film of silicone on the water surface and disrupting the mosquito life cycle. The film has very low surface tension, which affects the mosquito life cycle in two ways: (i) it discourages female mosquitoes from laying eggs on the surface, and (ii) it prevents pupae from attaching to the surface and emerging into adulthood. Other attractive features are that it is non-toxic, will spread around vegetation and completely cover the surface, is resilient to strong winds and is resistant to ultraviolet degradation.

Organophosphates. Use of traditional chemical insecticides, such as temephos and pirimiphos-methyl, is less recommended in the peridomestic environments where container-breeding *Aedes* vectors occur. The acute toxicity and broad-spectrum effects of these chemicals can make them harmful to non-target organisms and toxic to humans. Furthermore, insecticide resistance to organophosphates is increasing. The lower costs of these products compared with bacterial insecticides or IGRs can be outweighed by the increased precautionary measures required and potential adverse effects (Takken and van den Berg 2019).

The following insecticide compounds are not recommended for larviciding:

- organochlorines, such as DDT, because they persist in the environment (WHO 2006),
- pyrethroids because they harm non-target arthropods and their use may select for pyrethroid resistance (WHO 2006).

Deployment

The optimal cycle of larviciding applications depends on the seasonality of *Aedes* vectors, the amount of rainfall, and the residual activity of the insecticide product (which, in turn, is linked to temperature and sunlight exposure) (Takken and van den Berg 2019).

Focal application: Focal control of *Aedes* vectors is usually limited to peridomestic containers that cannot be eliminated and is achieved by hand application, commonly with bacterial insecticide or IGR products. In these situations the granular formulations are highly practical, as they can be easily added to container habitats (Takken and van den Berg 2019). When using liquid formulations, only modest amounts of spray mix are needed during operations because of the small volume of the containers. For this reason, manual compression sprayers usually suffice. This spray equipment can easily be carried around by individuals or in small teams (Takken and van den Berg 2019).

Perifocal application: Perifocal treatment uses hand or power sprayers to apply residual insecticide to larval habitats and their peripheral areas (i.e. internal and external walls of containers). The insecticide acts as a larvicide in the water and as residual insecticide to kill ovipositing adult mosquitoes, thereby destroying existing and subsequent larval and adult mosquito infestations. Perifocal treatment has been used for non-potable containers where alternative control methods are impractical, and includes treating large piles of tyres or collections of discarded food and beverage containers. The internal and external walls of containers are sprayed until they are covered by a film of insecticide; spraying is also extended to cover any wall within 60 cm of the container. The insecticides used in perifocal treatment are organophosphates. Application techniques include the use of power backpack sprayers, truck-mounted mist-blowers or ultra-low volume (ULV) sprayers. It is important to note that the evidence base for this application method is weak, and this method has not been subjected to critical cost-effectiveness analysis.

5.2 Targeted indoor residual spraying for Aedes

Overview

Indoor residual spraying (T-IRS) is the application of residual insecticides to the resting sites of *Aedes* mosquitoes *inside* houses, primarily for *Ae. aegypti*. When the vector comes into contact with the sprayed surface, it absorbs a lethal dose of the insecticide, resulting in mortality, which contributes to reducing vector densities. During an outbreak, T-IRS is the best method to quickly reduce the density of infected mosquitoes in the area. For step-by-step guidance see the PAHO Manual for indoor residual spraying in urban areas for *Aedes* aegypti control.

Advantages

T-IRS has some advantages.

- It uses a smaller quantity of insecticide than for space spraying.
- Insecticide has a residual activity so less frequent re-application is required.
    - The residual activity of T-IRS when applied indoors is up to 4 months, with slight variations dependent on the formula selected.
- It has demonstrated entomological (Ritchie et al. 2002, Ritchie et al. 2004, Vazquez-Prokopec et al. 2017b) and epidemiological (Vazquez-Prokopec et al. 2010, Vazquez-Prokopec et al. 2017a) efficacy.

Disadvantages

The T-IRS method:

- requires skilled staff and specialised equipment.

Deployment

Which locations to spray within the area

To reduce the density of infected mosquitoes there needs to be high coverage of at-risk premises across the community. Generally, *Aedes* mosquitoes have a short flight range, and therefore, when clusters or households with infected patients are identified, it indicates that the infective adult mosquitoes are close by. Consequently, vector control activities can be targeted to those households and adjacent properties that are considered high risk (Vazquez-Prokopec et al. 2017a). These include premises visited by viraemic patients, usually residences, work places, houses of friends and neighbouring areas. Locations where viraemic persons congregate are also important, such as outpatient departments and clinics.

Note that in the special case for Zika, T-IRS can be focused on the homes of pregnant women who are at risk of passing congenitally transmitted infection to their newborns.

List of sprayable locations:

- *Houses*
- *Apartments*
- *Hospitals*
- *Outpatient departments*
- *Schools/child care facilities*
- *Garden huts*
- *Fishing huts*
- *Stores*
- *Churches*
- *Rest shelters*
- *Clinics*
- *Motel/hotels*

Where to spray inside the structure

Within each selected structure, the application of insecticide should be carefully targeted to the common resting sites of *Aedes* mosquitoes. The specific sites where *Ae. aegypti* rest indoors tend to be dark refuges below 1.5 m, such as under tables, furniture, beds, staircases; inside wardrobes, boxes and crates; on black objects such as suitcases and boxes; in narrow corridors and lower walls (Perich et al. 2000, Dzul-Manzanilla et al. 2017). *Ae. aegypti* are mostly found resting in bedrooms, followed by living rooms and bathrooms (Perich et al. 2000, Chadee 2013). When access into buildings is restricted by window screening, *Ae. aegypti* seek outdoors peridomestic man-made habitats such as under elevated houses, and in sheds, garages, laundry areas and on outdoor furniture where they rest in darker, well-shaded sites.

List of sprayable surfaces in and around structure:

- *Walls below 1.5 m*
- *Under furniture*
- *Inside of crates*
- *Under house*
- *Under tables and chairs*
- *Back side of cupboards*
- *Walls next to dark objects*
- *Indoor plants*
- *Under beds*
- *Inside wardrobes*
- *Dark furniture*

IMPORTANT NOTE: Avoid treating near pets, especially fish tanks. Do not spray children's toys, food, kitchens, clothing or bedding.

Insecticides

Table 18: The insecticide compounds for T-IRS are the same as for *Anopheles* IRS

Insecticide compounds	Insecticide class	Formulation type [a]	Dosage (g a.i./m^2) [b]
Alpha-cypermethrin	Pyrethroid	SC, WP, WG-SB	0.02–0.03
Bendiocarb	Carbamate	WP, WP-SB	0.1–0.4
Bifenthrin	Pyrethroid	WP	0.025–0.05
Clothianidin	Neonicotinoid	WG	0.3
Deltamethrin	Pyrethroid	SC-PE, WG, WG-SB	0.02–0.025
Etofenprox	Pyrethroid	WP	0.1–0.3
Lambda-cyhalothrin	Pyrethroid	CS, WP	0.02–0.03
Pirimiphos-methyl	Organophosphate	CS, EC	1–2

Source: See up-to-date listing on WHO prequalified website. Accessed: 7 Nov 2019

[a] Abbreviations for formulation type: CS = capsule suspension; EC = emulsifiable concentrate; SC = suspension concentrate; SC-PE = polymer enhanced suspension concentrate; WG = water-dispersible granules; WG-SB = water-dispersible granules in sealed water soluble bags; WP = wettable powder; WP-SB = wettable powder in sealed water soluble bags.

[b] g a.i./m^2 = grams active ingredient per square metre

Note: wettable powders (WP) and water-dispersible granules (WG) are best suited to very porous surfaces such as mud walls, while suspension concentrates (SC) or emulsifiable concentrates (EC) are more effective on finished cement, finished wood or timber, or painted surfaces, especially those where oil-based paints have been applied. It should be noted that on smooth non-absorbent surfaces (such as painted brick walls) it is essential to apply less insecticide (i.e. 30 ml/m^2 instead of 40 ml/m^2) (WHO 2015a).

5.3 Targeted outdoor residual spraying for (T-ORS)

Overview

Targeted outdoor residual spraying (T-ORS) is the application of residual insecticides to the resting sites of *Aedes* mosquitoes outside houses. The vectors *Ae. albopictus, Ae. polynesiensis* and *Ae. hensilli* express a preference to rest in vegetation in the peridomestic area close to houses (Table 2). For these vectors, it is useful to apply residual insecticides to peri-domestic vegetation; this practice is commonly referred to as "barrier sprays" or "harbourage spraying".

Advantages

T-ORS has certain advantages.

- A smaller quantity of insecticide is used than for space spraying.
- Insecticide has a residual activity, so less frequent re-application is required.
  - The residual activity of T-ORS when applied outdoors is usually about 6 weeks, with slight variations dependent on the formula selected.
  - Once the product dries it is generally rain resistant and UV exposure is minimised due to targeting of shaded areas.
- It has demonstrated entomological efficacy (Li et al. 2010, Muzari et al. 2014, Muzari et al. 2017, Stoops et al. 2019)

Disadvantages

The main disadvantage of T-ORS is

- it requires skilled staff and specialised equipment.

Deployment

Where to spray in the peridomestic area

The application of insecticide should be carefully targeted to the common resting sites of outdoor resting *Aedes* mosquitoes (including *Ae. albopictus, Ae. polynesiensis* and *Ae. hensilli*). This usually involves application of insecticide to well-shaded vegetation below 2 m height and leaf litter on the ground in locations identified as actual or potential resting sites for the target mosquito species. Treatments are confined to backyard bushes and approximately a 3–5 m swath of fringing vegetation adjacent to residential and commercial properties. Applications can be made with backpack mist-blowers or a high-pressure truck-mounted spray unit with a handheld lance.

A note about techniques and training: T-ORS is technically different to indoor residual spraying, and, as such, requires specific training and application equipment.

Insecticides

The same range of insecticides is available as for T-IRS, see Table 18 above.

5.4 Personal protection measures

Personal protection measures should be used to protect against day-biting mosquitoes. These include the use of appropriate repellents and wearing of light-coloured, loose-fitting clothing. This is especially important for viraemic patients to prevent the onwards transmission of arboviruses. Pregnant women should also be protected in situations of Zika outbreaks.

5.4.1 Insecticide-treated bed nets

Since transmission of dengue occurs mostly during the daytime, the use of insecticide-treated bed nets (ITNs) has rarely been considered as a control strategy. However, ITNs can be important to prevent the onwards transmission of arboviruses from viraemic patients.

Hospitals are high-risk locations for arbovirus transmission, because of the density of patients, many of them with weakened immune systems. Especially during dengue outbreaks when viraemic persons are admitted, there is an increased risk that *Aedes* vectors transmit the virus from a viraemic patient to another patient or visitor. Hence it will be important to place nets around arboviral disease patients during the daytime. This will protect the hospital patients who are not infected, and it will also prevent mosquitoes from taking an infected blood meal from those patients who still have the virus in their bloodstream.

In the domestic sphere, ITNs can help protect young children or the elderly when they are sleeping during the day. Moreover, having ITNs hanging in houses may contribute to reduction of *Aedes* vector populations (Lenhart et al. 2008), because *Aedes* mosquitoes often rest on fabric or similar materials.

5.4.2 Protective clothing and topical repellents

Long-sleeved clothing can have an important protective effect by reducing skin exposure to mosquito bites during the daytime and especially during outbreaks. The clothing can act as a physical barrier against mosquito bites.

Repellents that are generally available for household use include mosquito coils, aerosols, vaporiser mats, liquid vaporisers, ambient emanators and topical insect repellent. Most of these products have high consumer acceptance and will provide some degree of protection, although the duration of protection is usually rather limited. In endemic or outbreak situations, repellents alone should never be relied on as the sole method of preventing virus transmission, but should be combined with other vector control methods.

5.5 Indoor space spraying

Overview

Space spraying (or "fogging") is the dispersal of minute insecticide droplets into the air. The aim is to kill flying mosquitoes upon their direct contact with the droplets. It has no residual effect. Space spraying may have some efficacy inside buildings. Outdoor space spraying only temporarily suppresses vector populations and has limited efficacy (WHO 2009, Esu et al. 2010). Consequently, the widespread use of this method may not be supported or warranted.

Advantages

There is a benefit from indoor space spraying:

- community acceptance of a visual vector control response.

Disadvantages

Disadvantages of space spraying are listed below:

- uses a larger quantity of insecticide relative to targeted residual spraying
- requires specialised technical skills and regularly calibrated equipment
- no residual activity, so repeated applications are necessary
- no demonstrated efficacy (Esu et al. 2010, Bowman et al. 2016)
- not cost effective
- can potentially have adverse effects on human health and the environment.

Deployment

The direction and speed of wind, temperature, timing of treatment, spray concentration, flow rate and droplet size need to be considered (WHO 2003). Space sprays are mainly applied as thermal fogs or cold fogs. Thermal fogging produces an easily visible fog, but is expensive, disrupts communities and is a fire hazard. Cold fogging, or ultra-low volume (ULV) application, requires higher technical skills but is more efficient. Indoor space treatments can be made with handheld thermal foggers or backpack cold fogging units. Only insecticides for which there is not confirmed resistance should be used.

Insecticides

Table 19: The insecticide compounds available for space spraying

Insecticide compounds	Insecticide class	Formulation type [a]
Deltamethrin	Pyrethroid	EW
Esdepallethrine; Permethrin; Piperonyl butoxide	Pyrethroid; pyrethroid; PBO	EW
Lambda-cyhalothrin	Pyrethroid	EC
Malathion	Organophosphate	EW, ULV
Prallethrin; Imidacloprid	Pyrethroid; Neonicotinoid	ULV
trans-Cyphenothrin	Pyrethroid	EC

Source: See up-to-date listing on WHO prequalified website. Accessed: 7 Nov 2019

[a] Abbreviations: EC = emulsifiable concentrate; EW = oil-in-water emulsion; ULV = ultra-low volume.

5.6 New technologies

Novel methods of *Aedes* vector control are under development. While several tools have demonstrated entomological efficacy, any strong epidemiological impact on *Aedes*-borne arboviral diseases is yet to be proven in clinical trials. For the tools listed below, the WHO Vector Control Advisory Group (VCAG) has recommended further pilot trials with entomological and epidemiological outcomes to build support for operational use, including trials across different settings and randomised control trials. Studies should include evaluation of their sustainability, feasibility, cost-effectiveness and community acceptability as well as long-term management (WHO 2016a). Until there has been confirmation of their public health value, widespread use of these interventions is not recommended.

Community engagement is a critical enabling component of these novel technologies. This is particularly true where large or repeated releases of mosquitoes are required, as occurs with the transmission-blocking approach, and where increases in bites from female mosquitoes could be expected. Community engagement can help to allay fears that releases will increase the risk of arboviral diseases; rather, releases can reduce risk over time.

5.6.1 Transinfection with Wolbachia

In the transmission-blocking method, *Wolbachia* is used to render mosquito populations less competent at transmitting arboviruses such as dengue, Zika and chikungunya (Moreira et al. 2009, Aliota et al. 2016a, Aliota et al. 2016b). The strain being used in field trials is the *wMel* strain of *Wolbachia pipientis*, which has been established in *Ae. aegypti* with minimal fitness costs (McMeniman et al. 2008). Mathematical modelling predicts this *wMel* strain could eliminate dengue transmission in most settings (Ferguson et al. 2015). Both females and males are released, and when they mate with the wild mosquitoes, *Wolbachia* is passed to the next generation through mother-to-egg transmission (WHO 2016a, Ritchie 2018). Releases occur weekly for several months, until *Wolbachia*'s positive-drive mechanism is independently able to self-sustain and propel upwards the *Wolbachia* frequency in the mosquito population. After *Wolbachia* is established in the local mosquito population, there is no need for further releases. To date this technique has been very successful, with no locally acquired dengue occurring amongst the 312,000 people living in *Wolbachia* release areas in northern Australia (Ritchie 2018, O'Neill et al. 2019). This method is currently being piloted by the World Mosquito Program in 12 countries across Asia, Central and South America and the Pacific region (Ross et al. 2019).

5.6.2 Incompatible insect treatment (IIT)

In the population suppression method, *Wolbachia* infection effectively creates an incompatible strain of male mosquitoes (Marris 2017). Multiple strains of *Wolbachia pipientis* have been used, including *w*AlbB in *Ae. aegypti* and *Ae. polynesiensis*, and *w*Pip in *Ae. albopictus* (Ross et al. 2019). Only infected male mosquitoes are released, and any mated wild female mosquitoes produce eggs that do not develop, an effect known as cytoplasmic incompatibility. This approach relies on repeated releases of sufficient numbers of male mosquitoes, with more releases needed where the number of wild mosquitoes is higher. In principle, the reduction in the number of biting female mosquitoes should decrease arboviral transmission. This method has been piloted by Verily Life Sciences with *Ae. aegypti* populations in California, Singapore and Australia, and by Institut Louis Malardé with *Ae. polynesiensis* in French Polynesia (O'Connor et al. 2012).

5.6.3 Sterile insect technique (SIT)

This technique involves the mass production, sex-separation and sterilisation of male mosquitoes. Mosquitoes are sterilised by exposing them to low doses of radiation. Sterile males released into the wild mate with wild female mosquitoes of the same species, resulting in the production of unviable eggs, leading to a decline in wild mosquito populations (Lees et al. 2015).

5.6.4 Genetically modified (GM) mosquitoes

The use of genetically modified (GM) mosquitoes has been pioneered by Oxitec, with the aim of suppressing the local populations and reducing the likelihood of disease transmission. OX5034 is a transgenic strain of *Ae. aegypti* engineered to carry a sex-specific, late-acting lethal genetic system (Bell 1989). Female larvae carrying the OX5034 gene are expected to die before emerging as adults. The OX5034 males are expected to survive and produce offspring. Note that sustained release of transgenic male mosquitoes is needed to maintain suppression of wild *Ae. aegypti* populations. Initial trials used the OX513A strain (Harris et al. 2012, Alphey 2014).

5.6.5 Combined IIT-SIT releases

The IIT technology has been combined with the SIT for *Ae. aegypti* and *Ae. albopictus* for population suppression. The technique involves triple-infecting laboratory mosquitoes with *Wolbachia* strains (*Ae. albopictus* is naturally infected with *w*AlbA and *w*AlbB; the triple infection incorporates *w*Pip) and irradiating the pupae to sterilise females (Zheng et al. 2019). Here, male mosquitoes are released. If females are accidentally released during the

IIT-SIT programmes they can establish new wild strains of *Ae. aegypti* that would not experience cytoplasmic incompatibility from mating with released males infected with the same strain of *Wolbachia*. For this reason, the release batches are irradiated to ensure that if any females were released, they would also be sterile. Pilot releases have been made in China (Zheng et al. 2019), Thailand (Kittayapong et al. 2018, Kittayapong et al. 2019) and Singapore.

5.6.6 Vector traps for disease management

Several traps for *Aedes* surveillance and control have been trialled, such as "lethal ovitraps" (Johnson et al. 2018, WHO 2018a). Vector trap technology may reduce mosquito populations by attracting and killing egg-laying female mosquitoes, and also has potential for improved vector surveillance (Rapley et al. 2009, Barrera et al. 2016, Johnson et al. 2017). The autocidal gravid ovitrap (AGO) has been shown to significantly reduce *Ae. aegypti* populations and CHIKV transmission (Sharp et al. 2019).

5.6.7 Attract-and-kill baits/attractive toxic sugar bait (ATSB)

ATSB is a an "attract-and-kill" strategy, where a highly attractive sugar lure is integrated into bait stations with an oral toxicant. Sugar-feeding female and male mosquitoes are attracted to the station and killed after they ingest the toxicant, usually garlic (Junnila et al. 2015, Sissoko et al. 2019).

5.6.8 Auto-dissemination augmented by males (ADAM)

This technique deploys male *Ae. aegypti* or *Ae. albopictus* that have been mass reared, dusted with pyriproxyfen (an insect growth regulator) and then released. The males either directly contaminate larval habitats or indirectly contaminate them via mating with females that then visit such sites. The contamination subsequently results in population suppression via inhibited adult emergence. This methodology has been piloted in North and Central America (Devine et al. 2009, Davis et al. 2015, Mains et al. 2015, Brelsfoard et al. 2019).

5.7 Insecticide resistance management

For vector control to be effective, the female *Aedes* mosquitoes must be susceptible to the insecticide selected. Pyrethroids are the most commonly used insecticide, and resistance of both *Ae. aegypti* and *Ae. albopictus* has been observed at numerous locations across the globe (Moyes et al. 2017). Interactive datasets detailing the insecticide resistance status of *Aedes* vectors are available at http://Aedes.irmapper.com/

Only insecticides to which there is no resistance should be used. If resistance is observed, another insecticide to which resistance is unlikely should be selected. Insecticide resistance management (IRM) is most effective when undertaken as a pre-emptive measure before resistance appears. For *Aedes* control, different tools are available for adult and larval control and should be considered for IRM, including chemical insecticides with unrelated classes/modes of action such as insect growth regulators (IGRs) or biologically derived toxins (e.g. *Bti*, spinosad) for larval control.

5.7.1 Available strategies

Options to prevent or limit the development of insecticide resistance are listed below (WHO 2012a):

- **Insecticide rotation:** To preclude the emergence of resistance, insecticides of unrelated classes with different *modes of action* should be sprayed in rotation, ideally in a six-monthly cycle. This is good practice and should be implemented wherever possible, even before resistance has been reported.

- **Combining interventions:** As adult and larval control must be done simultaneously to have an impact on vector populations, insecticides with different modes of action should be used for each stage (e.g. using an organophosphate as an adulticide, combined with a *Bti* or *Bti+Bs*, or IGR as larvicide).

- **Mosaics:** One compound is used in one geographic area, and a compound of different insecticide class and mode of action (i.e. organophosphate and pyrethroid) used in neighbouring areas. This strategy, while theoretically robust, is logistically difficult to implement – especially in an epidemic setting where rapid response is key to contain a disease outbreak.

A resistance management programme can either be based on a planned or triggered rotation scheme. In a planned rotation scheme, the programme manager will decide at the beginning of the programme to rotate insecticidal modes of action at set intervals. In a triggered scheme, one class of insecticides is only replaced with another after a trigger has been met. It is not uncommon for a vector control programme to consider changing the insecticidal intervention on the basis of epidemiological data, the number of outbreaks of dengue having increased, or simply because there are many reports that the mosquitoes are no longer controlled. While both these measures suggest that the intervention is losing effectiveness, other factors may also have led to this outcome, and they cannot replace insecticide susceptibility monitoring assays (IRAC 2011).

Both planned and triggered rotation schemes require that susceptibility monitoring be undertaken, in the case of planned rotation, to identify which class of insecticide to change to. In the case of triggered rotation, it is to identify whether a change is required, and if so, to which class of insecticides (IRAC 2011).

5.7.2 Insecticide choice

Resistance management requires application of multiple insecticides of *different biochemical modes of action* (see Table 20). It is possible for cross-resistance to occur between different classes of insecticides, and knowledge of the resistance mechanism can help elucidate this. Collaborative work with academic or research institutes will help the control programmes to generate this useful information with synergist assays, biochemical and molecular tests.

Guidance is provided by the *Insecticide Resistance Action Committee (IRAC)* https://www.irac-online.org/modes-of-action/

Table 20: The Insecticide Resistance Action Committee (IRAC) mode of action classifications for insecticides prequalified for mosquito control

Physiological functions affected	Mode of action	Classes of insecticide	Form of vector control
Nerve and muscle	Acetylcholinesterase (ache) inhibitors	Carbamates Organophosphates	Larvicide T-IRS Space spray
	Sodium channel modulators	Pyrethroids DDT	T-IRS Space spray
	Nicotinic acetylcholine receptor (nachr) competitive modulators	Neonicotinoids	T-IRS Space spray
	Nicotinic acetylcholine receptor (nachr) allosteric modulators	Spinosyns	Larvicide
Growth	Juvenile hormone mimics	Methoprene [a] Pyriproxyfen	Larvicide
	Inhibitors of chitin biosynthesis, Type 0	Benzoylureas	Larvicide
Midgut	Microbial disruptors of insect midgut membranes	*Bacillus thuringiensis* and produced insecticidal proteins *Bacillus sphaericus*	Larvicide

[a] Although methoprene has not currently been prequalified by WHO, it is included here as this product is commonly used for larval control.

It is important to remember that compounds within the same chemical class (e.g. pyrethroids) will all have the same mode of action. Rotating from one pyrethroid insecticide to another pyrethroid simply exposes the population to a single mode of action, and has no value in resistance management. Similarly, choosing compounds within the same chemical class for different vector control activities (e.g. conducting both larviciding and T-IRS with an organophosphate) will have no value in resistance management either.

Community acceptance: It is important to acknowledge that community acceptance is another driver for insecticide selection. Community acceptance may further limit the options for insecticide resistance management.

5.7.3 What to do if insecticide resistance is found

The course of action to be taken when insecticide resistance is found will depend upon the circumstances. Where appropriate, modifications can be made to the resistance management strategy in place, and may include further restrictions on frequency of use, rotation with insecticides with different modes of action, or restriction of product use, with the aim of encouraging susceptibility to return. This may allow for reintroduction of the product in the future (IRAC 2011). In general, the following actions should be considered.

- **Use a different class of insecticide.**
- Use insecticides judiciously.
- If not already in place, develop a resistance management strategy.
- If resistance is detected, confirm the data with subsequent tests and rule out misapplication or other causes of treatment failure.
- Assess the extent of the problem area.
- Notify WHO and regional authorities.

5.7.4 The role of synergists

Synergists are compounds that enhance the toxicity of some insecticides, although they usually have limited toxicity themselves. At non-toxic concentrations, insecticide synergists act by inhibiting certain enzymes naturally present in insects that would otherwise break down and detoxify insecticide molecules (IRAC 2011). Synergists, including piperonyl butoxide (PBO), enhance the effect of several classes of insecticide, including the pyrethroids, organophosphates and carbamates. This is achieved by inhibiting the enzymes that metabolise insecticides, P450s and esterases, within the insect. In susceptible insects, these metabolic enzyme systems are at a baseline level, whereas in resistant insects they are at an elevated level. Thus in susceptible insects, insecticides are already working at near maximum effect and the use of synergists may provide minimal enhancement. However, in certain types of resistant insects, synergists can significantly enhance insecticide performance due to the inhibition of the resistant insect's enhanced metabolic enzyme systems.

For *Aedes* control, piperonyl butoxide (PBO) has been combined with pyrethroids in products prequalified for space spraying (Table 19).

5.8 Proper pesticides management

Insecticide (pesticide) management is the regulatory control, proper handling, supply, transport, storage, application and disposal of insecticide products to minimise adverse environmental effects and human exposure. Additional guidelines and best practices are available through the WHO and FAO (WHO 2019b) as well as from manufacturers of the particular insecticide.

Important considerations are listed below.

- *WHO Prequalification* – All insecticidal vector control products should be WHO prequalified.

- *National insecticide registration* – National regulatory authorities, ministries of public health, and environmental authorities may require assessments in procedures (in addition to the WHO prequalification; for example US-affiliated countries and territories need to comply with the US EPA guidelines.)

- *Environmental risk* – Environmental risks include contamination that could adversely affect humans, domestic animals, wildlife and the environment. This can be mitigated through the safe use and appropriate disposal of insecticides.

- *Packaging of insecticides* – It is recommended that insecticides are procured that are pre-packaged to facilitate easier transportation, handling and efficient filling of the sprayers.

- *Storage* – Insecticides must be kept in a safe storeroom with a current inventory and stock control number and audit system. The storeroom must be free from moisture and heat and be well ventilated. Insecticides must be kept in the original packaging and only transferred into the sprayers as needed. Plan the delivery and distribution of pesticides and use the "first-in-first-out" principle to avoid expiry of stocks.

- *Spray workers* – Conduct regular refresher training for spray workers and supervisors.

- *Application* – The dosage of active ingredient or formulated product should be calculated in accordance with the indications on the label, applied to the specific setting or habitat.

5.8.1 Proper disposal of chemical wastes

Empty or almost empty containers of insecticide and larvicide products must be collected and properly disposed of (FAO and WHO 2008). The disposal of expired or discarded pesticides, empty pesticide containers, and other public health pesticide waste, should be conducted in compliance with international standards. Pesticide containers are considered toxic waste and should be disposed of at approved waste disposal sites, not buried in landfills, nor at general waste collection sites, and not burned (as this releases toxic fumes).

Countries or territories may not have high temperature incineration facilities for hazardous waste. If this is the case, obsolete pesticide products and waste may have to be shipped to other countries that are willing and able to incinerate it. The costs of repackaging, shipment and incineration are high and administrative procedures are complicated and time-consuming. Aid agencies may be prepared to assist countries or territories with one-time interventions to dispose of old stocks.

5.8.2 Equipment used for spraying

A weekly or, at minimum, monthly inventory of equipment should be conducted during spraying. The final inventory at the end of the spray round should indicate any necessary repairs, replacements or other requirements. Developing and implementing routine daily and weekly cleaning, together with monthly maintenance schedules during spraying, will maximise the life expectancy and performance of sprayers.

After use, equipment should be triple-rinsed. Reuse the contaminated wash water as diluents for subsequent spray applications. *Do not* dispose of contaminated waste water via the main drainage system or in the environment.

5.8.3 Personal protective equipment

Insecticides are inherently hazardous; however, when handled and applied according to label recommendations, WHO prequalified insecticides carry a low risk and will provide the desired results. When properly applied, the insecticides should pose no danger to spray workers, householders, domestic and wild animals or the environment. Steps to mitigate accidental contamination and spills should be implemented prior to commencing spray operations (WHO 2015a). Importantly, all spray workers must wear personal protective equipment (PPE) clothing when handling insecticides and during all spraying operations. In addition to PPE, staff should wear identification cards.

6 Monitoring, evaluation and quality assurance of vector control

The combination of monitoring and evaluation allows us to understand the cause-and-effect relationship between implementation and impact. Information is used to guide planning and implementation, to assess effectiveness, to identify areas for improvement, and to account for resources used. Quality assurance is used to assess the quality of products and services.

Monitoring is routine observing, gathering and use of data and reporting on programme implementation (weekly, monthly, quarterly or annually); its aim is to ensure that programmes are working satisfactorily and to make adjustments if necessary.

Evaluation involves a more comprehensive assessment of a programme; it is generally undertaken at discrete times and addresses the longer term outcomes and impacts of programmes. Evaluations are usually conducted by an external review team.

Quality assurance is the implementation of systematic and well-planned activities to prevent substandard services or products.

6.1 Monitoring and evaluation

The primary purpose of collecting data is to inform planning, decision-making and action at the local level. Monitoring, evaluation and review are essential functions to ensure that priority actions are implemented as planned against stated objectives and desired results.

The core indicators and targets for vector surveillance and control should link to the broad health sector targets. Indicators need to be comparable to baseline data and need to be SMART: specific, measurable, achievable, realistic, and time-bound. There are five main types of indicators: inputs, processes, outputs, outcomes and impact. Targets should be set for each indicator. Targets refer to the goal or objective that the programme plans to achieve by a certain date. Figure 14 provides a simple example for vector surveillance and control.

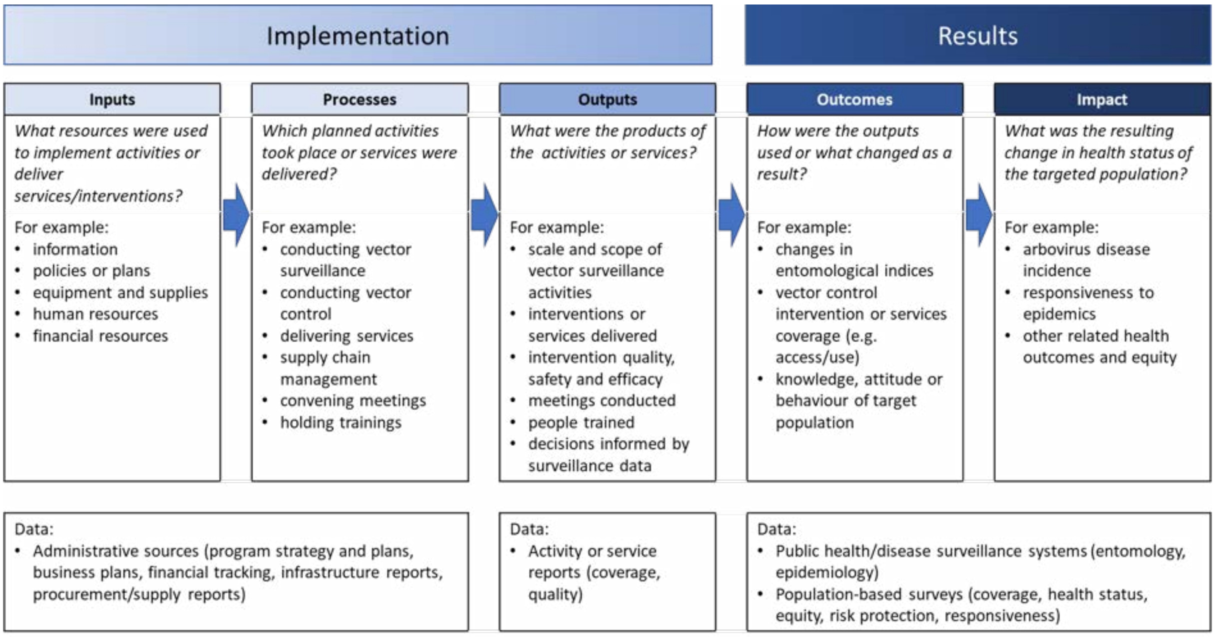


Figure 14: Monitoring and evaluation framework for an arbovirus vector control programme

6.1.1 Data collection and sources

Countries and territories benefit from instituting policies and enforcing commitment to implement a data architecture that is integrated with the national health information system. This includes providing comprehensive specifications on the content and accessibility of data sources. Innovative information technologies can play a role in strengthening data sources; for example, application of head-held devices for data collection, and data sharing and exchange through interoperable databases, which may be located at facility, district, regional and national levels (O'Neill et al. 2016). Further details regarding data sources are provided in the *WHO Malaria surveillance, monitoring & evaluation: a reference manual* (2018) (WHO 2018b).

6.1.2 Core essential indicators

Monitoring and evaluation should use standard indicators, so that results can be compared between areas, between years, and preferably also between countries and territories and regions. Indicators are easily quantified and analysed if they are enumerative data (numbers, percentages) or logical data (presence/absence, milestones). Indicators can be supplemented by more descriptive background information (qualitative type of data).

Selection of indicators should be informed by considerations of scientific soundness, relevance, usefulness for decision-making, responsiveness to change, and data availability. The core indicator set should provide an appropriate balance across the logical framework (i.e. covering inputs, processes, outputs, outcomes and impacts). Each core indicator must have a defined, time-bound target (O'Neill et al. 2016).

Target setting approaches

There are several approaches to framing targets, depending on the type of achievement and information available.

- *Absolute targets:* a specific numerical target citing a baseline value, e.g. larval source reduction coverage from 20% to 50% in five years.
- *Relative targets:* a relative change that is independent of the initial value of the starting point (for example, a reduction by half in the number of dengue cases. Relative target setting is often used when baselines are uncertain.
- *Annual rates of change:* describe the pace of change expected, especially during a period of ramping up of services, e.g. increase in expanded coverage from 2% to 4% per year.

Baselines for each indicator are determined by analysing the situation before implementing the strategic response plan. A common problem in monitoring and evaluation is that baseline values are not established at the onset of a programme, because it is considered counter-intuitive to start an evaluation before activities have started; nevertheless, it is essential. A list of recommended indicators for monitoring dengue, Zika and chikungunya programmes is presented in Annex 4 Recommended indicators for monitoring dengue, Zika and chikungunya programmes.

6.1.3 Data dissemination and use

Data collected by established methods and procedures must subsequently be processed, analysed and interpreted to assess the status of implementation and the outcomes and impacts. Data analysis involves synthesising data from multiple sources for the purpose of reviews, planning, policy analysis, regional and global reporting, and evaluation. This work is ideally carried out by institutions in each country or territory in collaboration with the ministry of health and the national statistics office. The focus of data presentation and dissemination is on major decision-making processes, where effective communication of results may lead to an adjustment of implementation and revisions of plans. Global reporting should be aligned as much as possible with national reporting. Communicating to the general public and media is also critical and usually requires special skills. The responsibility for data presentation and dissemination often lies with data analysts in government and academic institutions (O'Neill et al. 2016).

Programme planning: The principal use of information is in preparing a national strategic plan that defines the goals and objectives of the *Aedes*-borne disease control programme, how they will be achieved, and the resources required. The plan should include the roles of different stakeholders in its implementation and set targets for monitoring progress and ensuring accountability. Resources should be allocated to the most effective interventions and to the populations in the greatest need.

Programme monitoring and evaluation: The other major use of information is to monitor the implementation of the strategic plan for *Aedes*-borne disease and to assess coverage of interventions and their impact and determine whether programmes are proceeding as intended or adjustments are required. Managers at national level, district level and in health facilities should review the indicators at least every quarter. Annual reviews should be undertaken before budgets are prepared. A final programme review should be undertaken before the next strategic plan is developed.

6.2 Quality assurance of vector control interventions

Quality assurance is the implementation of systematic and well-planned activities to prevent substandard services or products (WHO 2019a). This relates to monitoring both the efficacy and effectiveness of vector control operations.

Efficacy can be defined as the performance of an intervention under ideal and controlled circumstances.

Effectiveness refers to its performance under "real-world" conditions.

Lower than expected effectiveness of vector control may be due to a variety of factors related to implementation:

- incorrect application of the intervention
- inadequate procurement planning
- poor quality of deployed products
- failure to achieve high coverage.

Quality assurance efforts should be continuous, systematic and independent. Continuous monitoring and supervision are required to ensure that staff are adequately trained and follow technical guidelines for pesticide application and personal safety. Vector control programmes must include a quality assurance programme designed to monitor the effectiveness of the control activities. A quality assurance programme should monitor applicator performance and control outcomes (WHO 2019a).

For vector control products, the key elements of quality assurance are:

- sourcing only products with a WHO PQ listing for deployment against *Aedes* vectors;
- requesting the supplier/manufacturer to provide a Certificate of Analysis for each batch of the product actually being supplied (WHO 2012b);
- pre-shipment inspection and sampling according to WHO guidance or International Organization for Standardization (ISO) standards, performed by an independent sampling agent;
- pre-shipment testing conducted by an independent quality control laboratory (WHO prequalified or ISO 17025 or Good Laboratory Practice accredited) to determine that the product conforms to approved specifications according to the WHO/CIPAC test methods;
- testing on receipt in country or territory (post-shipment quality control testing) only being conducted if specific risks related to transport have been identified or specific concerns over potential product performance justify this additional expense;
- tender conditions including provisions for free-of-cost replacement of shipments that fail quality control checks and disposal of failed lots;
- post-marketing surveillance when required, depending on the product and context, to monitor performance over time in order to ensure that products continue to conform to their specifications or recommended performance as set by WHO.

Quality assurance of the field application of vector control interventions should form an integral part of the national programme's strategy and should include:

- high-quality training for all staff engaged in field implementation of vector control interventions;
- regular supervision, monitoring and follow-up of field operations;
- periodic testing of the quality of IRS operations through WHO cone bioassay of sprayed surfaces;
- where larval source management (LSM) is used, determination of its impact by monitoring changes in vector density before and after implementation.

Various quality assurance measures are available for vector control (Table 21) and each programme should define requirements based on their situation.

Table 21: Quality assurance measures for each intervention

Activity	Quality assurance measures
Insecticide procurement	Ensure pre-shipment testing (see above)
Targeted indoor residual spraying-*Aedes* **Outdoor residual spraying-*Aedes***	Determine residual action (WHO cone bioassays) Monitor quantity of insecticide used
Space spraying	Monitor quantity of insecticide used
Larval control including source reduction and larviciding	Independent assessment or random spot checks

6.2.1 Targeted residual spraying operations and monitoring with WHO cone bioassays

The WHO cone bioassay is currently the only tool available for assessing the quality of the application of IRS insecticides to walls and other internal surfaces. The WHO has clearly outlined the protocol for cone bioassays (WHO 2013a).

The recommended frequency of testing is described below:

- IRS operations should be periodically tested when an insecticide is first introduced into a country or territory.
- Subsequent measurement of insecticide decay on sprayed surfaces should be done only if necessary, such as when spraying is done in areas with a different housing type (with different wall surfaces), as it will incur additional expense.

The sex and physiological state of the test mosquitoes should be:

- adult females aged 3–5 days that are non-blood-fed.

Origin of the test mosquitoes can be of two options.

- **Preference:** fully susceptible *Aedes* obtained from insectaries
- **Second option:** F1 generation of fully susceptible wild-caught specimens

WHO cone bioassay procedure

The first test for the evaluation of any given insecticide should be undertaken within a few days after its application or as soon as the deposit is completely dry. At least 10 points, variously situated, should be chosen for testing on a given day. They should be distributed in several houses, with not more than 3 points in any one house. At least 2 controls should be used for every 10 tests. The controls should be carried out at a suitable distance from the sprayed premises (over 100 m) and on an unsprayed surface.

The exposure chambers are conical and made of transparent plastic, commonly referred to as "cones". At least three cones should be attached to each surface spot to be tested. Remember that the cage of stock mosquitoes should not be taken inside the house that has been sprayed. Release 10 female blood-fed mosquitoes into each cone. Leave the cones undisturbed for 30 minutes. At the end of the exposure period, the mosquitoes are collected and transferred into holding containers. Mortality is monitored after 24 hours.

If control mortality is between 5% and 20%, the average observed mortality is corrected by applying Abbott's formula. If control mortality is above 20%, the series of tests should be discarded and repeated.

Average mortality with standard deviation (SD) should be calculated for each part of the wall. Wide differences in mortality rates from one point to another may reflect either unevenness of spraying or a differential in the rate of loss of potency.

6.2.2 Larviciding

Where LSM is used, its impact should be determined by monitoring changes in vector occurrence and density before and after implementation.

Larviciding is a "learning activity". Larviciding applicators learn where the local aquatic habitats are, and improve the effectiveness from one round to the next. Nonetheless it is essential to monitor the effectiveness of applications. This can be done in two ways.

1. Independent assessment: by a group of assessors to check the quality of the larviciding programme (Fillinger et al. 2008). This involves an observer following larvicide applicators doing their daily work. They report on whether the applicators followed their schedule correctly, whether they entered all the stipulated areas, how habitats were searched for larvae, and how they interacted with residents. This information can then be fed back to the programme manager (WHO 2013b).

2. Random larval spot checks: to monitor the larviciding applicators' performance, these should be carried out in treated areas throughout the arboviral transmission season(s) to determine the proportion of habitats containing early and late instar larvae. Ideally 30–40 habitats within every applicator's area should be checked at least once per month. Inspection of sites should take place 1–2 days after the habitats are treated with larvicide. The results from this spot checking will inform the programme manager of the performance of the applicators. In addition, sentinel sites should be checked in an untreated area outside the treated area to monitor the seasonal fluctuations in mosquito numbers. For a detailed description of such a programme, see (Fillinger et al. 2008).

Note: if juvenile growth hormones are the insecticide used, there will not be an immediate reduction in larval densities. It is recommended that any larvae and pupae be brought back to the laboratory and their growth be monitored in a sample of water collected from the aquatic habitat.

6.2.3 Operational research

The objective of operational research is to learn how to improve vector control by novel strategies. Ideally, applied research should be led and conducted by the national vector-borne disease control programme. However, because human and financial capacity in national programmes will often be focused on implementation, research may best be performed through collaboration with national research centres such as polytechnics, universities and institutes. In some cases, support may be provided by international partners to leverage advanced technologies and methodologies and strengthen research quality and outputs. Formal institutional agreements will strengthen links between the programme and collaborating institutions and ensure sustainability. Research findings of any relevant work conducted in the country or territory should be presented to the national programme as soon as available. Raw data should be provided in a format that is easy to manage and use. Basic and applied research and innovation must follow standard ethical guidelines to ensure that the results are obtained without adverse effects on humans and the environment (WHO 2017a).

7 Community engagement

Engaging communities is key to the success of the vector control implementation, including early detection and especially during outbreak response. Communities, when appropriately engaged, are the front line in detecting and managing epidemics. They are the ones who are affected, and their behaviour and actions can help contain an outbreak.

When properly engaged, community participation in *Aedes* vector control has the potential to substantially reduce the risk of arboviral diseases. Community participation in the design and implementation of interventions can improve compliance; increase cost-effectiveness through harnessing local knowledge, practices and contributions to inform behaviour change; foster local programme ownership; and, importantly, increase prospects for sustainability. Recent studies suggest that community-based, integrated control of *Aedes aegypti* reduced vector densities and had an impact on dengue transmission (Kay and Nam 2005, Kittayapong et al. 2008, Toledo et al. 2011).

Locally appropriate, integrated and coordinated communication across health departments and other stakeholders is necessary in order to achieve better awareness and knowledge of dengue, as well as to catalyse action before and during an outbreak.

Annex 5 Community engagement examples

7.1 Community engagement defined

Community engagement involves those affected in understanding the risks they face, and in response, expressing appropriate behaviours and actions that minimise their risk. Community engagement is the process by which organisations and individuals build a long-term relationship with a collective vision for the benefit of the community. The primary purpose is to empower communities to lead and facilitate change that benefits them.

Participatory community-based approaches involve a process of dialogue, learning, decision-making and action so that community members are empowered to recognise strengths and assets, and to self-assess, collectively identify, analyse and prioritise problems that affect them. This leads to the identification of practical ways – including adaptation of traditional practices if appropriate – to address acknowledged problems. If well executed, this will strengthen the community's capacity to continually identify new issues where action is required and will build mutual accountability, trust and partnership. Communities and service providers should meet regularly for mutual advocacy and to assess progress with the twofold aim of improving vector control while empowering communities to gain mastery over their risk of disease and ensure sustainable and locally owned development (WHO 2017a).

Community understanding of diseases and their spread is complex, context-dependent and culturally mediated. Thus, this manual does not prescribe how to engage with communities. There is no one-size-fits-all approach and decision makers, service providers and communities themselves must determine the most appropriate approach for collaboration in any given context and situation based on their joint interests and purpose.

7.2 Steps for successful community engagement

7.2.1 Purpose

To clarify the purpose of the community engagement process, it is important to complete the steps below.

1. *Define the purpose.* From the outset, it is important to define the reason for bringing different stakeholders together. This should involve outlining the problem to be addressed, the decisions to be made and the proposed roles and responsibilities of all parties. Understanding the reason for involving stakeholders and building relationships will inform all subsequent parts of the engagement process.
2. *Define the objectives.* It is also important to define the desired outputs of the engagement process. For example, the aim may be to reach a certain decision or to gather feedback on a proposal.
3. *Outline the scope and limitations.* The engagement process is likely to be limited by a range of factors. These may include time, staff, transport, funding and stakeholder capacity. It is important to outline the scope and limitations, as this will allow for a transparent and achievable engagement process.
4. *Identify negotiable and non-negotiable elements.* Each engagement project will have a set of factors or decisions that can be influenced by stakeholders and a set that cannot. These are the negotiable and non-negotiable elements. It is important to identify these elements at this stage so they can be communicated clearly to stakeholders during the engagement process. This will allow stakeholders to understand what they can influence and where their energy is best spent.

7.2.2 Stakeholder identification

It is important to understand who in the community is trusted and to build relationships with them. These actors need to be involved in design, planning and decision-making to ensure interventions are collaborative, contextually appropriate and that communication is community-owned. The key actors may include:

- community health workers
- school teachers and children
- youth groups
- respected members of the community, such as community elders, chiefs
- women's groups
- church leaders and faith-based organisations
- disabled people's organisations
- non-government organisations
- business leaders.

Agencies for community engagement

There is a clear need for integrated communication plans that span government departments and also coordinate with organisations such as the Red Cross, non-government organisations (NGOs) such as Save the Children, and local civil society organisations. Some countries and territories have a special agency for community engagement, e.g. Samoa. All communication efforts need to be channelled and cleared through this agency, which falls under the Ministry of Women and Community Development (community sector). In other countries or territories, such as Solomon Islands, the responsibility resides within a health promotion unit of the Ministry of Health. While others, e.g. Cook Islands, indicated that community engagement was only conducted when a task force was mobilised during an outbreak, highlighting the issue that during routine periods there was no proactive mechanism for multi-stakeholder community engagement.

7.2.3 Level of participation

It is important to clarify the specific roles and responsibilities of all stakeholders. Some projects will require a high degree of stakeholder participation throughout the project, while others may require specific groups to have input at different stages. Community engagement can also be seen as a continuum of community involvement (Figure 15). Projects should aim for the minimum level of engagement to be "involved". Over time, a specific collaboration is likely to move along this continuum toward greater collaboration and shared leadership. Note that community engagement may be achieved during a time-limited project; it frequently involves – and often evolves into – long-term partnerships (CSTA Community Engagement Key Function Committee Task Force 2011).

Increasing level of community involvement, impact, trust and communication flow

	INFORM	CONSULT	INVOLVE	COLLABORATE	SHARED LEADERSHIP
Goal	Some community involvement	More community involvement	Better community involvement	Community involvement	Strong relationship
Actions	Provides community with information	Gets information or feedback from the community	Involves more participation with community on issues	Forms partnerships with community on each aspect of the project – from development to solution	Strong partnership structure is formed
Outcome	Optimally established communication channels and channels for outreach	Develops connections	Visibility of partnership established with increased cooperation	Partnership building, trust building	Broader health outcomes affecting broader community. Strong bidirectional trust built
Examples	• Fact sheets • Web sites • Open houses • Social media	• Public comment • Focus groups • Surveys • Public meetings • Social media	• Workshops • Deliberate polling	• Citizen advisory committees • Consensus-building • Participatory decision-making	• Citizen juries • Ballots • Delegated decisions

Figure 15: Community engagement continuum

Modified from the International Association for Public Participation's Develop engagement plan

The plan should also include mechanisms to ensure proper documentation is maintained to promote equitable processes for stakeholders and transparent decision-making. An engagement plan should be a live document that describes the engagement process with the stakeholders. Specifically, an engagement plan should include the following (Victorian Government 2018):

- purpose
- objectives
- stakeholders
- inclusive engagement plan
- level of participation
- stakeholder commitment
- timeframes
- roles and responsibilities
- budget
- resourcing
- limitations
- risks and mitigation plan
- monitoring and feedback plan
- evaluation plan.

Engagement techniques

Many different approaches and tactics have been linked to community engagement, including:

- *social mobilisation* – a process that engages and motivates a wide range of partners and allies at national and local levels to raise awareness of and demand for a particular development objective through dialogue;
- *communication for development (C4D);*
- *behaviour change communication;*
- *health education* – aims to provide information to influence the future decisions made by community members with regard to their health;
- *health promotion* – aims at working on the needed social and political actions (e.g. legislation, movements);
- *community engagement;*
- *outbreak communication;*
- *risk communication;*
- *communication for behavioural impact (COMBI).*

Multiple strategies and tactics should be used to engage with communities. For larger, more complex projects, or those with multiple stakeholders, it is likely that a variety of different methods to engage different groups throughout the project will be needed.

7.2.4 Implement and monitor engagement

Engaging with communities is an approach that is founded on partnerships with all of the stakeholders having ownership, which needs to be reflected throughout the implementation of the plan. When implementing the engagement plan, remain aware of all of the stakeholders' needs and expectations to ensure their voices are heard. This is especially true with regard to stakeholders who are harder to reach or traditionally excluded groups. During your engagement, monitor the implementation of individual engagement tasks, as detailed in your engagement plan, especially for larger projects. By monitoring the engagement plan, risks can be managed by addressing issues as they arise, and anticipating or communicating any significant delays.

7.2.5 Feedback

The feedback process should continue through the life of the project and involve meaningful feedback to the stakeholders about how their input and feedback has been used. Reporting back could be done by providing participants with written feedback, by holding feedback sessions or forums, or by using digital communication.

7.2.6 Evaluate

All engagement processes should conclude with an evaluation to measure how effective the engagement plan was in achieving its objectives, and to capture the lessons learned during the project. Evaluating engagement processes will inform and improve future practice and engagement policy development, and increase the evidence base. The nature of the evaluation will vary depending on the complexity and size of the engagement process. This is a key step and should not be excluded (Victorian Government 2018).

8 Risk communication

For public health emergencies, risk communication refers to the real-time exchange of information, advice and opinions between experts or officials and people who face a threat (hazard) to their survival, health or economic or social well-being. Its ultimate purpose is so that everyone at risk is able to take informed decisions to mitigate the effects of the threat (hazard) such as a disease outbreak and take protective and preventive action (Gamhewage 2014).

Modern risk communication is recognised as requiring both two-way and multi-directional communications and engagement with affected populations so that they can take informed decisions to protect themselves and their loved ones. It can and should utilise the most appropriate and trusted methods and channels of communication and community engagement. Ideally, it needs to bring together a diverse range of expertise in the field of communication, social sciences and systems-strengthening techniques in order to achieve public health goals in emergencies (Gamhewage 2014).

The following actions underly effective risk communication.

- Build and maintain trust.
- Communicate early and often, even in the face of uncertainty.
- Involve and engage communities.
- Establish and use locally appropriate listening and feedback systems.
- Use a combination of methods, including social media, as appropriate.
- Ensure resources for risk communication operations.
- Treat emergency risk communication as a strategic role, not as an add-on.
- Establish coordination and information systems.
- Build capacity outside times of crisis or emergency.
- Manage rumours.

8.1 Audience analysis

Determining the important characteristics of an audience is important in order to choose the best style, format, information and channels for risk communication. There is a need to understand the identity, personality and characteristics of the target audience. Conducting an audience analysis can be very difficult, time-consuming and expensive. Direct methods of analysis (i.e. interviewing audience members, conducting focus groups, etc.) are always preferred to indirect methods (i.e. using existing sources of information).

8.2 Understanding the situation and framing your communication

The most fundamental skill that a good communicator possesses is a clear understanding of the change they want to see, regardless of what they say or how they say it. The SOCO, or single overarching communications outcome, is the desired change to be made by the audience as a result of the communication.

- It is an outcome, and therefore is expressed from the perspective of the audience.
- It is not an objective, which usually reflects your perspective.
- It must be explicit about the change you want, and be time limited.
- It must be realistic and achievable.
- It must, together with other interventions, contribute to the larger programme objective.
- It will be the fixed point on which you keep your mind when communicating.

Table 22 illustrates an example of how to develop your SOCO.

Table 22: A step by step example of how to develop your SOCO

Step 1	What is your issue?	Epidemiological surveillance system under-represents the extent of the dengue outbreak.
Step 2	Why do you want to focus on this issue and why do you want to focus on it now?	The occurrence of dengue outbreaks is increasing. There is a need to understand the extent of transmission to target vector control resources.
Step 3	Who needs to change their behaviour (audience)?	Patients and their families.
Step 4	What is the change that you want to see in your audience as a result of your communication? (This is your SOCO)	Community members should seek early medical attention if experiencing dengue-like symptoms.

8.3 Communication in outbreaks

Best practices for effective risk communication on dengue fever and any other public health threats or emergencies include building and maintaining trust, especially through communicating early and often, even in the face of uncertainty; coordinating with partners; involving and engaging those affected; using a combination of strategies; and, planning and continuing to build capacity outside times of crisis or emergency.

Steps for effective risk communication include:

- analysing the problem in a particular area or population (surveillance and risk assessment data);
- conducting a situation and audience analysis to assess people's attitudes and behaviours in relation to dengue risk factors (can use a *Knowledge, attitude and practice* (KAP) survey);
- developing and delivering messages to the intended target audience on what needs to change;
- developing a communication plan with communication activities, methods and channels;
- evaluating whether the communication was effective in achieving the desired outcome.

The programmes and situations are very diverse across the Pacific region and it is essential that communication strategies are tailored to local and disease-specific needs. Key messages need to be clear and concise. The messages need to be developed in collaboration with all relevant stakeholders and approved by the body specific to each country or territory.

The approach and messaging directed towards each community has to evolve with the epidemic and incorporate new messages and communication methods as it unfolds. These messages must also proactively detect misinformation and rumours.

8.4 Overarching messages

The main messages are summarised below.

- Dengue is one of the fastest spreading mosquito-borne diseases. Worldwide, the incidence of dengue has increased 30-fold over the past 50 years.
- The current risk of dengue in the local area (including geographic extent of the outbreak) needs to be communicated.
- Everyone has a role to play in controlling *Aedes*-borne diseases – individuals, communities, businesses, governments and societies.
- Early medical attention must be sought if dengue-like symptoms are experienced.

Dengue, chikungunya and Zika are all transmitted by* Aedes *mosquitoes, which bite mainly during the day.

- *Aedes* mosquitoes can transmit dengue, chikungunya and Zika.
- *Aedes* mosquitoes usually bite during the day, with peaks during early morning and late afternoon/ evening. They can bite outside and inside dwellings if there are no screens.
- *Aedes* mosquitoes inhabit stored and stagnant water found in and around the home.

What can people do to protect themselves from mosquito bites?

- The best way individuals can protect themselves from getting sick from dengue and other mosquito-related diseases is to avoid getting bitten.
- Residents and travellers should take extra precautions.
    - Use insect repellents containing tropical strength DEET picaridin, citriodiol, IR3535.
    - Wear clothing that covers the skin – light-coloured clothing if possible.
    - Sleep in rooms that are either screened against mosquitoes or sleep under a mosquito net – especially when sleeping during the day, in the early morning and around sunset.
- Zika: the community, and particularly pregnant women and women of reproductive age, should be educated about the risk of transmission and how to minimise this risk by reducing contact with mosquitoes.

What symptoms do people need to look out for and what should they do if they suspect they've been infected?

- A person infected by the dengue virus develops severe flu-like symptoms.
- The disease, also called "break-bone" fever affects infants, children and adults alike and can be fatal. Symptoms of dengue fever vary according to the age of the patient, but generally individuals should suspect dengue when a high fever (over 38°C/104°F) is accompanied by two or more other symptoms:
    - severe headache
    - pain behind the eyes
    - nausea, vomiting
    - swollen glands
    - muscle and joint pains
    - rash.

- Symptoms usually last for 2–7 days, after an incubation period of 4-10 days after the bite from an infected mosquito.

- There is no specific treatment for dengue fever. If a person suspects they have dengue, in particular if they live or have recently visited a place where dengue fever is circulating, they should seek immediate medical advice.

How do people help to prevent the spread of disease?

- The main prevention measure is to proactively **eliminate or reduce potential mosquito habitats** to minimise mosquito populations, even before cases are reported.

- Source reduction is a continuing activity that requires concerted effort from local authorities, communities and households.

- Local authorities and partners should implement campaigns that build awareness and mobilise communities for sustained vector control, especially as the common vector for dengue (*Aedes aegypti*) is known to breed in and around households. Everything that can collect water can be a potential breeding site for mosquitoes.

- Dispose of solid waste properly and remove artificial man-made habitats.

- Apply insecticides through targeted spraying or space spraying during outbreaks as an emergency vector control measure in densely populated areas.

- Conduct active monitoring and surveillance of vectors to determine effectiveness of control interventions.

- Treat water in large storage containers with larvicides, in accordance with sanitary regulations, to kill larvae and eggs.

Communities and households are encouraged to follow the suggestions below.

- Clean surroundings of all waste and garbage that can retain water.

- Change water in flower vases, pot-plant drip trays or any other water-filled container at least once a week.

- Always keep water in covered containers, tanks and drums. If possible, use mosquito-proof covers.

- Empty, wash or scrub once a week all water storage dishes and containers to remove any mosquito eggs that may exist.

- Drain roof gutters and assure free flow of water.

- Report mosquito breeding grounds in abandoned lots, public spaces, playgrounds and workplaces.

- Report broken pipes or water to the authorities.

Suggestions for the contents of information, education and communication (IEC) materials are in Annex 6 Information, education and communication (IEC) materials.

8.5 Communication channels (from national to community level)

The formats for communication should be fun, interactive and promote community buy-in. Examples include:

- public talks at community gatherings
- radio announcements
- social media (e.g. Facebook)
- education posters (especially in areas with vulnerable populations, e.g. health clinics and schools)
- television
- radio
- newspapers
- community radio
- events and competitions (e.g. fairs)
- government website.

For more detailed examples, see the International Association for Public Participation (IAP2) toolbox.

Two-way communication should be achieved through the most socially acceptable and effective channels. Messages must be translated into local language, put into the local context and should match the education levels and preferences (e.g. visual, written or oral cultures) of the target population. All communication with communities should be transparent, timely and easy to understand, and should acknowledge uncertainty, address affected populations, link to self-efficacy, and be disseminated using multiple platforms, methods and channels.

8.6 Managing adverse communications

Risk communication is an essential intervention in any response to disease outbreaks and involves three main strands that must work together.

1. **Talk.** Authorities, experts and response teams must quickly relay information on the nature of the event and the protective measures that people can take.
2. **Listen.** Responders, experts and authorities must quickly assess and understand the fears, concerns, perceptions and views of those affected, and tailor their interventions and messages to address such concerns.
3. **Manage rumours.** Disease outbreaks are often accompanied by the presence of false rumours and misinformation. Responders need to have ways to listen to such misinformation and correct examples of it in appropriate ways without delay (WHO 2018c).

Another useful technique is to develop a list of frequently asked questions that can be disseminated on websites or mainstream media.

Dealing with rumours

Rumours can be very damaging to efforts to control an outbreak. They may give people the wrong information about how to protect themselves, or they may create distrust of public health officials (for example if there is a rumour that the government is lying to the public).

Rumours spread quickly and they must be dealt with quickly. The best way to control rumours is to prevent them by providing early and honest information. However, once rumours occur, do not ignore them. Do not waste time trying to argue with the rumours. Instead, just tell the public that you are aware of the rumours, and then provide them with the truth.

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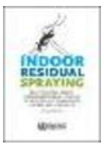
Annex 1. List of relevant guidance by topic area

Global or regional strategies and reports	
	Global strategy for dengue prevention and control, 2012–2020 https://www.who.int/denguecontrol/9789241504034/en/
	Western Pacific regional action plan for dengue prevention and control (2016) https://iris.wpro.who.int/handle/10665.1/13599
	Global vector control response 2017–2030 https://www.who.int/vector-control/publications/global-control-response/en/
	Zika strategic response plan (Revised for July 2016–December 2017) https://www.who.int/emergencies/zika-virus/strategic-response-plan/en/
	Asia Pacific strategy for emerging diseases and public health emergencies (APSED III): advancing implementation of the International Health Regulations (2005): working together towards health security https://iris.wpro.who.int/handle/10665.1/13654
International Health Regulations	
	International Health Regulations (2005) https://www.who.int/ihr/publications/9789241580496/en/
	Vector surveillance and control at ports, airports, and ground crossings (2016) https://www.who.int/ihr/publications/9789241549592/en/
Healthy Islands	
	2015 Yanuca Island Declaration on health in Pacific Island countries and territories: Eleventh Pacific Health Ministers Meeting, 15–17 April 2015 https://iris.wpro.who.int/handle/10665.1/12508
	WHO Country Cooperation Strategy 2018-2022: Pacific Island Countries and Areas https://iris.wpro.who.int/handle/10665.1/14097

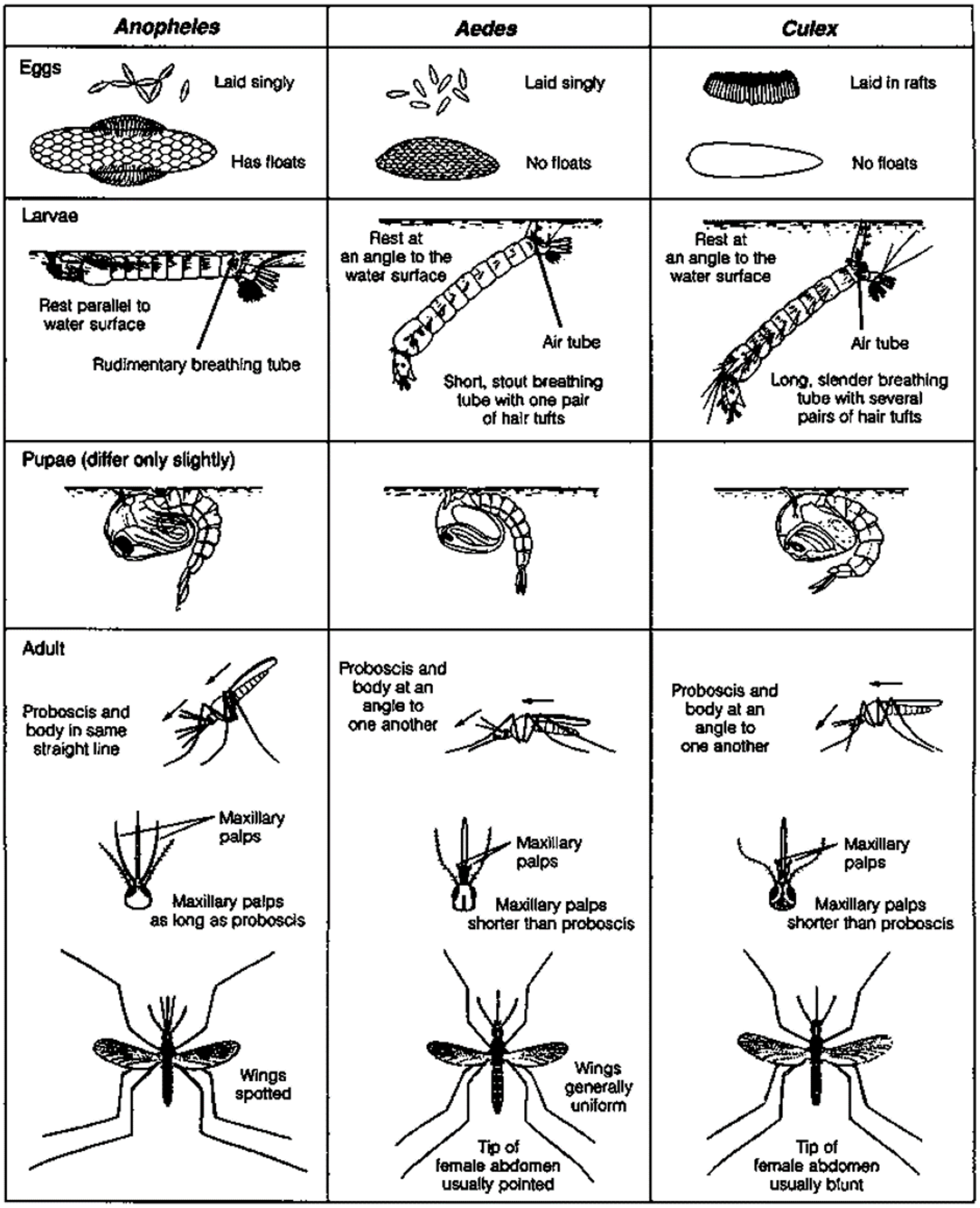
Heathy environments	
	Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum (2017) https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/
	Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks (2016) https://apps.who.int/iris/handle/10665/204585
Vector surveillance	
	Entomological surveillance for *Aedes* spp. in the context of Zika virus (2016) https://apps.who.int/iris/handle/10665/204624
	Malaria surveillance, monitoring and evaluation: A reference manual (2018) https://www.who.int/malaria/publications/atoz/9789241565578/en/
Vector control	
	Dengue guidelines for diagnosis, treatment, prevention and control (2009) https://apps.who.int/iris/handle/10665/44188
	Mosquito (vector) control emergency response and preparedness for Zika virus (2016) https://www.who.int/neglected_diseases/news/mosquito_vector_control_response/en/
	Vector control operations framework for Zika virus: Operations framework https://www.who.int/csr/resources/publications/zika/vector-control/en/
	Larval source management – a supplementary measure for malaria vector control. An operational manual (2013) https://www.who.int/malaria/publications/atoz/9789241505604/en/
	Manual for indoor residual spraying in urban areas for *Aedes aegypti* control (PAHO, 2019) http://iris.paho.org/xmlui/handle/123456789/51637
	Indoor residual spraying: An operational manual for IRS for malaria transmission, control and elimination, 2nd edition (2015) https://www.who.int/malaria/publications/atoz/9789241508940/en/
	Space spray application of insecticides for vector and public health pest control: A practitioner's guide (2003) https://apps.who.int/iris/bitstream/handle/10665/68057/WHO_CDS_WHOPES_GCDPP_2003.5.pdf?sequence=1&isAllowed=y

Insecticide resistance	
	Monitoring and managing insecticide resistance in *Aedes* mosquito populations (2016) https://www.who.int/csr/resources/publications/zika/insecticide-resistance/en/
	Test procedures for insecticide resistance monitoring in malaria vector mosquitoes, 2nd edition (2016) https://www.who.int/malaria/publications/atoz/9789241511575/en/
	Framework for a national plan for monitoring and management of insecticide resistance in malaria vectors (2017) https://www.who.int/malaria/publications/atoz/9789241512138/en/
	Insecticide Resistance Action Committee. Prevention and management of insecticide resistance in vectors of public health importance, 2nd edition (2011) https://www.irac-online.org/documents/irm-vector-manual/?ext=pdf
	Global plan for insecticide resistance management in malaria vectors (2012) https://www.who.int/malaria/publications/atoz/gpirm/en/
Pesticide procurement and management	
	The international code of conduct on pesticide management: Managing pesticides in agriculture and public health. An overview of FAO and WHO guidelines and other resources (2019) https://www.who.int/whopes/resources/9789241516020/en/
	Guidelines for procuring public health pesticides (2012) https://www.who.int/malaria/publications/atoz/9789241503426_pesticides/en/
	International code of conduct on the distribution and use of pesticides: Guidelines on management options for empty pesticide containers (2008) http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/Containers08.pdf
	International code of conduct on the distribution and use of pesticides: Guidelines for quality control of pesticides (2011) http://www.fao.org/3/a-bt477e.pdf
	Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets (2006) https://apps.who.int/iris/bitstream/handle/10665/69296/WHO_CDS_NTD_WHOPES_GCDPP_2006.3_eng.pdf?sequence=1&isAllowed=y
	Guidelines for laboratory and field testing of mosquito larvicides (2005) https://apps.who.int/iris/bitstream/handle/10665/69101/WHO_CDS_WHOPES_GCDPP_2005.13.pdf?sequence=1&isAllowed=y%0D

Community engagement and risk communication	
	Communication for behavioural impact (COMBI): A toolkit for behavioural and social communication in outbreak response (2012) https://www.who.int/ihr/publications/combi_toolkit_outbreaks/en/
	Communicating Risk in Public Health Emergencies: A WHO Guideline for Emergency Risk Communication (ERC) policy and practice (2018) https://www.who.int/risk-communication/guidance/download/en/
	WHO community engagement framework for quality, people-centred and resilient health services https://apps.who.int/iris/bitstream/handle/10665/259280/WHO-HIS-SDS-2017.15-eng.pdf
	CDC's Crisis and Emergency Risk Communication (CERC) manual https://emergency.cdc.gov/cerc/manual/index.asp
PPHSN resources	
	Pacific Outbreak Manual. Pacific Public Health Surveillance Network (PPHSN) https://www.pphsn.net/Publications/PPHSN-Pacific-Outbreak-Manual.htm

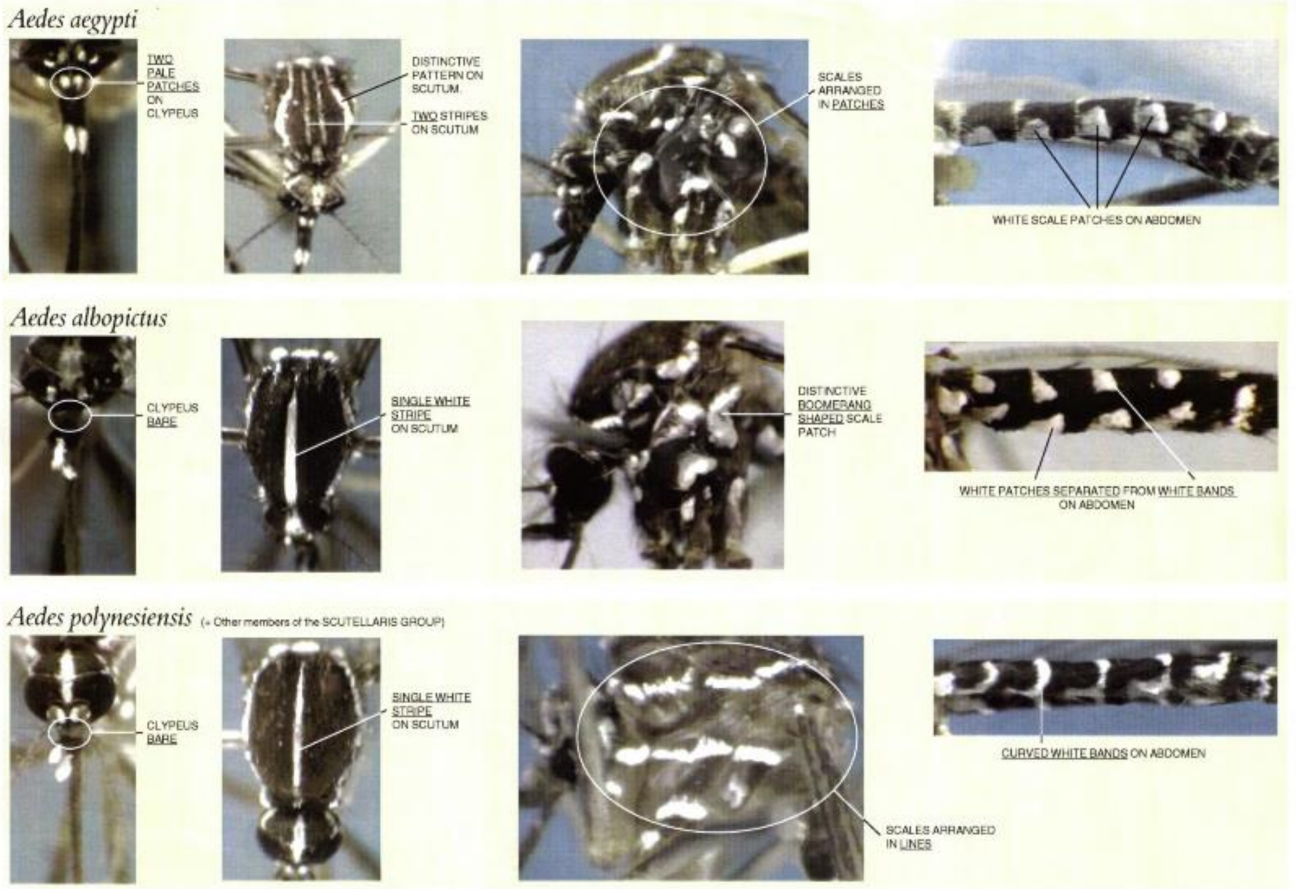
Annex 2. Mosquito identification keys

The main characteristics for differentiating *Anopheles*, *Aedes* and *Culex* mosquitoes



Source: World Health Organization

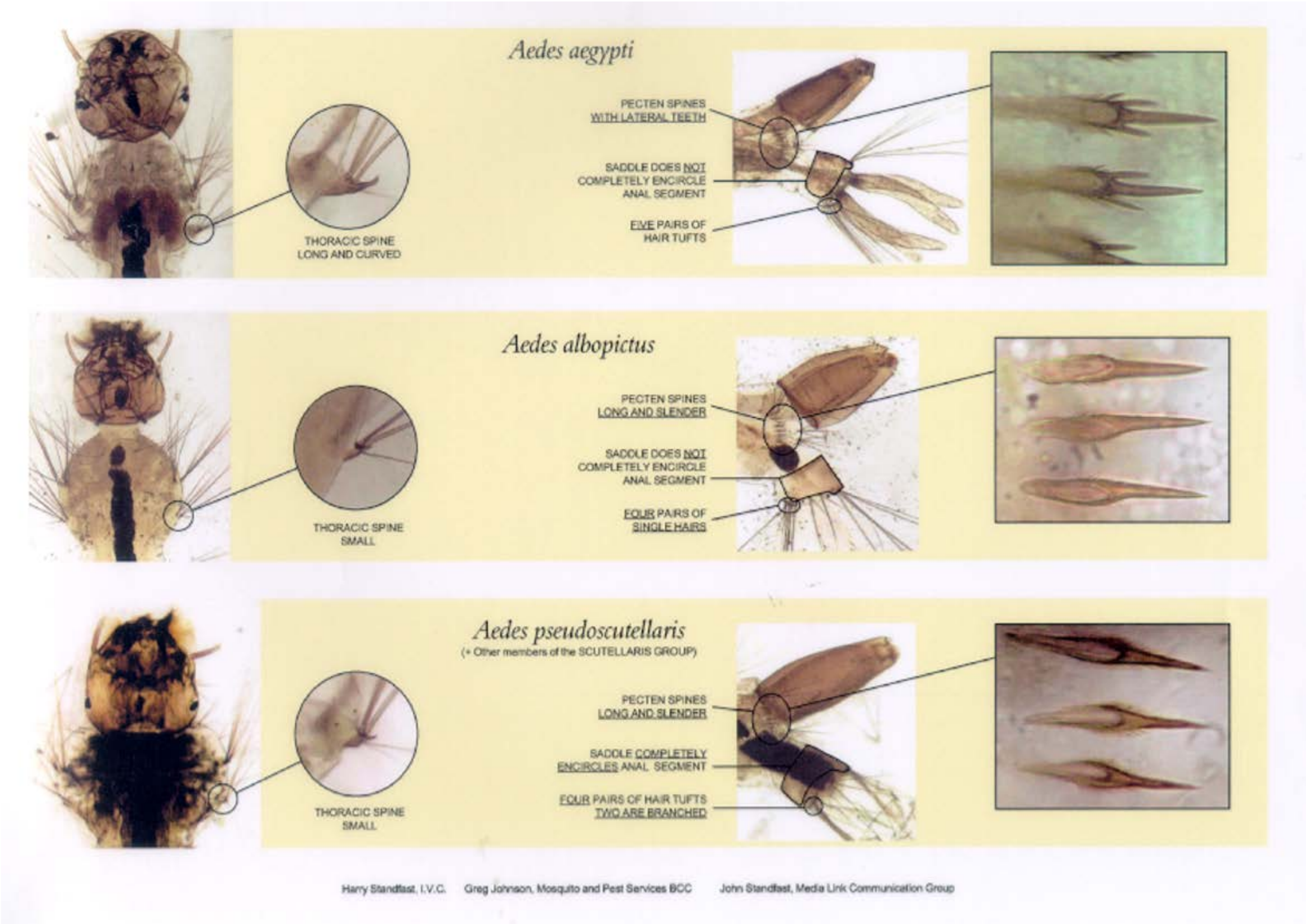
Pictorial aid to identifying adult *scutellaris* group mosquitoes



Harry Standfast, I.V.C. Greg Johnson, Mosquito and Pest Services BCC John Standfast, Media Link Communication Group

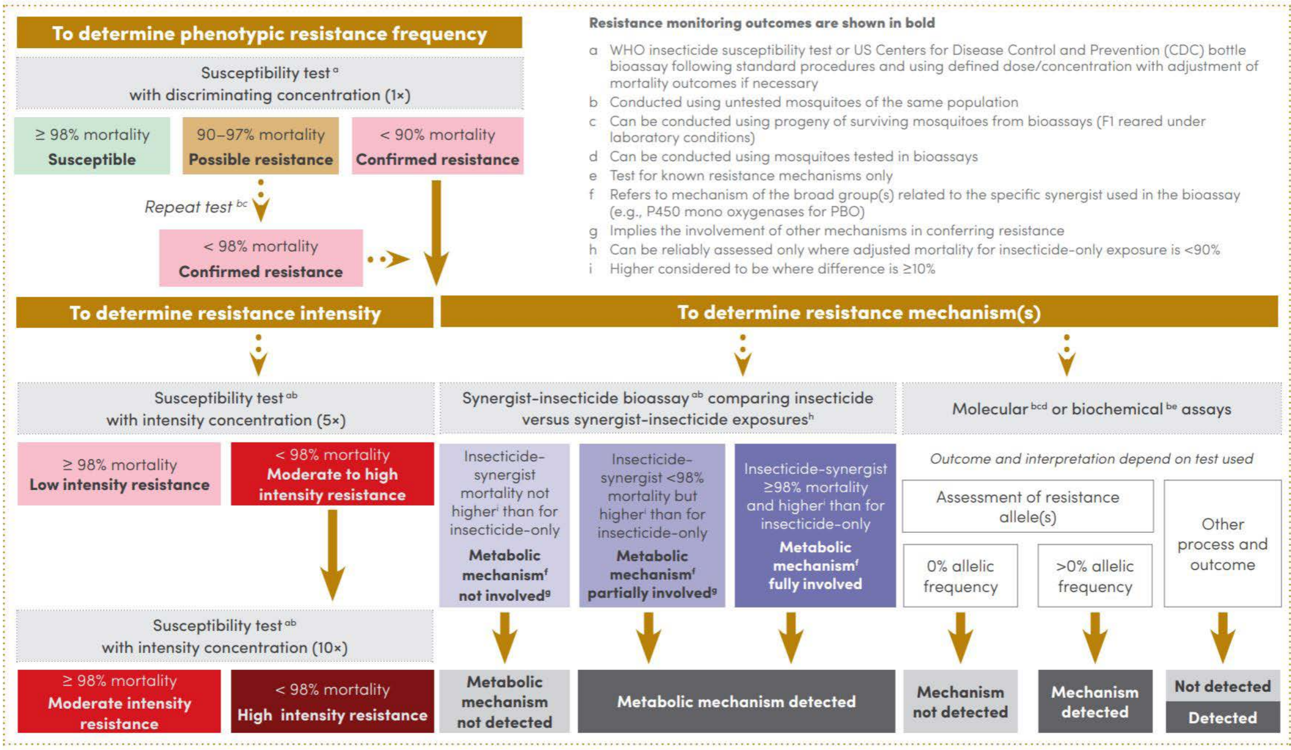
Produced by the PRVBD project, Secretariat of the Pacific Community

Pictorial aid to identifying larval *scutellaris* group mosquitoes



Produced by the PRVBD project, Secretariat of the Pacific Community

Annex 3. Overview of the process and outcomes for insecticide resistance monitoring for mosquitoes



Includes measures of (a) phenotypic resistance frequency via discriminating concentration bioassays, (b) resistance intensity via intensity concentration bioassays, and (c) resistance mechanisms via synergist-insecticide bioassays, molecular and biochemical assays.

Source: Test procedures for insecticide resistance monitoring in malaria vector mosquitoes, 2nd edition (2016)

Annex 4. Recommended indicators for monitoring dengue, Zika and chikungunya programmes

◆ High priority; ○ moderate priority

		Transmission intensity		
Indicator	**Indicator**	**High**	**Moderate**	**Low**
Inputs				
Policy	National *Aedes* vector surveillance and control strategic plan in place	◆	◆	◆
Policy	National public health pesticide management policy in place, with interagency participation	◆	◆	◆
Policy	Risk communication strategy in place	◆	◆	◆
Financing	Expenditure per capita for arbovirus control	◆	◆	◆
Institutional	National coordinating team or unit for vector control in place	◆	◆	◆
Outputs				
Vector surveillance	Number of sentinel sites with functional routine vector surveillance	◆	◆	◆
Vector surveillance	Number of sentinel sites having assessed vector resistance profiles to insecticides	◆	◆	
Community engagement	Number of villages at which campaigns on behavioural change on vector control were conducted	◆	◆	○
Community engagement	Number of villages at which communities have been mobilised for clean-up campaigns	◆	◆	○
Larval control	Number of aquatic habitats that are treated (include source reduction and larviciding)	◆	◆	○
T-IRS	Number of households that are sprayed	◆		
T-ORS	Number of peridomestic areas that are sprayed	◆		
Outcome				
Personal protection	Number of viraemic patients that were issued with a bed net or topical repellent	◆	◆	
Case detection	Proportion of children <5 years with fever in the previous 2 weeks for whom advice or treatment was sought	◆	○	
Case detection	Proportion of detected cases that contacted health services with 48 h of symptoms	◆	○	
Diagnostic testing	Proportion of patients with suspected dengue who received laboratory confirmation	◆	○	
Surveillance	Proportion of expected health facility reports received	◆	◆	◆
Surveillance	Proportion of cases investigated and classified	◆	◆	◆
Surveillance	Proportion of foci investigated and classified	◆	◆	◆

Indicator	Indicator	Transmission intensity High	Moderate	Low
Surveillance	Notification of all suspected cases of dengue, Zika or chikungunya	◆	◆	◆
Treatment: Zika	Percentage of Zika associated Guillain-Barré syndrome hospitalised	◆	○	
Treatment: Zika	Percentage of microcephaly cases in live births in settings of Zika virus transmission neuro-imaged	◆	○	
Treatment: Zika	Percentage of pregnant women with confirmed Zika infection having ultrasound screening	◆	○	
Impact				
Prevalence	Arbovirus prevalence: proportion of population with evidence of infection with dengue, Zika or chikungunya	◆	○	
Prevalence	Number of circulating serotypes (DEN-1, -2, -3 or -4)	◆	○	
Incidence	Arbovirus case incidence: number and rate per 1000 people per year for dengue, Zika or chikungunya	◆	◆	
Mortality	Arbovirus mortality: Number and rate of deaths per 100,000 people per year for dengue, Zika or chikungunya	◆	○	
Mortality	Number of deaths among severe dengue cases (suspected or confirmed)	◆	○	
Mortality	Proportion of inpatient deaths due to arboviruses	◆	○	

Annex 5. Community engagement examples

COMBI project targeting selected areas in Fiji by the Ministry of Health
Purpose: A COMBI-based community engagement project was implemented in Fiji with the purpose of mobilising communities to engage in source reduction to reduce the number of aquatic habitats available to the mosquitoes. **Stakeholders:** Community members, school teachers and church leaders, and intersectoral agencies. **Implementation:** The project involved formulating and approving the behavioural messages; IEC materials were designed and produced. A training workshop was held on the management of mass communication and community participation, and dengue prevention volunteers were recruited and trained. The community was engaged through house-to-house visits by dengue prevention volunteers and the programme supervisor. Points of service were also established in the schools and churches. **Evaluate:** Pre-intervention and post-intervention surveys were carried out to assess entomological indices and behavioural change.

World Mosquito Program (Kolopack et al. 2015)
Purpose: The purpose of the community engagement programme was to gain community acceptance of open-releases of Wolbachia-infected mosquitoes into their area. **Stakeholders:** Individuals engaged by the program either as residents of the host communities, as local or national leaders or representatives of local organisations. **Implementation:** The operational practices were: 1. Building the community engagement team; 2. Integrating community engagement into internal programme management; 3. Mapping the community of stakeholders; 4. Establishing and maintaining a presence in the host communities; and 5. Socialising the technology and the research process. **Evaluate:** Community acceptance of the method was determined by survey methods.

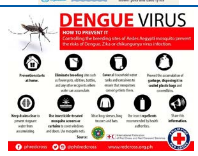
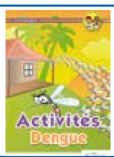
Dengue Day Campaigns Across Asia (WHO 2011b)
Purpose: To promote individuals, communities, private sector and government agencies (including non-health) to work together to fight dengue. **Stakeholders:** Communities and member states of all Association of Southeast Asian Nations (ASEAN) countries. **Implementation:** ASEAN launched the ASEAN Dengue Day to be held annually on 15 June. The ASEAN Dengue Day is used to increase public awareness on dengue prevention and control. Activities are conducted at regional, national and subnational levels to raise awareness. **Evaluate:** Reports (https://asean.org/?static_post=asean-dengue-day).

Guam Environmental Public Health Education Campaign
Purpose: To educate the public about mosquito biology and anatomy, bite prevention and control, mosquito-borne diseases, common predators, and identification and elimination of breeding sites. **Stakeholders:** Members of the public; public and private schoolchildren of Guam; military; and pest control companies. **Implementation:** The Division of Environmental Health, Guam Department of Public Health held its 1st Annual Guam Environmental Public Health Education Month (GEPHEM) in September 2016 with the theme of Fight the Bite! to bring awareness to the public about mosquito-borne diseases. The celebration began with a Proclamation Signing by Lieutenant Governor Ray Tenorio on 30 August 2016. A poster contest was held for students of the island's public and private elementary schools. The prizes were donated by the Environmental Public Health Association (a prior event was hosted to raise money for the prizes). The poster contest had 1,763 participants from 186 teachers of 31 public and private elementary schools. The top three posters were chosen from each of three categories: Category I (K-1st grade); Category II (2nd–3rd grade); and Category III (4th–5th grade). The GEPHEM celebration concluded with a public fair on mosquito bite prevention and control at the Micronesia Mall Center Court. Displays on mosquito bite prevention and control were presented by Department of Environmental Health; industry partners; US Naval Hospital Preventive Medicine Unit; Andersen Air Force Base; and the Guam Environmental Protection Agency's Pesticide Program. All poster entries were also displayed at the Center Court. Entertainment was provided by dancers from Mercy Heights Catholic School and Step Up Entertainment dancers. There was also a photo booth and a very popular balloon-animal table.

Community engagement programme in New Caledonia
Purpose: Community engagement programme implemented in New Caledonia with the purpose of mobilising communities to eliminate breeding sites. **Stakeholders:** Community members, vector control agents. **Implementation:** About 30 dengue prevention agents are recruited and trained each year during high-risk season in the South Province of New Caledonia. They conduct house-to-house visits to engage the community to eliminate breeding sites and to protect themselves against mosquitoes. **Evaluate:** Pre-intervention and post-intervention surveys are carried out to assess entomological indices and behavioural change of the population.

Dengue fight week in New Caledonia
Purpose: To promote individuals, communities, private and public sectors to work together to fight dengue. **Stakeholders:** Community members, prevention and vector control agents, private and public sectors. **Implementation:** In November (before high-risk season) an annual special dengue fight week is organised by the government in partnership with cities, provinces and public/private sectors, to increase public awareness on dengue prevention and control. Activities are conducted at regional levels to raise awareness, in markets, schools, shops and some events. Biodegradable bags are distributed to the population to eliminate breeding sites. Clean-up campaigns are organised. End-of-life vehicles and other big waste objects are removed. Prevention actions are organised at school with distribution of documents, games (colouring, card games, bingo, mosquitoes hunt). **Evaluate:** Reports, number of actions realised.

Annex 6. Information, education and communication (IEC) materials examples

	WHO dengue and severe dengue fact sheet https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue
	CDC fact sheets and posters https://www.cdc.gov/dengue/communication-resources/factsheets-posters.html
	SPC. Dengue, chikungunya, and Zika. Recognising the symptoms poster http://purl.org/spc/digilib/doc/cnc5f
	SPC. Fight the bite poster. Protect yourself and your family against dengue, chikungunya and Zika http://purl.org/spc/digilib/doc/34bh7
	SPC. Fight the bite poster. Simple steps to eliminate mosquito breeding sites in and around your home http://purl.org/spc/digilib/doc/xwyaj
	Zika virus disease infographics https://www.who.int/mediacentre/infographic/zika-virus/en/
	Philippine Red Cross https://twitter.com/philredcross/status/762120510259892224
	Cook Islands. Dengue fever flyer http://www.pphsn.net/Outbreak/Dengue/Cooks_dengue_flyer_english.pdf
	Guam Department of Public Health & Social Services educational materials https://www.dropbox.com/sh/276xnm5k65dkxy4/AACNOj2BgVUA0WksHbWVUPrIa?dl=0
	New Caledonia Service de Santé Publique information materials (click on "La dengue") https://dass.gouv.nc/votre-sante-maladies/la-dengue-le-chikungunya-et-le-zika
	PAHO WHO dengue infographics https://www.paho.org/hq/index.php?option=com_topics&view=rdmore&cid=6615&Itemid=40734&lang=en

Produced by the Pacific Community (SPC)
Address: Private Mail Bag, Suva, Fiji
Email: spc@spc.int
Phone: +679 337 0733

Website: www.spc.int

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