Climate Change and Vector-Borne Disease

Proceedings of the Workshop

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Ministry of Health & Medical Services
Shaping Fiji's Health

FIJI
Protecting Human Health from Climate Change

World Health Organization
Western Pacific Region

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Foreword

It is clear that climate change is affecting human health. Average temperatures are rising; rainfall patterns are changing with apparent climate variability. Fiji is not exempted from these changes and impacts on our population's health. It is within this context that we commenced enhancing capacity for development of appropriate adaptations to protect vulnerable individuals and communities from climate sensitive health risks. The formulation of this workshop booklet is timely for our environmental health team to build adaptive capacity. It is a tool for field officers of the Ministry of Health and Medical Services and our stakeholders.

Therefore, I am pleased to present this Climate Change and Vector Borne Disease booklet as a working tool for our environmental health officers and climate change partners. The support from the World Health Organisation, Ministry of Foreign Affairs and other partners was immense and timely.

Dr Eric Rafai

Deputy Secretary of Public Health

Ministry of Health & Medical Services, Fiji

Preface

Ni sa Bula vinaka everyone,

I welcome you all to this workshop. Actually, this is the first workshop on vector-borne disease and Climate Change that WHO and the Ministry of Health and Medical Services have done. As scientists say, by 2100 we will be living in a world where it is 4 degrees Celsius hotter than now and the sea level will be 1 m higher. All countries must reduce CO_2 emissions and some people say that we have lost the battle against climate change already. If we do not change our behaviours, imagine what the world will be like in 2200 or 2300 and what the life of the future generations will be like. Climate Change also brings severe health implications. Some of the health threats are caused by floods, droughts and cyclones.

The purpose of this workshop (and also the symposium) is to inform you about the useful and meaningful results of the 5 year program that was led by the World Health Organisation and the Ministry of Health and Medical Services in Fiji. Why are we talking about vector-borne diseases? One reason is because we (Fiji) have experienced a severe outbreak of dengue in late 2013 and early 2014, with around 27,000 reported cases, with supposedly many more unreported ones. This was the largest outbreak of dengue in the history of Fiji, with the last one being 1998.

This is why it is crucial to prepare the people of Fiji for the future – to prevent any further outbreaks as well as possible and to prepare for the case of another outbreak. Everyone has to act now, the Neglected Tropical Disease Unit, the Non-Communicable Disease Unit and also the Climate Change Unit - separately and also as a team we have to work together and do what we can do.

Thank you very much. I wish you have three informative days and hope that we can all learn from each other and take home valuable information for our future work here in Fiji.

Dr Rokho Kim

Environmental Health Specialist

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Introduction

It is evident that all the regions of the world will be affected by climate change; however, the extent and intensity of health risks vary depending on where and how people live (WHO, 2009). Estimates reveal that average global temperatures will have risen by 1.0–3.5°C by 2100 and researchers have predicted that this situation will also increase the likelihood of many vector borne diseases. Observed changes in temperature, rainfall and humidity that are expected to occur under different climate change scenarios will affect the biology and ecology of vectors and intermediate hosts and consequently the risk of disease transmission. Climate, vector ecology and social economics vary from one continent to the other and therefore there is a need for a regional analysis of the Pacific.

Vector borne diseases are highly climate sensitive. The vector borne diseases of significance to the Pacific region include dengue, malaria, lymphatic filariasis, zika virus and chikungunya, all of which are transmitted by mosquitoes.

In order to reduce the impacts of climate change on vector borne disease incidence in Fiji and the Pacific, it is vital to understand the association of these diseases and climate change in the region. The Pacific region host mosquito species such as *Anopheles farauti, Anopheles puntulatus, Culex quinquefasciatus, Aedes albopitus* and *Aedes aegypti* which are responsible for transmission of most vector-borne diseases, and are sensitive to temperature changes. If water temperature rises, the larvae take a shorter time to mature and consequently there is a greater capacity to produce more offspring during the transmission period. In warmer climates, adult female mosquitoes digest blood faster and feed more frequently, thus increasing transmission intensity (Githeko et al., 2000).

The workshop goal is to develop a pilot, but executable, climate based early warning system for vector borne diseases for the participating parties and review current district and country vector surveillance and control protocols.

In addition to the workshop a one day symposium was organised to inform stakeholders of climate change and health, the achievement of the PCCAPHH project and similar programs in the Pacific.

Session 1. Analysing the current practice and the way forward

Situational analysis: The current plan and procedures

Dr Matthew Shortus

When a program completes a strategic planning cycle it is very important to review and assess both the effectiveness of the previous strategies and whether the objectives of the program are still relevant moving forward into the next strategic period. A plenary session was held with some of the key stakeholders within the Fiji government that contribute to and assist in the implementation of controlling vector borne diseases in the country. This included staff from national Ministry of Health, town councils and divisional public health workers. The aim of this plenary sessions was to examine in detail the elements of the previous national dengue strategic plan and the related key indicators, and to analyse through group discussions whether these elements and indicators were achieved, and if not why not, and whether they are still relevant to the country when formulating the next strategic plan. The results of this analysis are presented below. When the next national dengue strategic plan is being formulated it will be important to use the results of the below situational analysis to help guide the strategic direction of the vector management approaches that will be incorporated within the final dengue management plan.

Element2012-2014 Strategic Plan	Key indicators in 2012-2014 Strategic Plan	Verification source	Results of Plenary Analysis
1. *Improved vector surveillance system and insecticide monitoring*	1. Number of vector sentinel surveillance sites established and following the new standard operating procedures 2. Entomological data (indices) analysed, and interpreted regularly and vector species distribution and abundance monitored	a) Entomological survey teams trained b) Entomological surveillance reports c) Vector species distribution maps d) Maps showing seasonal fluctuations in vector density and dengue case distribution	1.1 Established, need to improve links between Sub Division -> Division -> National Vector Control - SOPs need to be standardized 1.2 Yes it is practiced 1.3 Vector Control needs to

	3. Vector distribution and seasonality and dengue epidemiological maps updated 4. Comparative pupae-per-person index in three sentinel survey sites (urban vs rural areas) 5. Number of insecticide susceptibility tests carried out in the sentinel sites on *Ae aegypti* and *Ae albopictus* symmetrically, using the WHO standard test protocol	e) Key containers analysed and pupae-per-population index stratified f) Insecticide susceptibility data presented based on diagnostic doses of permethrin, delatmethrin and malathion	update records and data (GIS and MN's). However, this only happens in outbreak, needs to be routine 1.4 Focuses on larval 1.5 What is status? Need to assess! - No ento survey team from HQ especially in outbreaks - Need ento expertise in MHMS for internal training - Need better representation in methods
2. *Evidence-based strategy for vector control using IVM approach and elements*	1. IVM policy adopted by the National Dengue Steering Committee and dengue task force. 2. National public health pesticide management policy in place, with interagency participation 3. National dengue strategy and plan approved 4. Integrated selective intervention strategies implemented, based on	a) Meeting minutes/meeting records and joint field visits b) Pesticide safe handling and usage regulatory framework drafted, approved and implemented c) Number of dengue high-risk areas implementing selective vector control interventions based on vector surveillance	1.1 Other agency responsible -> piloted in Suva 1.2 Is it in place?? Unsure?? Probably not. 1.3 Strategy approved (needs to be reviewed each year and disseminated) 1.4 Based on hot spots. Needs to be continually reviewed and updated

	surveillance results 5. Appropriate container management conducted based on environmental management and source reduction 6. Mosquito-proof screen covers inspected and ill-fitting covers rectified	data d) Environmental sanitation strategy in place for removal of old tyres and discarded containers and implemented by town councils in collaboration with the Ministry of the Environment e) Number of supervisory visits and reports	- Strategy needs to be clearly communicated to operational staff - in outbreak hotspots need to be identified quickly for better targeted control 1.5 Not included as activity in field forms and screens not provided for in budgets * Larviciding strategies?? (currently not captured in field form)
3. *Implemented pilot COMBI project in two selected areas*	1. COMBI task force established 2. Target areas selected and behavioural messages formulated and approved 3. Advocacy meetings held and intersectoral agencies mobilized 4. Mass communication plan prepared, with the involvement of the mass media 5. Training workshop held on the	a) National teams in mass communication/ community participation b) Social scientists from various institutions c) COMBI national plan d) Number and types of IEC materials e) List of local agencies involvement	3.1 Not aware at sub divisional or divisional level if this is established 3.2 Yes, but need for more "targeted" messaging 3.3 Yes at national level 3.4 Yes 3.5 Yes, conducted 3.6 Yes, conducted 3.7 Only during outbreak

	management of mass communication/community participation 6. Pre-intervention and post-intervention surveys carried out on entomological evaluation and behavioural change 7. Number of dengue prevention volunteers recruited and trained 8. IEC materials, including two-page document on COMBI and flag, designed and produced 9. Personal selling implemented (weekly house-to-house visits by dengue prevention volunteers and programme supervisors) 10. Points of service established (in schools, churches, temples, etc.) 11. Surveys tracked by supervisors	f) Community participatory meeting records g) Reports of dengue prevention volunteers h) Records of house-to-house inspections i) Six-month monitoring and evaluation reports j) Post-project meeting report	3.8 Completed 3.9 Yes, conducted 3.10 Yes 3.11 Yes
4. *Implemented evidence-based emergency*	1. Number of vector control staff trained in insecticide handling, spraying techniques and machine calibration	a) Stock lists of insecticides, PPE and spraying equipment maintained	4.1 Training on Vector Control only during outbreak 4.2 Responses based on epi data

response for effective transmission containment during an outbreak	and maintenance 2. Number of epidemic vector control responses based on epidemiological reports and case investigation records (from the Epidemiological Surveillance Unit) 3. Number of epidemic vector control responses based on rapid entomological assessment 4. Percentage of post-entomological valuations based on ovi trap and/or rapid vector assessment 5. Intersectoral agencies mobilized to participate in source reduction and dengue campaigns 6. Community mobilized for source reduction 7. Number of localities implementing indoor selective residual spraying 8. Number of timely vector control interventions (within three days of the outbreak being reported) 9. Number of localities where dengue	b) Training course conducted c) Training materials prepared d) Report on vector control monitoring and evaluation e) Outbreak report	from SD Medical Officer> Daily/weekly, very patchy, not consistent nationally 4.3 Yes, used 4.4 Yes, conducted, unless no resources available 4.5 Yes, SD -> intergovt, NGOs, etc. 4.6 Yes, house visits, TV, radio, newspaper 4.7 Not practised for now 4.8 Yes 4.9 Data recorded but not tracked and councils not informed * Social mobilization and communication very important

	outbreak persisted more than 20 days from the date the first outbreak response was carried out

Session 2. Principles of Vector Surveillance and Control

1. Theory of mosquito management - integrated vector management

1.1 PUBLIC HEALTH & MOSQUITOES

Mosquitoes are the most important group of bloodsucking insects that cause nuisance and transmit diseases to humans and other warm-blooded animals. An insect that transmits a disease-causing organism from one vertebrate host to another is called a 'disease vector'. The vector mosquito and the parasites and pathogens that it can transmit, are now recognised to have played an important role in the development and dispersal of the human race, being responsible to a greater or lesser extent for events that have changed the course of history.

The study of the role of mosquitoes as vectors began more than a century ago. In 1878 Patrick Manson announced the filarial worm now known as Wuchereria bancrofti underwent development in mosquitoes. This was the first real evidence that an organism causing disease in humans had an obligatory development phase in an insect — a mosquito. In the next 50 years, a variety of insects, ticks, mites and other arthropods were incriminated as vectors of pathogenic organisms in both medical and veterinary science.

It is now realised that mosquitoes are vectors for three types of human pathogenic organisms: (i) the filarial 'worms' (nematodes which cause lymphatic filariasis), (ii) the plasmodia (protozoans which are the casual organisms for the malarias), and (iii) arboviruses (viruses causing such diseases as yellow fever, dengue fever and various encephalitis and arthritis; the term 'arbovirus' is derived from the 'arthropod-borne-virus': mosquitoes are insects which belong to the category of animals known as the *Phylum Arthropoda*, and arboviruses are viruses that are transmitted between vertebrate hosts via an arthropod acting a as an intermediate host).

Although vaccines, chemoprophylaxis, chemotherapy, insecticides and other vector control measures are becoming more sophisticated, none of the major mosquito-borne diseases of the world may be said to be under complete control. Malaria still claims millions of lives annually throughout the tropics; yellow fever is still firmly entrenched in jungle areas of Africa and South America, occasionally emerging to initiate urban outbreaks; dengue fever continues to cause suffering and death in South America, Southeast Asia, the Caribbean and Pacific regions; chikungunya and zika virus continue to expand their range with large outbreaks having significant impacts on populations and on health systems and economies; other viruses causing fatal encephalitis and various debilitating symptoms are still transmitted in tropical and temperate parts of the African, American, Asian and Pacific

regions; and filarial worms carried by mosquitoes are responsible for urban and rural ill-health in many tropical and sub-tropical regions.

Some of these disease spread by mosquitoes are associated with animal reservoirs and are called zoonoses (e.g. yellow fever, the virus encephalitis, brugian filariasis), while others involve only human reservoirs (e.g. malaria, dengue, bancroftian filariasis). However, in all cases the crucial factor in the transmission pattern to man — the epidemiology of the disease — is the amount and type of contact between the mosquito vector and the human host. The incidence of the disease will be dependent on what may be called 'human-vector contact'; this is a function of the habitat and behaviour of the mosquito vector, and the habitat and behaviour of the human host.

The more that the potentially infective mosquito intrudes into the human environment or the more that humans intrude into natural environments where mosquitoes harbour pathogenic organisms, the greater the risk of transmission to an individual and a subsequent risk of initiating and urban outbreak or epidemic. Therefore, the greater knowledge and appreciation that we can have of the natural history and ecology of the mosquito and the pathogenic organisms, the better prepared we can become to avoid, combat or control a potential or actual disease situation.

Mosquito-borne diseases are especially complicated communicable diseases, because they involve the vector as an additional component of the disease system. Social, behavioural, environmental and immunological factors may affect the human component, yet with vector involvement further influences impinge on the system and still more may arise if the disease is a zoonosis, involving other vertebrate animals as well as humans. Such a complex system may seem formidable, but the more complicated the system, the greater the number of 'weak-points' to target for attack — the prime reason for seeking the fullest possible understanding of the system we are trying to disrupt (i.e. control).

The main thrust of research in vector-borne disease is often toward control of the disease through control of the pest or vector. Although vector control programmes in various parts of the world have often failed, or have been interrupted, for a variety of reasons such as administrative problems, insecticide resistance, or behavioural characteristics of the vector population, a detailed knowledge of the ecology and behaviour of the target species is considered a prerequisite to planning a control campaign. The value of obtaining base-line data on the vector populations if control is to be undertaken has often been stressed by scientists working with mosquito-borne diseases, and a reduction of a vector population to a certain level (rather than its eradication) can often be achieved and indeed be sufficient for control of the transmission of disease.

The problems of containing mosquito populations at tolerable levels with the various techniques developed for mosquito control have led to an appreciation of the value of developing an educated approach wherein different methodologies are integrated such that reliance on one particular control operation, whether physical, chemical or biological is avoided. As a result, many of the problems inherent in long-term control are avoided.

Mosquito problems are a product of the contact between humans and mosquitoes, i.e. an interaction of human habits/habitats with mosquito habit/habitats. Understanding mosquitoes, their place in the natural environment, and the strengths and weaknesses of their ecology are essential prerequisites for successful control efforts.

1.2 MOSQUITO BIOLOGY

As far as the transmission of disease causing pathogens are concerned, it is only the adult female mosquito that is important since the male does not suck blood nor bite in any way. However, to understand the complexities of diseases and therefore the specific methods of control that are appropriate in different situations, various aspects of the natural history of mosquitoes should be understood.

Basically, the mosquito life cycle (Figure 1) begins with an adult female laying eggs. From the egg emerges an aquatic immature stage called the larva (plural = larvae), which develops through four moults, increasing in size until at the final moult it reaches a non-feeding stage the pupa (plural = pupae). Inside the pupal skin the adult is forming as either a male or female, and the terrestrial/aerial adult stage emerges from a split in the back of the pupa. The adults feed, mate, and the female develops eggs to complete the cycle and begin the next generation. Some species of mosquito may have only one generation per year, others will have several generations during a season of favourable climatic conditions, others will continue to breed throughout the year; much depends on climatological aspects of the local environment, particularly temperature and rainfall.

Before proceeding further, some simple knowledge of the classification and naming of mosquitoes is necessary. Within the 'Animal Kingdom', the insects as we know them are grouped together as the Class Insecta. The group of insects known to us as mosquitoes belong to the category of insects known as the Order Diptera, i.e. the two-winged 'flies'. Within the Diptera, all mosquitoes belong to a family group known as *Culicidae*. Within this family, mosquitoes with a range of similar characters are grouped into Subfamilies e.g. the *Culicinae* and the *Anopheline*. These groupings are further subdivided into closely related sub-groups called Genera (single = genus); important genera are *Anopheles* in the subfamily *Anophelinae,* and *Aedes* and *Culex* in the subfamily *Culicinae*.

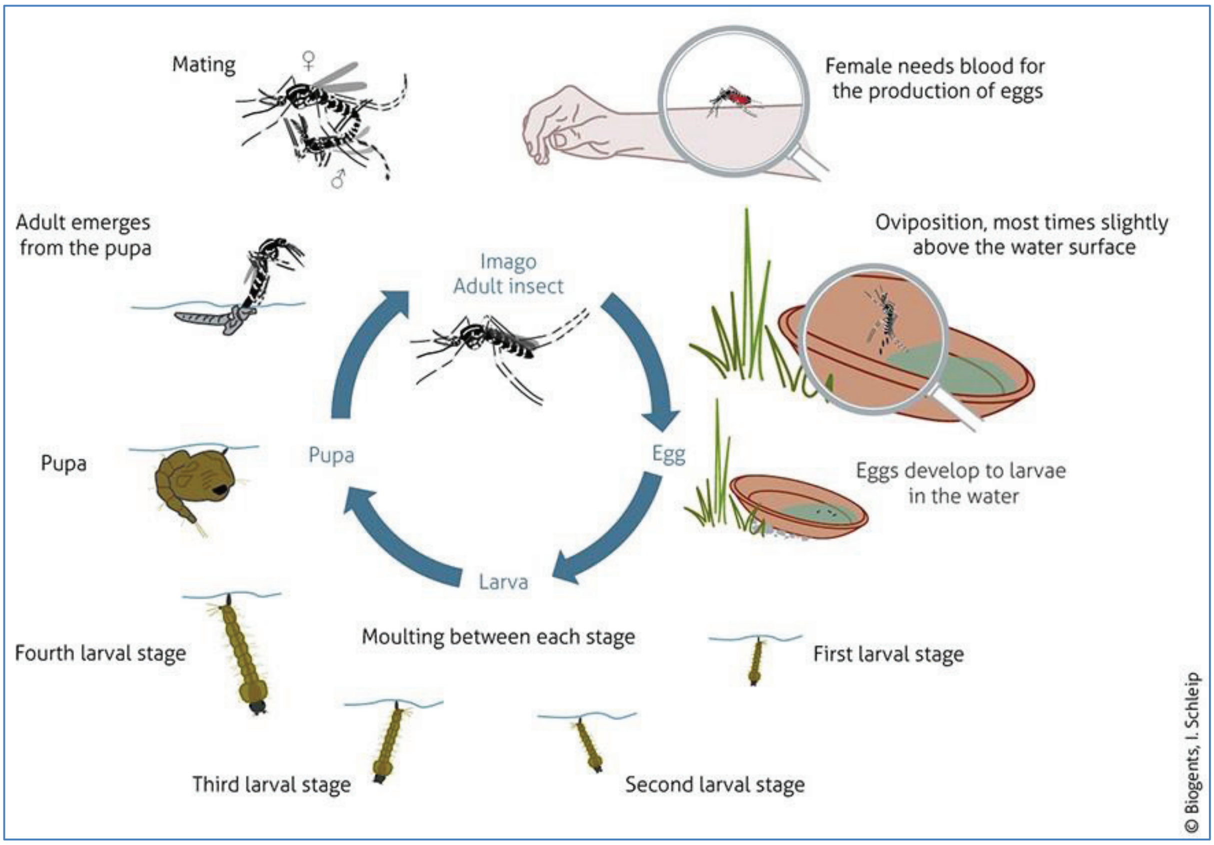


Figure 1. *Aedes* mosquito life cycle

Mosquitoes which are of the same species are assigned specific names, giving them a 'double-barrelled' title (e.g. *Anopheles farauti*, *Aedes aegypti*, *Culex quinquefasciatus*). By convention, the species name is always underlined or written in italics.

As the physical appearance of different species allows them to be grouped together in a genus, so these species have biological traits which are common to members of that genus. These traits can be exhibited from the initial phase of the mosquito life cycle, and there are three major 'models' within the aquatic life cycle that can be illustrated by the genera *Aedes*, *Anopheles* and *Culex*.

THE EGG

Aedes species lay their eggs as single units and deposit them, not on a free water surface, but on a moist substrate (e.g. rock surface, moist earth, inside wall of a tree-hole or container) above the receding water level or insert them under debris, and into crevices in soil and drying mud where they will be subsequently flooded. These eggs are able to withstand desiccation and can survive long periods, until the water level rises with rain, flood or tide to inundate them, at which time they begin to hatch, often only in batches rather than all at once. *Aedes* species are generally found associated with temporary bodies of water, or those that might be persistent but have fluctuating levels.

Culex species deposit their eggs on a free water surface with the eggs in a compact cluster, glued upright together in the form of a raft, which floats on the water surface. The eggs cannot withstand desiccation, will hatch after 2 days or so if not stranded by water movement, and are usually associated with permanent or semi-permanent bodies of water.

All species of the genus *Anopheles* lay their eggs (oviposit) as single units on the surface of a collection of water. These eggs are completely dependent on the presence of free water and usually hatch in about 2 days after laying (oviposition). If stranded by the water drying up or by wave action they will perish.

THE LARVAE

The habits and habitats of mosquito larvae are rather diverse; but essentially the larval stage of the mosquito life cycle is an aquatic animal and must have an aquatic habitat in which to complete its development to the pupal stage. The larval habitat is selected by the female when she deposits her eggs; she is able to discern physical and chemical properties of different collections of water and choose between sites available for her selection.

Larvae can be found in many different habitats, and for the Pacific the most relevant habitats include permanent fresh and brackish water creeks for *Anopheles*, natural and man-made permanent water bodies for *Culex* and natural and man-made containers for *Aedes*.

Species usually have a preference for a particular type of breeding site, but features visible to us may not always be the characteristics selected by the gravid female looking for a place to lay her eggs. In many instances such factors as shade or sunlight; presence or absence of floating, emergent or marginal vegetation; pollution; salinity; temperature; and others (such as the texture of the substrate for *Aedes* species) may influence the female, and we can often recognise a number of these factors as being characteristic of the typical breeding site of a particular species.

The larvae hatch from the egg and grow through four instars or stages, in between which they moult their rigid outer skin in order to increase in size. They feed on microscopic organisms in the water, or on decaying vegetation and other bottom detritus, either by filtering water through their mouthbrushes of fine hairs or by grazing with specially adapted mouthbrushes; some larvae are predatory and their mouthbrushes are strongly modified to grasp prey. Some species feed habitually at the surface (e.g. *Anopheles*), some in the middle range below the surface (e.g. *Culex*), and others typically feed on the bottom of the habitat (e.g. *Aedes*). Larvae breathe air, from openings (spiracles) at the 'tail' end of the body, generally through a tube (siphon) which can penetrate the surface of the water.

Although they will submerge when disturbed and may remain motionless on the bottom for some time, larvae need to return to the surface for air to prevent suffocation.

The time taken for development through the larval stages is dependent on a number of environmental factors, the most important of which is temperature, although availability of food and the extent of larval crowding within the habitat are also important. During favourable summer conditions *Anopheles* and *Culex* species may complete larval development in 7-10 days, *Aedes* species may complete development in as little as 4-5 days.

Identification of larvae is most easily accomplished with mature larvae, i.e. the fourth instar, and microscopic examination is usually required. However there are some genus characteristics that enable partial identification in the field. Larvae of *Anopheles* species have no siphon (breathing tube) and when feeding or resting they lie flat at the surface of the habitat. *Culex* and *Aedes* species have siphons and hang suspended from the surface when obtaining oxygen; *Culex* typically have 'longer' siphons than *Aedes*, and while *Aedes* species generally may be described as grazing 'bottom feeders', *Culex* species generally feed from the surface to the bottom.

THE ADULT

The adult mosquito rests on the water surface for a short time after emergence from the pupal casing, to allow its wings and body to dry, before flying off to pursue the next phase of its life cycle.

In a single generation, the males of the species usually develop marginally more quickly than females, and males are usually first to emerge from the larval habitat. However, this is not always noticeable in the field where generations may overlap. Male mosquitoes, upon emergence, do not normally travel far from the breeding site. They feed on plant juices, flower and fruit nectars, and mate with the females. Males generally have a relatively short life span, and as they do not bite humans nor feed on blood from any source, they are of little importance as far as disease transmission or pest nuisance is concerned. However, they are of some significance for surveillance operations in that when male mosquitoes are detected, it usually indicates that a breeding site is relatively close nearby and breeding may be current.

Following emergence, the adult female will generally seek out a carbohydrate meal of plant juices to replenish expended energy reserves. It will then mate with a male, usually near the breeding site and often at dusk. Female mosquitoes mate only once, the sperm packet introduced by a male during the mating act serving the female to fertilise all batches of eggs she subsequently produces. For mating, male mosquitoes may form swarms, often at dusk

and associated with markers such as a bush, tree stump, or bare patch of ground. The males recognise females flying close to the swarm by their wing beat frequency, team up with a female and copulate.

For development of eggs, female mosquitoes require protein and this may be provided either from nutritional reserves carried from the larval stage or from a meal of a high protein source such as blood. A few species can develop a first batch of eggs without a blood meal, but will then attack a blood source for the nutrients required for second and subsequent batches.

Females can survive on plant juices, but most of the species important as pests or disease vectors seek blood soon after mating, about 2-3 days of age, and then embark upon a life of repetitive cycles — feeding, resting, developing and laying eggs — feeding, resting, developing and laying eggs; and so on.

The preferred source of the blood meal can vary widely between mosquito species and with different situations. The source of the blood meal is epidemiologically important, as some pathogens/parasites are associated with particular vertebrate hosts. Some mosquitoes feed on snakes, frogs and even fish, and these cold blooded feeders are of little concern for humans. Generally, the potentially important species for transmission of zoonotic diseases (e.g. West Nile virus, Japanese encephalitis) are those that feed on bird and/or mammal hosts and also on humans — the opportunist feeders; and for primarily human diseases (e.g. malaria, dengue) the most potentially important are those that feed preferentially on humans.

A mosquito species can be more or less particular about its source of blood, but with some species this may vary with circumstances and with different populations of that species — it could depend on the range of blood hosts available for instance. A mosquito which generally prefers animal stock, even in the presence of humans, may readily feed on humans in the absence of the preferred host. A species normally feeding on birds may well seek mammalian blood when mosquito populations are high and extend beyond their normal habitat, or when humans enter the mosquito habitat while hunting/fishing or walking. In this scenario it is possible for humans to be infected with pathogens considered to be normally associated with birds/mammals in forest/swamp habitats and rarely infecting humans.

In general terms, mosquitoes are attracted to a warm blooded host by a combination of factors. Carbon dioxide, a product of respiration is an important attractant, as are various body odours, and these factors seem to be the 'long range' attractants. At closer distances temperature can be a factor and visual perception may be important at very close range.

Other circumstances of feeding behaviour can vary between mosquitoes and be characteristic of particular species. Many species feed primarily during the twilight hours of sunset and at dawn; others have peak biting periods during the deep of night, and their behaviour may be influenced by moonlight; others may be described as daytime biters, although some will only bite in shaded conditions; other species may bite virtually any time a host is available. The twilight biters are termed 'crepuscular', the night biters 'nocturnal' and the day biters 'diurnal'. Apart from the influence of light conditions, it is known that temperature and humidity also play a role in determining host-seeking behaviour.

Some species will readily enter a building/dwelling/shelter to obtain a bloodmeal, while others will only bite 'out-of-doors'. Some species will rest 'indoors' before or after a bloodmeal, while others even if they bite indoors will immediately fly out to find a resting place.

After taking a blood meal, the female searches for a secluded resting spot where the meal can be digested and the ovaries can develop eggs. In the field, mosquitoes will find suitable conditions for resting, for instance, amongst dense vegetation, inside a hollow log or tree, rock cave. The time needed for complete egg development is dependent on mosquito species and the prevailing temperature, but the minimum is of the order of 2 days (*Anopheles* species and some *Aedes* species). *Culex* species may take at least 4 days to mature the eggs, and at lower temperatures in spring and autumn the period may involve 10 days or more. When the eggs are mature within the ovaries the female will fly from the resting site in search of a suitable larval habitat where she can deposit her egg batch — often in late afternoon or evening. She will then fly off in search of a bloodmeal in order to repeat the cycle; subsequent bloodmeals can be taken the night of oviposition if a host is nearby, otherwise a day or more may elapse before the next feed. Thus some mosquitoes may feed every 2-3 days, others no more than every 5-6 days, repeatedly throughout their life.

For some species, a single bloodmeal is not sufficient for the production of the first egg batch, and although many species will produce eggs from a single meal, laboratory studies have shown that some require a second meal. In general terms the size of the blood meal (and also its source) determines the number of eggs that can be oviposited, and although as few as 20-30 eggs may be laid by some species under some circumstances, egg batches of other species may contain up to several hundred eggs at the other extreme.

The longevity of adult mosquitoes is a complex but very important issue. They are subject to the attack of many predators including birds, bats, frogs and other insects; parasites and pathogens such as worms, protozoa, viruses, bacteria and fungi; they are also at the mercy

of the rigors of the environment with the vagaries of wind, rain, humidity and temperature all taking their toll on the small and fragile insect. In the laboratory some mosquitoes can be kept alive for many months under certain circumstances, while others will not survive more than a few days even under apparently favourable conditions. In the natural environment an age over one month would be considered very old, although some species are innately more long-lived than others.

Age of a female mosquito, particularly one which is of threat as a vector of disease, is a most important factor in the epidemiology of disease transmission. For a female mosquito to become a disease vector, she must first take a bloodmeal from a host infected with the parasite or pathogen and must take up 'infecting' stages with that bloodmeal. If she is susceptible and becomes infected with the pathogen, she must survive for the period of incubation required for the pathogen before she becomes infective herself and can transmit the pathogen to another host at a subsequent bloodmeal.

This period of incubation within the mosquito varies with pathogen or parasite and with temperature, but for dengue it is approximately 10 days. If the incubation period required is of the order of 10 days, a mosquito must survive for that 10 day period after she takes her 'infecting' bloodmeal before she can possibly transmit the disease organism. During that period she may bite a number of subsequent hosts without transmitting the pathogen, but all the time exposing herself to death via the different agencies mentioned above. Mosquito age can be determined by dissections of the ovaries indicating the number of egg-laying cycles completed and, with knowledge of the period required for egg development, the calendar age can then be estimated; results from studies of some common mosquito species indicates that less than 10% may survive to 10 days of age.

Dispersal is an important factor in mosquito ecology. Many mosquito species typically move only relatively small distances (sometimes no more than 50-100 metres, as for *Aedes aegypti*) from their larval habitats, providing appropriate blood sources are available in the vicinity, while some move back and forth within a range of 1-5 kilometres; other species have a definite 'migratory' behaviour component that may be facultative with large population densities or obligate as part of their normal biology. There are a few species known to be able to able to disperse at least 50 km, often downwind, associated with periods of peak adult activity.

The time taken for development from egg to adult varies greatly with environmental variables, particularly temperature, but an estimate of 1-2 weeks under optimum conditions should see most common tropical species reach the adult stage. Species which normally inhabit temporary situations such as tree holes, rain-filled depressions, and containers usually have

a shorter development period than those species that use more permanent waters, and may complete development in a week or less in summer periods.

1.3 THEORY OF MOSQUITO CONTROL

Before initiating a mosquito control programme there are a number of questions that should be addressed in order to ensure an effectual, economical and environmentally acceptable programme.

a) WHY (Surveillance & Monitoring)

Is it for the prevention of disease amongst the human or animal populations, or is it because the 'quality of life' of the human community is affected by the biting of pest mosquitoes as either a seasonal occurrence or as a year-round problem?

Either of the above reasons may justify the implementation of a control programme, but each will involve considerations and decisions on issues related to social, economic, environmental and political implications before, during and after the course of the programme.

b) WHEN (Surveillance & Monitoring)

When will the control programme begin and when will it be terminated? The confirmed presence of dengue will almost certainly signal the need to start control operations, but an 'early warning system' that reduced the risk of human disease would be a great advantage. This is not an easy problem to overcome, but surveillance of climate and pathogen activity and/or vector mosquitoes, and the monitoring of vector population abundance may provide such a pre-epidemic signal.

With respect to an anticipated outbreak of disease, there are options for either 'pre-emptive' or 'reactive' control action. There may be strong arguments for control to begin early in the 'season of activity' of either the target species (*Aedes*), or it may be more appropriate to wait until there are definite indications that transmission has already begun; the nature and likely severity of the potential outbreak in question will also influence decisions.

The effects of the control operations on non-target species and on the environment in general, and with regard to particular factors such as the development of insecticide resistance in the target species, will need to be considered. Such implications are particularly relevant to both long term programmes and intensive short term programmes.

c) WHERE (Surveillance & Monitoring)

In any situation where disease is being transmitted, the prime objective is the interruption of transmission as soon as possible, and all vector control methods should aim to disrupt contact between humans and vectors, and to interrupt transmission effectively and economically. It will be important for the program to decide 'where' this can be done, both within the vectors lifecycle as well as the geographical scale and locations to be targeted. In order to better direct the programs decision on where to target control efforts, tools such as epidemiology, disease stratification and vector surveillance can help with making informed and logical choices.

d) HOW (Planning & Implementation)

How will the mosquito programme be devised, organized and supervised? The methodologies and technologies available for incorporation in modem dengue mosquito control programmes can be quite varied, and decisions on 'how' to implement often relate to programs capacities in planning, implementation and evaluation. The choice of control technique/s will involve considerations of availability, economy and efficacy, with particular tailoring of the recommendations to the specific circumstances of the particular national programs and their circumstances.

In an attempt to pre-empt disease transmission, a control programme may be mounted early in the vector season and directed primarily against the vector mosquito's larval populations to retard the build-up in adult populations for the time that the pathogen is expected to become active. Control programmes directed against a vector species during an outbreak of disease, when the pathogen is already being transmitted, may be principally directed against the adult mosquito population, in an attempt to reduce the numbers of those mosquitoes already infected with the pathogen and likely to be involved in transmission within the immediate future.

It should be remembered that the larval control programmes will not have an immediate effect on adult population numbers, and are generally not appropriate for interruption of disease transmission in epidemic circumstances, however larval control should be undertaken in conjunction with adult control during an epidemic (if at all possible) to inhibit replenishment of adults if the pathogen is still active in vertebrate reservoirs or hosts.

Although adult control programmes reduce the overall age (which is most important in the dynamics of transmission) of the vector population, larval control programmes can actually increase the age of the adult population (by reducing the input of younger individuals) and thus create an 'older' and, from a disease perspective, a more dangerous vector population.

Therefore, before beginning a vector management programme we must be able to define the problem as accurately as possible, formulate objectives that are practicable, select the appropriate control measures carefully, know how we can monitor the effectiveness of the operations during the programme, and establish procedures for an evaluation of the control operations at the completion of the programme.

2. Pacific vectors - biology, ecology, breeding habits and identification

The purposes of this chapter are to provide an overview of both the historical and the current impact that vector borne diseases have on Pacific Islands Countries. The impact of vector borne diseases on both the health of a countries population and on its health systems and economy can range from being very mild, to crippling, depending on a range of factors such as the disease type, disease epidemiology, population immunity, vector status, socio-economics, climate, seasonality, level of clinical care and public health responses.

In the Pacific context, there are three main types of vector borne pathogens that are endemic to the region, filarial worms (lymphatic filariasis), plasmodia protozoa (malaria parasite) and arboviruses (arthropod borne viruses such as dengue and chikungunya). While the presence and impact of each of these diseases in the Pacific may have their own story, in medical terms none of them could be considered to be 'under control'. In fact in recent years the risk that vector borne diseases are posing to countries in the Pacific could be said to be increasing dramatically. This is probably due to a host of causes, but the primary areas of concern that are creating this increased pressure are:

- unplanned urban development
- poor water storage and sanitary conditions
- climate change (changing rainfall patterns, increasing temperatures etc.)
- high population density
- poor housing construction
- increased international travel

The nature of a vector borne disease is that the epidemiology of the disease is closely linked to the inter-relationship of the vectors, the pathogen and the hosts. All of the above mentioned factors exert some sort of influence on this relationship, whether it is through higher than usual minimum temperatures, allowing faster virus replication within the mosquito vector, or higher proportions of host populations living closer to each other creating larger more intense transmission cycles. As well as increased transmission pressures from environmental and behavioural changes within countries, there is also the increasing risk of importing arboviruses from other PICs and regional countries where arboviruses are endemic, through the growing trend in international air travel and trade.

As mentioned above, when discussing vector borne diseases, the three crucial elements of the disease transmission cycle are the pathogen, the vector and the host. All vector borne pathogens have their own life cycle, some of which are quite complicated and can include multiple host stages across a range of animal hosts. For instance Japanese Encephalitis and

Ross River virus, while transmitted by a mosquito vector, can have multiple hosts, including humans as secondary or dead end hosts, and additional primary hosts such as pigs, birds or marsupials. Other vector borne disease such as (human) malaria and dengue are much simpler and only have one host, humans, and one vector, mosquitoes. Vector borne diseases that include an animal reservoir in their life cycle are classified as 'zoonotic' diseases and those with only human reservoirs are classified as 'non-zoonotic'.

The distribution or presence of VBDs in PICs (and anywhere else) is very much dictated by the presence/absence of the vectors and the pathogen. For instance Solomon Islands and Vanuatu are the only countries in the Pacific where malaria mosquitoes (*Anopheles*) are endemic, whereas the major dengue vector (*Aedes aegypti*) can be found in almost all Pacific countries (Figure 2). While effective vector control interventions and case management strategies are successfully reducing the impact of malaria in the Pacific, in recent years the severity and occurrences of arboviruses such as dengue, chikungunya and zika have been increasing in almost all PICs.

Disease	Country/Region	PIC Vectors
1. Dengue	Pacific wide	*Ae. aegypti, Ae. albopictus, Ae. polynesiensis* & numerous other species in the *scutellaris* group
2. Chikungunya	New Caledonia, Tonga, FSM	*Ae. aegypti, Ae. albopictus, Ae. polynesiensis*
3. Zika virus	FSM, French Polynesia, New Caledonia, Cook Islands	*Ae. hensilli, Ae, aegypti*
4. Lymphatic filariasis	Pacific wide (except in 6 countries)	*Cx, quinquefasciatus, An.farauti, Ae. albopictus*
5. Malaria	Solomon Islands, Vanuatu	*An. farauti, An. hinesorum, An. punctulatus*
6. Epidemic Polyarthritis (Ross River virus)	Fiji, Cook Islands, New Caledonia, Tonga, Samoa	*Ae. vigilax, Cx. annulirostris, Ae. polynesiensis*
7. Japanese Encephalitis	Micronesia (Guam), Nth Mariana	*Cx. tritaeniorhynchus, Cx. annulirostris, Cx. sitiens*

Figure 2: VB Disease & Major Vector Distribution in the Pacific

2.1 Dengue virus

Dengue is a member of the *flavivirdae* family of viruses, and has four serotypes, simply labelled dengue type 1, dengue type 2, dengue type 3 and dengue type 4. It has historically

been a very significant disease which can burn through susceptible populations with high rates of morbidity, and in some cases high mortality. It is one of the fastest spreading diseases globally, that now affects over 100 countries. It is especially crippling in developing countries where socio economic factors, such as housing, water and sanitation, leave these countries more vulnerable to explosive outbreaks, and where the weaker health care systems are easily over burdened.

The first dengue epidemic was recorded in Hawaii in 1844, with waves of epidemics in other Pacific countries following in the 1940s, 1970-1990s, and then increasing since 2000. This disease is progressively becoming one of the most burdensome public health diseases in the Pacific region, with over 50 outbreaks recorded over the previous 30 years. Over the past five years there have been significant outbreaks in Solomon Islands, Vanuatu, Fiji, New Caledonia, French Polynesia, Marshall Islands, Nauru and Tonga.

The major vectors for this disease in the Pacific are *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis*, however there are a number of other vector species which may play important roles in transmission that are endemic to a limited number of countries.

2.2 Chikungunya Virus

Chikungunya is an alphavirus, which is part of the togaviridae family, and was first discovered in Tanzania, Africa, in the 1950s, and has now become one of the most significant emerging disease threats over the last 10 years. The first recorded outbreak of this disease outside Africa occurred in the Reunion Islands in the Indian Ocean in 2005, with over 25,000 people affected. It has quickly spread from since then to Asia and more recently the Pacific. While the disease does not generally display symptoms as severe as dengue, the level of morbidity can very high and symptoms can longer for months and years in some cases. The vectors for this disease are the same as for dengue, however *Aedes albopictus* is considered to play a more significant role as a vector of this disease.

The first recorded chikungunya virus outbreak in the Pacific was in New Caledonia in 2011, and other outbreaks have since been experienced in Yap Island, Tonga, Samoa and French Polynesia. As with dengue, every PIC has at least one potential vector species present for this disease, creating a high risk situation for all countries, with increasing risks of exposure the longer that chikungunya is circulating through the Pacific.

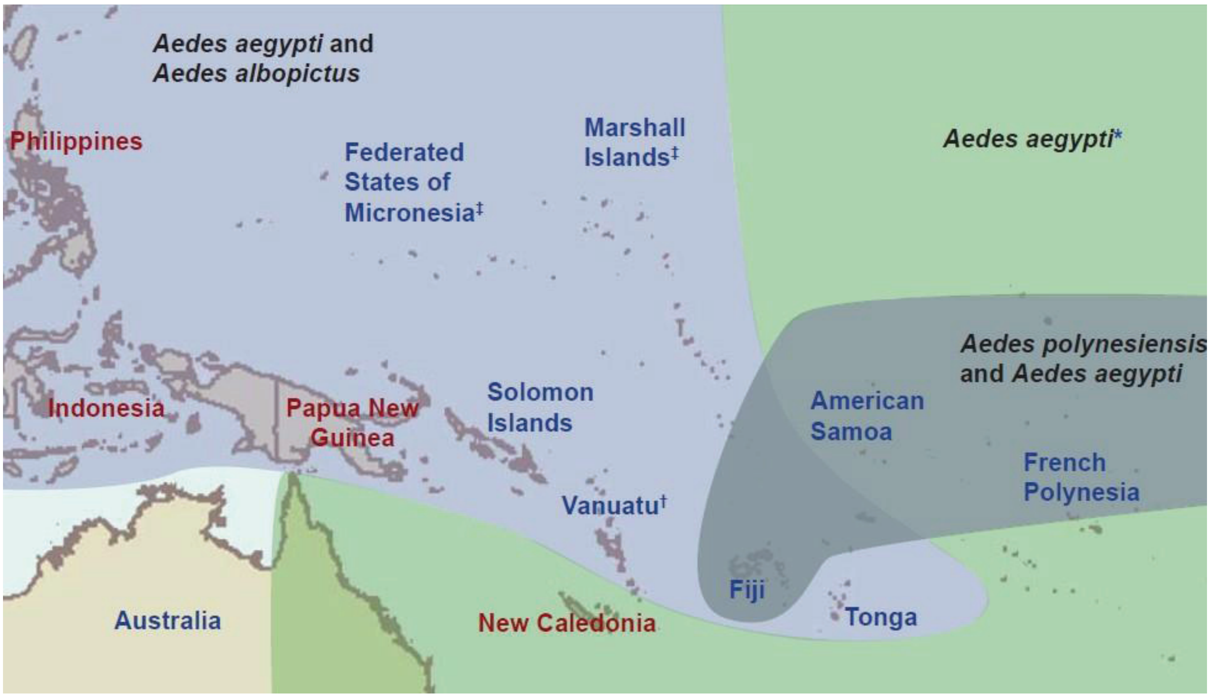


Figure 3: Distribution of chikungunya virus vectors in the Pacific

2.3 Zika Virus

Zika virus is another recently emerged vector borne disease. It was also first detected in Africa in the middle of last century, and while some cases were diagnosed in Asia in the 1980s and 1990s, this disease was also not associated with any major outbreaks until early this century, when a large number of cases were recorded in the Federated States of Micronesia (Yap Island) in 2007. Since then the disease has moved further into the Pacific, with epidemics in French Polynesia, New Caledonia, Cook Islands, Easter Island, Solomon Islands and Vanuatu.

Zika has similar symptoms to dengue and chikungunya; however they are usually milder and do not last as long. For this reason, as well as there being no specific Rapid Diagnostic Test (RDT) for this disease, and its cross reactivity with flaviviruses in some RDTs, it can be difficult to detect. There is some increasing evidence that outbreaks of this disease can be associated with auto immune illnesses, however studies on this association are not yet conclusive. The vectors for this disease are again the *Aedes* species, specifically *Aedes aegypti* and *Aedes albopictus*, however there may be other localised endemic *Aedes* species in some PICs that are also able to transmit this disease, but this will not be known until further research is conducted in this area.

2.4 Malaria

As mentioned previously, there are only two PICs where malaria is endemic, Solomon Islands and Vanuatu, as these are the only countries in the region where the mosquito

vector for this disease are found (*Anopheles farauti* and *Anopheles punctualtus*). The burden of malaria in these counties has been historically very high, although there have been some periods of reduced transmission due to concerted control efforts. This was especially evident during the 1950s - 1970s when there was a global malaria eradication effort, with large financial investments made by colonial governments and wide spread use of DDT to reduce mosquito populations and chloroquine to target the malaria parasite. Once the environmental impact of DDT became better understood, and the presence of resistance to the insecticide by the target mosquito vector species, as well as resistance by the malaria parasite to chloroquine, was detected in many countries, this strategy was abandoned and the rates of malaria in Solomon Islands and Vanuatu returned to naturally high levels.

In the previous ten years other malaria control strategies have been adopted globally, using a more targeted approach that has less environmental impact (long lasing insecticide treated bed nets) and will hopefully slow the rates of resistance by the parasite through the use of a combined anti-malarial treatment (ACT – Artemether Combined Therapy). Due to the large investments by local governments and external donors such as Bill and Melinda Gates Foundation, Global Fund and the Australian Government, the malaria programs in Solomon Islands and Vanuatu have implemented nearly 100% coverage of these strategies to their at risk populations, creating a huge drop in incidence rates that are nearing the lowest levels ever seen, and approaching a period where elimination of this disease in the region could become a reality.

2.5 Lymphatic filariasis

Lymphatic filariasis is a parasitic disease (nematode) that can lead to a disease commonly known as elephantiasis. It affects nearly 1.4 billion people in 73 countries worldwide. The disease is most often transmitted by the *Culex* mosquito, which are especially widespread across urban and semi-urban areas of the world. However in some countries in the Pacific (such as Solomon Islands and Vanuatu), *Anopheles* is the main culprit, where transmission occurs in rural areas, and *Aedes* has also been shown to be an efficient vector in other pacific countries such as Fiji and Samoa.

To interrupt the spread of the infection of LF WHO recommends an annual large-scale treatment with single doses of 2 medicines to all eligible people where the infection is present. In 1999 WHO launched the Pacific Program to Eliminate Lymphatic Filariasis (PACELF), which aimed to eliminate lymphatic filariasis by 2020 in all PICs by interrupting of transmission through Mass Drug Administration (MDA). Lymphatic filariasis was endemic in 16 of 22 pacific countries, and 11 of these endemic countries implemented MDA programs

through the PacELF program, resulting in huge decrease in the prevelance of this disease in these countries, some of which are nearly qualified as having eliminated LF.

2.6 Ross River virus and Japanese Encephalitis

These two diseases, while major arboviruses in some other contexts, are not of chief concern in the Pacific, especially in light of the waves of dengue, chikungunya and zika that the region has been experiencing the last few years. Japanese Encephalitis (JE) is very significant globally, with over 50,000 cases annually, and 15,000 deaths, it does not have a large presence in the pacific. There is a high level of mortality in symptomatic cases, but 98% infections are asymptomatic. JE is a zoonotic disease, with important reservoir hosts in pigs and birds and the major vector species in the Pacific are *Culex tritaeniorhynchus* (only in Mariana Islands), *Culex annulirostris* (widespread in Pacific) & *Culex sitiens* (widespread in Pacific).

Ross River virus was first isolated from Ross River, Queensland, Australia in 1959, and is the most common arbovirus in Australia. There have been outbreaks of this disease recorded in Fiji, the Cook Islands, New Caledonia, Tonga and Samoa, but as with JE, however the impact and burden of this disease in the Pacific is minimal when compared to malaria, dengue and chikungunya. It is a zoonotic disease, with reservoir in non-human hosts (i.e. rodents, marsupials), but humans-mosquito-human transmission may occur. In the Pacific, the main vector species are: *Aedes vigilax*, *Aedes polynesiensis*, *Culex annulirostris* & *Aedes notoscriptus.*

2.7 Conclusions

It is suggested that climate change will increase the risk and the impact of vector borne diseases in many countries, including PICs. Any change in environmental conditions (whether through climate change or other changes like behaviour) has the potential to affect the relationship between pathogens, vectors and hosts. For example hotter and wetter conditions could theoretically manifest alterations in VBD patterns by changing the levels and frequency of mosquito production and development, and also by creating longer seasonal activity for the vector and the pathogen, and by causing faster replication and incubation periods for diseases in the host and the vector. Changes in climate are already a reality in most pacific countries, and it is acknowledged that these disease are sensitive to these changes, however the pattern of these sensitivities for each country is not known, and it may well be greater for some diseases and some vector species, and for some regions, but lesser for others. What is clear at the moment is that VBD are increasingly becoming a burden on the populations, the economy and the health systems of PICs, and that more effort, from all stakeholders, is required to address and halt this trend.

3. Vector surveillance - An integral monitoring and evaluation tool

Vector surveillance (or entomological surveillance) is the monitoring of seasonality, abundance, behaviour and infectivity of vector populations. Surveillance of *Aedes* density is important in determining the risk of dengue transmission in order to initiate vector control interventions or to prioritize areas for intervention. Vector surveillance is also important for evaluating the effect of vector control. Selecting the appropriate surveillance strategy depends above all on the objective of surveillance: Is the objective to determine whether dengue vectors are present, to determine their fluctuations in abundance, their absolute population density, risk of virus transmission or a selection of all these options?

3.1 Larval/pupal indices

For practical reasons, larval surveys have been the most commonly used method for dengue vector surveillance. Three types of indices (House Index, Container Index, Breteau Index) have long been in use in many countries because they are simple and quick. These indices are intended to indicate the presence of *Aedes* mosquitoes, but are not meant for measuring the density or abundance of species. The House Index was originally developed for programmes aiming for elimination of vector populations, not for vector control programmes, so is not very relevant to Pacific countries.

House Index: $\frac{Number\ of\ houses\ with\ positive\ sites}{Total\ number\ of\ houses\ inspected}$ x 100%

The Container Index: $\frac{\text{Number of positive containers}}{\text{Total number of containers inspected}}$ x 100%

The Breteau Index: Number of positive containers per 100 houses

These indices give only a relative measure of vector population density. Therefore, they are poor indicators of transmission risk. Among the three indices, the Breteau Index is the most informative, because it combines data on containers and houses. Still, these indices do not provide any information on the size or productivity of containers. For example, no distinction is made between a highly productive water storage container and less productive breeding containers.

Consequently, the three traditional indices have often failed to provide the required information on transmission risk or programme impact, because they do not provide absolute estimates of the vector population. Only a small fraction of *Aedes* larvae will successfully develop into a pupa, whereas approximately 90% of pupae will successfully emerge to adulthood. Therefore, pupae are much better indicators of emerging adult population than are larvae.

To address this concern, the Pupal Index has been developed, and extensively tested in field situations.

Pupal Index: $\frac{Avg\ number\ of\ pupae\ collected\ per\ house}{Average\ number\ of\ persons\ per\ house}$

Unlike the traditional indices, the Pupal Index provides an absolute measure of the number of pupae per person, which represents transmission risk. Movements of people (e.g. daily commuting to work) will complicate the data recording on the number of persons per house. The Pupal Index is more labour-intensive than the traditional indices but, considering the quality of information generated, it will provide an invaluable surveillance tool to dengue-endemic countries.

Because each index has certain advantages and disadvantages, each providing a different type of information, it has been recommended that dengue vector surveillance systems should use a combination of indices. Counting the number of pupae in each breeding site gives a good indication of the importance of breeding site, which can be used to establish risk thresholds and focus control operations towards those most productive containers. This allows programmes to use their surveillance and control resources more efficiently by concentrating on productive containers and omitting the breeding sites known to be unproductive.

3.2 Sampling adult mosquitoes

The purpose of adult sampling is to get an indication of mosquito population fluctuations in time or space. For regular adult sampling during control programs, the method chosen may not necessarily be the method that catches the most number, as long as it accurately reflects population changes.

Once off adult sampling rather than regular sampling from the same trap sites is of limited value in a mosquito control program but is useful to determine the presence of various

species in broad faunal surveys or to locate particular areas of high mosquito activity. Once off surveys need to be timed during potentially productive periods and include as many methods as possible to increase the accuracy of species records.

For routine monitoring purposes, a single method is usually most convenient. Once a method is chosen it is important that the method and equipment is standardised, so that comparisons actually reflect the variations in mosquito population and are not the result of a change of trap type or location.

Aedes surveillance methods have largely focused on the larval/pupal stage. Catches or trapping of adult mosquitoes have been rarely used in most dengue vector management programs, however, this is a method that is now becoming more widely accepted and practised, especially with the development of new passive tools such as the GAT trap. Because the density of adult *Aedes* mosquitoes is more directly linked to dengue incidence than larval or pupal indices, adult mosquito collections can provide more valuable and usable real time data than larval surveys. Routine adult *Aedes* mosquito trapping data can also provide valuable longitudinal (over time) data that can be used to analyse how, why, where and when mosquito populations fluctuate. When combined with other variables, such as climate, this data can help provide an early warning or risk identification system, which can be used an effective communication tool for health promotion activities. This data is an invaluable tool during an outbreak situation, where it can provide linkages with the location and timing of disease incidence data, as well as identifying hotspots and monitoring the effectiveness of vector control activities. Adult collection methods include:

> Human Landing Collection (HLC): is a method that measures the vector-to-human contact as a measure for the risk of virus transmission. However, there are ethical considerations regarding the risks of exposing one individual directly to potentially infective mosquito bites. HLC also tends to be labour intensive and heavily dependent on the collector's proficiency and skill. Hence, the need for more standardized procedures.
>
> Sticky trap: Sticky ovitraps are composed of acetate sheets with an adhesive facing inwards to the inside of the ovi-trap an d placed inside an ovitrap suitably baited with water and feed or organic water. Female container breeding mosquitoes are attracted to the ovitrap and are caught on the adhesive. This method is useful in *Aedes aegypti* sampling to determine the presence of adults that come to lay eggs, and to remove them from the population.

Figure 4. Sticky ovitrap

Resting collection: Most adult mosquitoes rest in the day in cool, dark, humid places. Careful searching may locate particularly productive resting places, from which regular collections can be made. These collections can then give an idea of the relative mosquito population. These particular sites are usually productive for only one and two separate species. The mosquitoes are collected with an aspirator, small hand held adapted vacuum collector or large powered back pack aspirators.

BG Sentinel trap: This trap was specifically designed to attract the dengue mosquito *Aedes aegypti*. The trap consists of a collapsible white cylinder with white mesh covering the top. In the middle of the mesh cover is a black tube through which a down flow is created by a 12V DC fan that causes mosquitoes in the vicinity of the opening to be sucked into a catch bag. The catch bag is located above the suction fan. The air then exits the trap through the mesh top. This design generates ascending current similar to that produced by a human host, both in its direction, geometrical structure, and chemical composition of the attractants. Attractants, a combination of lactic acid, ammonia, and fatty acids are given off by the BG-Lure®. The lure releases the long-lasting attractant for up to five months.

Figure 5. BG Sentinel trap

GAT trap: This is a new passive trap designed for settings in developing countries where access to a power source for *Aedes* surveillance is an issue. Female mosquitoes are attracted by water and ovipositioning cues and enter the transparent chamber through the funnel. Once inside the chamber, they come into contact with insecticide treated nets and are contaminated. The transparent chamber hinders the mosquitoes' ability to escape and the black mesh net provides a barrier between mosquitoes and the infused water as well as retains dead mosquitoes without damaging them.

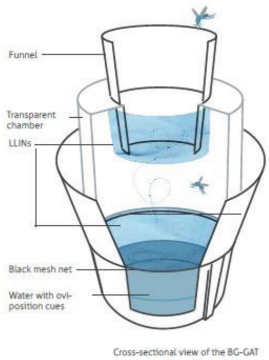


Figure 6. GAT trap

3.3 Eggs

Ovitraps are used to detect the rate of egg laying by *Aedes* females. These traps are a useful surveillance tool for early detection of new infestations. Ovitraps are inexpensive and easily installed without any specialized training; these traps are normally examined in the field once per week, and throughout the year. The disadvantage of using ovitraps for sampling vector population density is that the catches are strongly dependent on the presence of other oviposition opportunities for female mosquitoes. During the dry season, oviposition sites are few, and the mosquitoes will readily chose for the ovitraps. But during the rainy season, there will be plenty of other oviposition sites, and relatively few eggs will end up in the ovitraps.

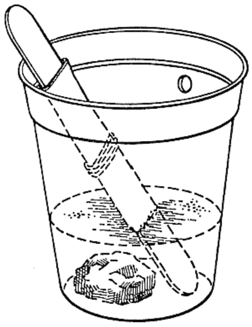


Figure 7. Ovitrap (egg trap)

3.4 Sampling strategy

A sampling strategy should obtain a representative sample of the target population or area. A bias towards easily accessible or preferred houses or sites should be avoided. Sampling techniques include: systematic sampling (every nth sample or house), randomized sampling (selection using random numbers), stratified random sampling (random sampling within certain strata), or cluster sampling (higher sampling rates in more dense areas).

The Premise Condition Index (PCI) is a shorthand way of estimating if a property is likely to breed Ae. *aegypti*. The index consists of three components, each of which is scored from 1 to 3: house condition, yard condition, amount of shade. High scores reflect untidy houses and yards, along with more shade. Premises with a poorly maintained house, a cluttered yard and lots of shade are more likely to have containers that will breed Ae. *aegypti* than a new house with a bare, clean, shadeless yard. The PCI is assessed from the street, a record of high PCI houses and areas can be used to target surveillance. If it is not practical to check all three of the above noted components, the amount of shade coverage should be used as a criterion to select premises to inspect for mosquito larvae.

The frequency of sampling depends on the frequency and expected duration of the control measures. For example, for insecticide application, it is important to monitor the residual activity to ensure that intervals between cycles of treatment are optimal. The sampling size (number of measurements) will depend on the risk of dengue, the available resources for sampling, and the degree of variation between measurements.

3.5 Recording Data

The results of all collections should be collected on standardised collection forms that capture: locality, date, collector's name, sampling station, type of collection, number of mosquitoes, sex of mosquitoes, species of mosquitoes, population index (larvae per dip, number of adults biting per hour), and meteorological and habitat data. All collection forms should be entered into a database specifically designed to input and output this data.

In addition, ongoing tabulation and graphing of all results should be maintained on a weekly basis during outbreaks and monthly during non-outbreak periods so that a quick visual inspection will show the current status of mosquito populations. Other variables such as temperature, rainfall and humidity should be incorporated into the visual presentation or analysed with the monitoring data to gain an insight into the reasons for population fluctuations. The monitoring data should also be analysed with information on dengue cases to determine whether the control program is achieving the ultimate aims.

Each year the whole program should be examined to determine annual patterns of abundance and reasons for annual variation. Annual Reports should be compiled outlining all aspects of the program and include up to date vector control maps, changes in procedures and equipment, and details of all control operations. Assessments and conclusions about the surveillance program and the overall control program should be made so that annual progress can be assessed.

If the surveillance programs and an integrated control program have been properly planned and carried out, you should see reductions in mosquito populations and hopefully corresponding reductions in potential or actual mosquito borne disease.

Vector surveillance a vital part of dengue control program. Methods of surveillance depend on purposes and availability of resources. Vector surveillance should be linked with climate, epidemiological surveillance and virological surveillance. It is used to determine distribution, abundance, species profiles & effectiveness of control and can help with risk assessments & EWS. Vector surveillance is a backbone of a dengue control programme and should include insecticide resistance surveillance.

GROUP TASK 2

Get into groups and complete “Activity 2 – Designing a Mosquito Surveillance Program”.

ACTIVITY

Based on your countries level of resource availability (human resources, financial, technical, infrastructure, equipment etc.) prepare and design a vector surveillance program that will specifically suit the context of your national vector management program.

GROUP 1 (Town Council staff)			
Disease Status	Components	Larval Surveillance	Adult Surveillance
1. Routine	Methods	House to house larval survey, random inspection	Sticky ovitrap
	Frequency	50-100 households per month	Monthly
	Level of Implementation	Municipal boundary and national	Municipal boundary and national
	Analysis	Container index and pupal rapid assessment index	Positive per container and population index
	Outputs	Monthly	Monthly
2. Outbreak	Methods	Larval survey/spray and house to house clean up campaign	N/A
	Frequency	daily	
	Level of Implementation	municipal boundary and hot spots	
	Analysis	Larval ID	
	Outputs	Daily	

GROUP 2 (Western Division EH staff)			
Disease Status	Components	Larval Surveillance	Adult Surveillance
1. Routine	Methods	Hot spots and 45/100 random, sentinel 5% margin of error monthly	Introduction as a routine activity
	Frequency	Monthly	Monthly
	Level of Implementation	District	District
	Analysis	District, district better	Divisional
	Outputs	Representative larval indices	More effective results
2. Outbreak	Methods	Case households + 100 m	45% representations
	Frequency	Weekly	N/A

	Level of Implementation	District	
	Analysis		
	Outputs	Efficient result dissemination	

GROUP 3 (North Division EH staff)			
Disease Status	Components	Larval Surveillance	Adult Surveillance
1. Routine	Methods	Sentinel surveillance	To be carried out by government
	Frequency	100 households per month and hot spot areas	
	Level of Implementation	1 or 2 officers	
	Analysis	BI, CI, PI	
	Outputs	Weekly, monthly	
2. Outbreak	Methods	Rapid assessment, case to case, larval survey, source reduction, spraying, awareness	
	Frequency	Confirmation of cases/area	
	Level of Implementation	Sort & dot	
	Analysis	Larval identification	
	Outputs	Daily, weekly	

4. Dengue Outbreak Response

4.1 BACKGROUND

An epidemic is the occurrence of cases in a community or region that are clearly in excess of the expected level or pattern. The term 'outbreak' is used to indicate a localized epidemic; for example the detection of several locally-acquired cases could be the trigger for declaring an outbreak situation. The term 'epidemic' is used only when outbreaks have spread at a larger geographic scale (e.g. province or country level).

Dengue epidemics have become frequent events across the globe, often with a major disease burden, and the frequency and intensity of dengue outbreaks have also increased in the Pacific in the last few years. Outbreaks and epidemics of dengue generally develop rapidly, and are relatively short-lived. DengueNet database was initiated to inform countries about the contemporary situation on dengue in countries in the region and globally.

The natural pattern of an outbreak or epidemic will typically start with a rapid rise in the number of new cases until the peak is reached. This rapid increase is due to the very efficient transmission of the virus by the vector, especially where the density of a susceptible human population is high (urban environments), and where temperatures are high. As an epidemic sweeps through the population, it will eventually come to an end, after which the number of new cases starts to drop.

The epidemic shows a declining pattern as the remaining vulnerable human population quickly shrinks, because those that have already been infected cannot become re-infected. Among those who cannot become re-infected are those persons who were infected but did not show disease symptoms (asymptomatic cases). As a result, the natural pattern of the epidemic shows a declining trend, and the epidemic ends. Strategies to mitigate an outbreak should have preventive measures, predictive capacities and a prompt emergency response if the situation so requires.

Where no disease cases have been detected, preventive activities should include routine surveillance and sustainable vector control, aiming to keep vector populations low irrespective of the presence of dengue virus. This will help reduce the risk of transmission upon introduction of the virus with in incoming traveller. Prediction of dengue epidemics has proven to be difficult. The strongest predictor is the arrival of a new virus serotype in a country or area, because the new serotype will encounter a susceptible human population (susceptible to that specific serotype) in which it can spread.

Outbreak response is vital to contain an impending outbreak at an early stage. This is possible only when a surveillance system is in place that can detect sporadic cases. Once an infected case is detected, it will be necessary to step up the control action, for example to investigate whether this is a locally-acquired case. If it is locally acquired, 'emergency vector control' in and around the household of the detected cases will be important to stop any further transmission of dengue virus, by eliminating any infected vectors, and by preventing movement of viraemic persons to other locations.

The purpose of the outbreak response is to prevent or weaken the natural pattern of an epidemic. The effectiveness of an outbreak response can be expressed in terms of 'cases prevented'. Figure 8 illustrates that an outbreak response will only prevent cases when is started at an early stage, at a time that new cases are still slowly building up. This requires both an early detection and a rapid response. If the outbreak response is only started in an advanced stage of the epidemic, following a late detection and slow response, it will not be able to prevent many cases. The response action should be accompanied by the provision of supportive care to those who have become ill.

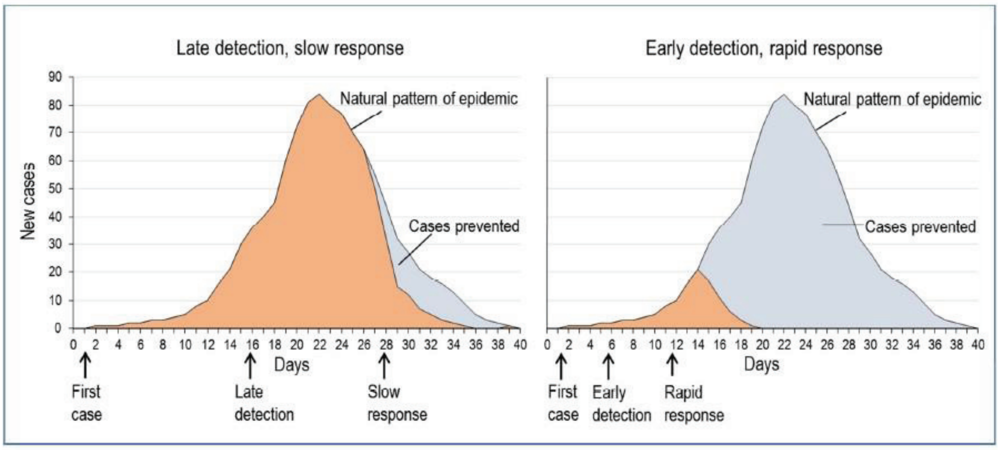


Figure 8. Representative graph of results of outbreak response times

4.2 ONSET OF AN OUTBREAK

Wherever the dengue vectors *Aedes aegypti*, *Aedes polynesiensis* or *Aedes albopictus* are present, there is a risk that viraemic persons (e.g. infected incoming travellers) will introduce dengue virus, which could subsequently be transmitted from person to person. When conditions are favourable, this could result in a local outbreak of disease. After a person is bitten by an infective mosquito, the virus needs to develop inside the human host (intrinsic incubation period, 4-7 days) before the infected person becomes infective. Vectors that blood-feed on these infective persons will ingest the virus and subsequently pass through an

extrinsic incubation period (7-14 days) - after which these mosquitoes also become infective. This pattern with incubation times can result in several ‘waves’ of transmission.

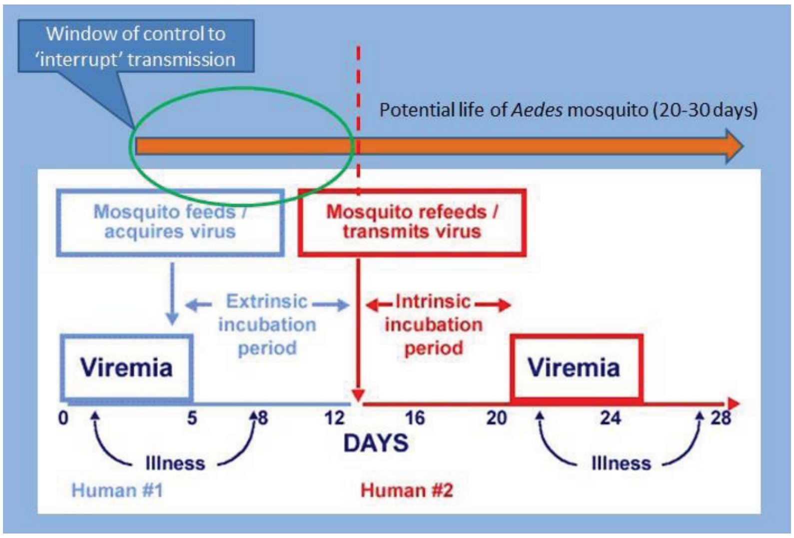


Figure 9. Intrinsic & extrinsic timelines for dengue incubation

A substantial proportion of infected persons will not develop disease symptoms (they are asymptomatic), but these persons can still become infective and thus contribute to viral transmission; this is called ‘silent transmission’. It is usually difficult if not impossible to prevent the ‘first wave’ of transmission. Current laboratory-based methods to confirm the diagnosis and to identify the virus serotype require up to 4 days. By the time the first fever cases have been successfully diagnosed, it is likely that the virus has already spread. The role of an emergency response, however, is to prevent the next waves of transmission, beyond the persons initially infected in the ‘first wave’. Elimination of larval habitats with community involvement and the appropriate use of insecticides inside houses, combined with capacity building and laboratory support, are crucial for the successful control of dengue outbreaks.

4.3 ROLE OF SURVEILLANCE

A rapid response is only possible when a strong disease surveillance system is in place through which suspected and confirmed dengue cases are routinely reported to the health authority. Upon detection and laboratory confirmation of the first cases (sporadic cases) in an area or country, active surveillance in the vicinity of these cases should detect further spread of the virus, aiming to contain it. An early detection of cases should immediately alert the response units to take appropriate action. Arrival of a new serotype is a particular concern because of the vulnerability of the population and because of the risk of severe dengue.

4.4 ACTIVATION AND DEACTIVATION

Where new cases of dengue have been reported, rapid case investigation should determine whether these cases were imported or locally-acquired. The response action aims for local elimination of the disease virus. The viremic cases must be protected from mosquito bites, to stop further spread of the virus. Also the 'case contact points' (i.e. places visited by a case during the viremic period) should be mapped. In these locations, which could include schools or places of work, emergency vector control should be implemented in an area 100-200 m from each contact point, or as appropriate.

If a case is found to be locally acquired, this is an indication that transmission is ongoing and that more persons may have been infected. Hence, the confirmation of one or more locally-acquired cases should be the trigger for declaring a local outbreak situation.

4.5 PREPAREDNESS AND PLANNING

Authorities should anticipate that dengue outbreaks will occur and be prepared to take prompt and full-fledged action if the situation so demands. In the absence of disease outbreaks, or when the intervals between outbreaks is long, preparedness for disease emergencies is easily overlooked by programme managers and policy-makers. Therefore, preparedness plans should be in place, ready to be deployed at any time.

The outbreak response will impose high demands on human and financial resources during a short period of time. Therefore, it is essential that several agencies and ministries are actively involved, contributing their resources, but with one agency (usually the health authority) taking the role as lead coordinator. To facilitate the coordinated planning and response action, it is important that a multisectoral action response committee, and/or with equivalent teams at field level, is in place with the responsibility to be prepared at all times for the initiation and coordination of an emergency response to a dengue outbreak. This team should have a health coordinator, and expertise represented on clinical, laboratory, vector control, community mobilization, and environmental sanitation. An outbreak response plan should be agreed by all participating agencies.

The following components are proposed for the preparedness plan:

1. Identify a lead coordinating agency
2. Establish organizational linkages with those agencies and sectors that have assumed responsibilities for implementation of the plan
3. Formalize the outbreak response plan, which includes:
    a. Enhanced disease surveillance
    b. Enhanced vector surveillance and targeted vector control

   c. Management of the health system to deal effectively with an influx of dengue cases
   d. Strategy for communication and community mobilization
4. Define triggers for the activation and deactivation of the plan
5. Outbreak investigation, to confirm cases, study entomological parameters and to define the extent and spread of the outbreak in time
6. Define roles and responsibilities of each agency
7. Conduct multisectoral exercises to practice and validate the plan
8. Costs and human resources development
9. Monitoring and evaluation

The roles and responsibilities of the participating agencies should be clearly delineated, so that all involved will know what to do when the emergency arises. In the event of a suspected outbreak, the multisectoral action team should increase the frequency of its meetings to review incoming surveillance data to plan and adjust the response actions. Human resources development should be part of the preparedness plan, to provide training, and refresher training, necessary for implementation of the response action.

Monitoring and evaluation is important because it will keep track of inputs, describe the implementation process, and record effects of the response action. Evaluation of the outbreak response, including the surveillance, detection, response action, and case management, will provide important lessons learnt which are necessary to improve the plan for preparedness and response and to identify gaps in policy making and decision making.

5. Plenary discussion on community collaboration and participation strategies for Fiji

5.1 BACKGROUND

The dengue vector *Aedes aegypti*, and to a lesser extend Ae. *albopictus*, lives in close association with humans. They breed in human-made aquatic habitats inside or around people's houses, and they feed almost exclusively on human blood. Therefore, the affected people themselves have a major role to play in the prevention and control of dengue. No matter how intensive the interventions by the dengue control programme, if the community does not do its part, the effect on dengue will be inadequate. Wherever the dengue vectors *Aedes aegypti* or *Aedes albopictus* occur, the community should actively contribute to the sustainable control of vector populations by making their houses, surroundings and public spaces inhospitable for the mosquitoes. Also, people should protect themselves against mosquito bites and seek treatment when the signs and symptoms of disease appear. When well implemented, community participation in dengue vector control has potential to substantially reduce the risk of dengue. Recent studies suggest that community-based, integrated control of *Aedes aegypti* reduced vector density and had an impact on dengue transmission. Community participation in dengue prevention and control is expected to improve compliance with public health interventions, and increase the cost-effectiveness of vector control through people's own practices and contributions. Equally important, community participation increases the prospects for sustainability of dengue prevention through a change of mindset, practices and behaviours of people, particularly if empowerment and local programme ownership is created.

5.2 SITUATION ASSESSMENT

All methods and tools for community participation should be based on an assessment of people's attitudes and behaviours in relation to dengue risk factors in and around people's homes, to identify needs and devise solutions. Commonly used methods are knowledge, attitude and practice (KAP) surveys, with questionnaires to collect information on what is known, believed and done in relation to the topic of interest.

5.3 METHODS AND TOOLS

Broadcast media, information, education and communication (IEC) and communication for behavioural impact (COMBI) are tools used for communicating messages to targeted communities or the general public. These tools aim to bring about a change in people's behaviour, for example, in relation to the removal of vector breeding sites or the seeking of health care upon dengue sign or symptoms.

These tools have been compared for their advantages and disadvantages for use in disease vectors control. The broadcast media can be used to create awareness about dengue, with the obvious advantage that it can reach a large audience at low cost. A disadvantage is that awareness alone does not easily change people's behaviour for dengue prevention. IEC is less intensive than COMBI, and therefore less costly to implement, but this could reflect a limited effect on behavioural change. COMBI has a strong focus on behavioural outcomes, and has been used in dengue control and outbreak response, but with mixed success. A weakness of COMBI is that it lacks a coherent model for maintaining community involvement, especially where community members simply participated and did what they were told.

As an alternative to these communication tools, methods that emphasize the empowerment of communities (e.g. farmer field schools) are expected to be most sustainable. These methods, which could be implemented through NGOs, include the development of skills among the community for critical analysis, planning, implementation and evaluation of the community's own dengue control activities or programmes.

5.4 STRATEGIC CHOICES

The selection of communication methods should be adapted to the short-term or long-term goals. During non-outbreak periods, the methods should emphasize the community's continuous role in prevention activities, with long-term goals and sustainable effects. In the case of outbreaks, or where sporadic cases are encountered, the communication strategy should be intensified, with the short-term goal to contain the outbreak. Here, a combination of communication methods should be used to raise awareness and change behaviour.

Session 3. Planning and implementing an integrated vector management plan

6. Plan and implement – Epidemiological and vector assessments

To improve the efficacy, cost effectiveness, ecological soundness and sustainability of vector control, better informed decision-making about the course of action is required. Decision-making is therefore central to IVM, in relation to implementation, policy, capacity-building and advocacy. Decision-making necessitates inquiry and analysis and results in a choice or, in the case of IVM, a strategy. Various decisions must be made in planning IVM, such as the type of intervention, the targets and timing of interventions, management of resources and stakeholder participation. Planning involves continuous adaptation of management choices to a heterogeneous and ever-changing environment.

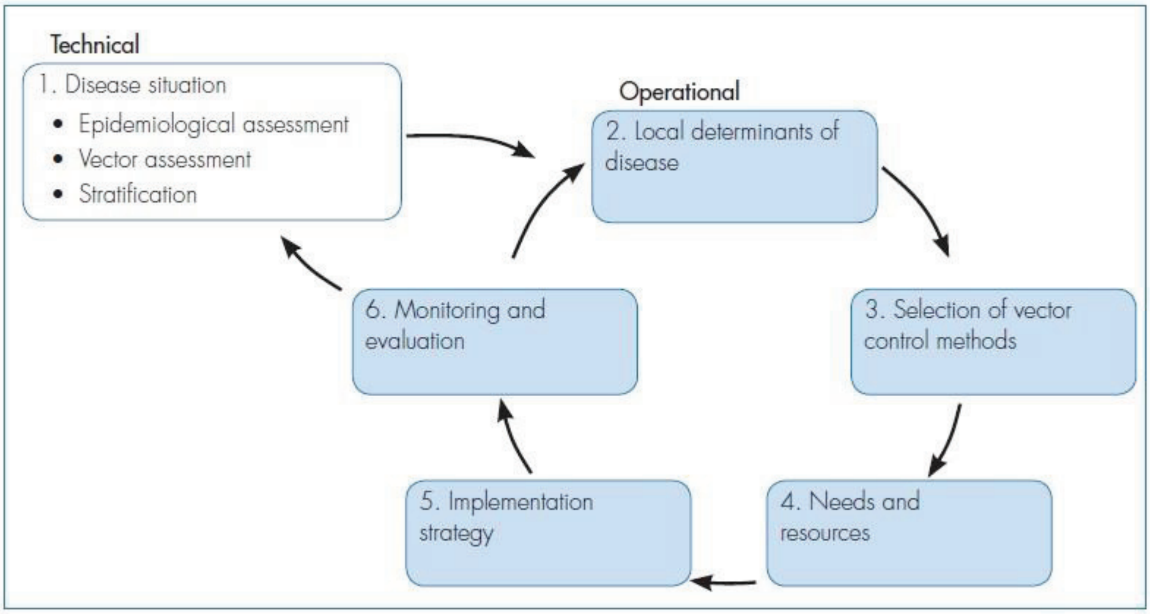


Figure 10. Technical & Operational Planning Inputs

6.1 EPIDEMIOLOGICAL ASSESSMENT

The first step in decision-making is to determine the burden of vector-borne diseases. This is fundamental for designing and evaluating strategies for vector control and provides the basis for policy formulation at national level. Data on disease should also be relayed to decision-makers at district and village level. Measuring the burden of disease requires reliable, current data on disease incidence, prevalence and mortality, as well as information on work days lost, school days lost, seasonal variations, subpopulations affected, the proportion of outpatients affected and other issues. Information is needed for each vector-borne disease, with overlay mapping to identify areas in which two or more diseases coexist.

Data on disease are obtained by a combination of passive and active collection methods. Passive data are collected as records of disease diagnoses at health facilities and do not necessarily reflect disease trends in communities. These data are commonly available in a

summarized form in annual reports. In passive data collection, however, cases that are not reported to health facilities are missed, and these might represent a substantial proportion of all cases. Active data collection is conducted during on-site surveillance, such as sampling for symptoms or evidence of pathogens in target populations. Active data collection is continuous and requires dedicated human and financial resources.

Whenever possible, links should be formed with the health management information systems that have recently been set up in many countries. These systems have markedly improved the estimates of disease burden at national and international levels. Furthermore, data are increasingly being made available at weekly or monthly intervals at district level. This reporting provides feedback to programmes and improves the decisions made locally. An epidemiological assessment contributes to policy formulation and prioritization for individual vector-borne diseases.

6.2 VECTOR ASSESSMENT

Understanding the biology, ecology and behaviour of potential vectors is essential to planning vector control strategies and choosing the most effective methods. This requires the expertise of professional entomologists and other trained personnel, who convey their findings to decision-makers at national, district and village level. The assessment of vectors of disease comprises five aspects: their ecosystem, their role in disease transmission, their habitat and seasonality, their behaviour and their susceptibility to insecticides.

An ecosystem analysis is essential for identifying the diversity and habitats of vector species and the prevalence of diseases in a given ecosystem. The analysis is essential for designing and planning appropriate vector control interventions. Vectors often show clear differences in diversity, biology and disease transmission in, for example, coastal, riverine, savannah, urban, forest, agricultural, high-altitude and plantation ecosystems. Each type of ecosystem, and zone of bordering ecosystems, is usually home to its own species or complex of disease vectors. The way in which vectors exploit breeding habitats and feed are typical of each ecosystem type in each region.

The role of the vector in disease transmission should be ascertained under real-life conditions by studying the association of the vector species with its hosts (human, intermediate or alternative) in space and time, their direct contact with humans and evidence of pathogens inside the vector. Measurement of the rate of infection helps to distinguish between minor and major vectors, as described in. In the absence of disease, or at low disease prevalence, it may not be possible to confirm the ability of species to act as vectors locally. The presence of dengue virus in adult mosquito samples can also be tested using

standard NS1 antigen test kits. This surveillance method can be an important complimentary tool to firstly detect the presence of dengue and to secondly help establish the vectorial status of a species.

For identification of species, microscopic techniques based on morphological characters usually suffice; however, to differentiate between subspecies and strains of vectors (e.g. the *Anopheles* gambiae complex of malaria vectors), molecular techniques are required.

The seasonal occurrence of vectors is closely linked to the ecosystem type and climatic conditions. Therefore, the habitats and seasonality of vectors must also be understood. Most vector species have relatively unique associations with their habitat. For example, larvae of malaria vector species may occupy different breeding habitats, some preferring sunlight and others shade or standing rather than streaming water.

Vector behaviour has implications for the risk for pathogen transmission and, consequently, for selection of the appropriate interventions to reduce transmission. Certain mosquito species feed predominantly outdoors, whereas others are adapted to feed indoors where people sleep, thus affecting the effectiveness of, for example, the use of ULV applications. The preferred harbourage, including the resting sites of flying vectors, should be known, because these are potential targets for control procedures, including the application of residual insecticides. The preference of vectors for feeding on human rather than animal hosts should be ascertained.

Few insecticides have been recommended for insect vector control, and there is a constant risk that vector populations will develop resistance to the pesticides being used. For mosquitoes, the standardized WHO protocol is recommended for testing and monitoring their susceptibility to insecticides. Susceptibility to insecticides must be monitored regularly wherever insecticides are used in vector control, in order to detect the development of resistance or reduced efficacy at an early stage.

6.3 STRATIFICATION

In the context of disease control, the term “stratification” refers to the classification of disease endemic areas by their epidemiological and ecological characteristics. Hence, stratification is conducted to identify areas in which different approaches to disease control are indicated. Stratification can range from basic to very complex. In its basic form, stratification is conducted to differentiate between areas with different incidence rates of a disease within a country, in relation to population census data. For instance, the WHO Global Malaria Programme uses stratification to differentiate provinces or districts according to four level of malaria endemicity: with 100, 1–100, <1 and 0 cases per 1000 population per year.

An important function of stratifying disease incidence at national level is to provide information for allocation of the national budget to lower levels of administration. Hence, disease control programmes can be planned according to the disease prevalence in a district. Districts with a high prevalence require a different approach from that for districts at risk for epidemics. From a technical and operational level, stratification also helps managers in deciding how to allocate resources and to select the appropriate surveillance and control activities.

The main determinants of vector-borne disease are usually not uniformly distributed, showing heterogeneity across the local landscape (e.g. due to concentrations of human habitation or of a vector breeding habitat).

6.4 LOCAL DETERMINANTS OF DISEASE

After a technical assessment of vector-borne disease at national level, the operational steps in decision-making are identified. The technical assessment requires study by a team of experts, whereas the operational steps are more appropriately conducted at local level. From this phase onwards, it is crucial that local stakeholders, such as individuals, health workers and local authorities, participate in analysing local conditions and making decisions on vector control.

A number of risk factors, or "determinants of disease", determine the spread of vector-borne disease. It is important that all of the determinants of disease be understood, to ensure a comprehensive approach to disease prevention and for appropriate action to disease control.

An entomological analysis identifies the local determinants of the transmission and prevalence of vector-borne disease. The determinants are related to the pathogen, the vector, human activities and the environment. Vector-borne disease control programmes usually focus on the vector; however, if the disease, the human and the environmental determinants are ignored people will continue to be at risk for infection and the vectors will continue to proliferate in the environment.

The answers to the following questions will help in identifying local determinants of disease:

- Pathogen determinants: Which VBD pathogens have the potential to cause disease outbreaks? The answers to these questions should be provided by epidemiologists.
- Vector-related determinants: Which are the main local vectors? Where and when do the vectors breed? What are the local densities and fluctuations of the vectors? What are the characteristics of the vectors? What is the status of insecticide resistance? The answers to some of these questions should be provided by entomologists.

- Human-related determinants: What is the distribution and structure of the population? Where do vulnerable groups live? Which populations live close to the vector breeding habitat? Where do people meet? What are the patterns of population movement? What are local practices and attitudes towards vector-borne disease? What are the domestic conditions of the population? What is the income of the population? Do people serve as a reservoir of disease?

- Environment-related determinants: What are the rainfall patterns? What are the local ecosystems? How is land used? What is the extent of the aquatic breeding habitat?

6.5 TACKLING THE DETERMINANTS

A local analysis of determinants of vector-borne disease helps to understand in detail where and when the risks for vector-borne disease occur. For example, the analysis could show that communities living at the edge of an industrial area or in lower income areas are at high risk for infection. This would provide a basis for identifying the options for reducing the risks.

Most determinants can be influenced by human intervention, for example, through vector control, personal protection, environmental management or a change in behaviour or living conditions. Risk factors such as rainfall patterns obviously cannot be controlled.

Many determinants of disease are outside the scope of conventional programmes for vector-borne disease control, such as irrigation systems, urban development, sanitation, and housing. These call for the involvement of other health divisions, other sectors and local communities.

7. Plan and implement - Selecting the right methods and implementing them

7.1 BACKGROUND

The successful implementation of dengue vector control relies on carefully planned processes with several steps of decision making. For example, decisions should be made on whether or not to intervene, and how to target geographic areas at risk of dengue transmission. A selection should be made of the optimal set of vector control methods. Careful planning is needed to put the available resources to their best use; resources are not limited to the health sector but include the participation of other sectors and the general public.

All decisions should be based on adequate knowledge about the contemporary disease situation, risks of transmission, and evidence on the effectiveness of vector control interventions. Vector surveillance provides information on vector population densities, their local differences and seasonal occurrence and is vital for informing the decision making process because vector density is an important risk factor for dengue transmission. Other risk factors that could also be considered when prioritizing vector control interventions are: abundance of suitable breeding sites, urbanization, and influx of tourists or foreign workers.

There is a strong association between rainfall, temperature and humidity and dengue incidence in many countries. Peak transmission rates are mostly, but not always, during periods of high rainfall and high temperatures. Rain leads to an abundance of vector breeding sites. At high temperatures, the risk of virus transmission is increased, due to several reasons. At high temperatures, the female mosquito requires more regular blood meals, whereas the extrinsic incubation period (the time it takes from ingestion of dengue virus to becoming infective) reduces at high temperatures.

Disease surveillance produces data on the locations of historic and current disease cases. Efficient linkage between the dengue surveillance unit and the vector control programme is critical for timely and well-targeted interventions.

Using the available information sources, tools, and resources, a locally-appropriate strategy for dengue vector control is prepared. Such strategy could specify the required activities, materials, criteria and thresholds for vector control, and should outline the roles and responsibilities of those involved.

Routine monitoring and evaluation will be needed to account for the resources used, identify weaknesses, and assess the impact of interventions. The results of monitoring and evaluation provide feedback to improve the decisions taken in the time ahead.

7.2 SELECTION OF VECTOR CONTROL METHODS

In the selection of mosquito control methods, it is important to revisit the mosquito life-cycle. The mosquito life-cycle has an aerial phase – with free-flying adult mosquitoes, and an aquatic phase – with larval and pupal stages are confined to small water-holding containers. Vector control methods are aimed to break the mosquito life-cycle at a certain stage.

The aquatic phase is the most vulnerable because it is confined to small breeding containers, which can be controlled or removed, thus breaking the life-cycle. Nevertheless, it may be difficult or impossible to locate and eliminate all breeding sites in a given area, especially where the vector breeds in natural habitats including tree holes and plant axils (e.g. Ae. *albopictus and* Ae. *polynesiensis*).

The aerial phase is free-flying, and thus more difficult to control, were it not that dengue vectors, in particular *Aedes aegypti*, live is close association with people's homes, which are targets for vector control. These mosquitoes depend almost entirely on human hosts for blood feeding and, because of their short flight range, often remain in or around the same house. Because *Aedes albopictus* and Ae. *polynesiensis* can also feed on other hosts, such as mammals, birds and reptiles, it can occur further away from people's houses.

In the selection of the most appropriate and cost-effective vector control tools in a particular context, several criteria should be used:

1. Efficacy
2. Safety for human health and the environment
3. Risk of insecticide resistance
4. Community acceptability and participation
5. Costs of implementation and maintenance
6. Capacity requirements

A certain vector control method may be more efficacious in killing mosquitoes than others. For example, removal of breeding sites will abruptly stop breeding, whereas application of larvicides into breeding sites may kill only part of the larvae and will lose its efficacy after some time. Several methods bear concerns over safety or insecticide resistance.

Knowledge about community acceptance of a vector control method is another important consideration. The effectiveness of some methods, such as source reduction and personal protection, rely heavily on active community participation.

Costs of interventions depend largely on the vector control product, specialist human resources, and frequency of operations. Environmental management whereby other sectors

and the community part-take in implementation reduce the financial burden on the dengue vector control programme. Certain methods, such as space spraying, are particularly expensive due to the equipment, vehicles, insecticide, and demand technical skills and timeliness of operations.

Sustainable vector control aims to keep vector densities at low levels during non-outbreak periods. In most country situations, however, dengue vector control has been reactive, which is, as a response to an impending outbreak. The problem with relying on reactive vector control is that it takes time from infection of a person to laboratory confirmation of a dengue case, and sometimes to mobilise the necessary resources (i.e. financial and HR) to mount an effective control response, resulting in a crucial delay. Also, asymptomatic infections are usually not noticed, but can contribute to silent transmission of dengue virus. Hence, it is important that vector populations are kept at a low level as a preventive measure.

7.3 NEEDS AND RESOURCES

Dengue vector control programmes should identify the available human, financial and technical resources at each administrative level. Human resources include staff from other sectors, civil society organizations and the affected communities. Financial resources are not limited to the budgets of the health sector, but include support from other sectors and in-kind contributions from the affected communities. The budgetary allocation for dengue prevention by sectors other than health is a positive indicator for intersectoral collaboration.

Once an area has been targeted for vector control, and methods of vector control have been selected, further assessment may be necessary for planning operational activities. For example, spray operations should be based on the assessment of the human population, housing conditions, breeding sites, accessibility, topography, and vector behaviour (e.g. peak flight-activity times).

7.4 IMPLEMENTATION STRATEGY

Based on the available surveillance data, stratification of geographic areas, selection of vector control methods, and identification of needs and resources, a strategy for implementation of dengue vector control can be developed. A strategy should outline the activities, roles, responsibilities and targets. A strategy should not be static but able to adapt to changing circumstances.

The strategy should establish for each selected vector control method: when to implement, where to implement, what coverage levels to achieve, which communication strategy to use, who is the responsible agency, who are partners in implementation, and who conducts

external monitoring and evaluation. Monitoring and evaluation are necessary to establish and confirm whether the targets are being met and whether resources can be accounted for.

If other vector-borne diseases co-exist with dengue (i.e. chikungunya and zika), the opportunities for a combined strategy for more than one disease should be utilized to make efficient use of available interventions, resources and expertise.

8. Monitoring and Evaluation – indicators and methods of evaluation

The requirements for monitoring and evaluation have been mentioned briefly in some of the preceding sections (vector surveillance and planning and implementation). Monitoring and evaluation are essential tools in the management of any development activity. The main functions are:

1. To guide in planning of interventions
2. To measure the effectiveness of the activities
3. To identify areas requiring improvement
4. To account for the resources used

"Monitoring" refers to examining a programme's process or performance, which, in the context of a dengue vector management strategy, consists of the activities or interventions. "Evaluation" refers to assessment of the outcomes and impacts that can be attributed to a programme's activities. Hence, monitoring involves examining the cause, which is the intervention, and evaluation involves analysing the effect, which is the outcome and/or impact.

In combination, monitoring and evaluation aid understanding of the relations between the performance of activities and the observed outcomes or impacts. This permits identification of gaps or weaknesses and their reasons or causes, as the basis for remedial measures. Thus, lack of an outcome in a certain area can often be traced back to inadequate performance or to some other constraint.

8.1 FRAMEWORK

Different types of indicators are used to determine process, outcomes and impact. Process indicators reflect the performance of a programme (i.e. whether the planned activities were adequately conducted in a timely manner). Outcome indicators show the desirable outcomes of the activities conducted, and impact indicators reflect the impact that can be attributed to the programme's outcomes.

8.2 METHODS

8.2.1 DESIGN

Monitoring and evaluation of vector control programs are generally conducted longitudinally, to record changes over time. Therefore, a baseline is required, and information is collected during interventions. Changes in indicators of progress, outcomes and impact are observed relative to the baseline. Monitoring and evaluation should use standard indicators, so that

results can be compared between areas, between years, and preferably also between countries and regions.

8.2.2 DATA COLLECTION

For demonstration purposes, three types of data are specified for the indicators in the above table: descriptive, numerical and logical. A number of indicators cannot be measured numerically or logically and require descriptive data and qualitative assessment. Qualitative data can be obtained by interviews with stakeholders, review of documents, field visits and community or household surveys. Questions for interviews and formats for measuring knowledge and skills should be designed by evaluators, and survey tools or monitoring forms should be field-tested before use. Interviews and surveys are time-consuming and require careful planning.

Vector populations should be monitored at sentinel sites in an established vector surveillance system, and the data can be used to evaluate the impact of vector control activities. Evaluating impacts on disease transmission requires special studies, with observations adapted to the requirements for each disease. Impacts on attack rate disease morbidity and disease mortality can be difficult to assess and reliably attributed to the interventions.

There are several methods for collecting health data. Routine surveillance with health management information systems has been used in a number of disease-endemic countries, in which data are produced weekly or monthly at district level (showing, for example, variations in space and time). Such systems could be used to obtain data on crude death rate, disease-specific death rate, cases of disease, disease incidence and other parameters. Similar types of data, often of better quality and reliability, are collected in demographic surveillance systems established in certain countries. A more costly but often preferable option is collecting data in a dedicated epidemiological assessment.

Sampling schemes should be designed on the basis of the requirements of each indicator. For an indicator such as household coverage, as wide an area as possible should be sampled. For other indicators, more time-consuming or costly methods might be required, with smaller but properly selected samples or sentinel sites.

8.2.3 USE OF RESULTS

The results of monitoring and evaluation should be used effectively for their intended purposes, which are to account for the resources used, to learn from the experience and to decide what strategic or operational adjustments are needed. Those who should learn from the experience are stakeholders and partners at all levels of administration. District-level

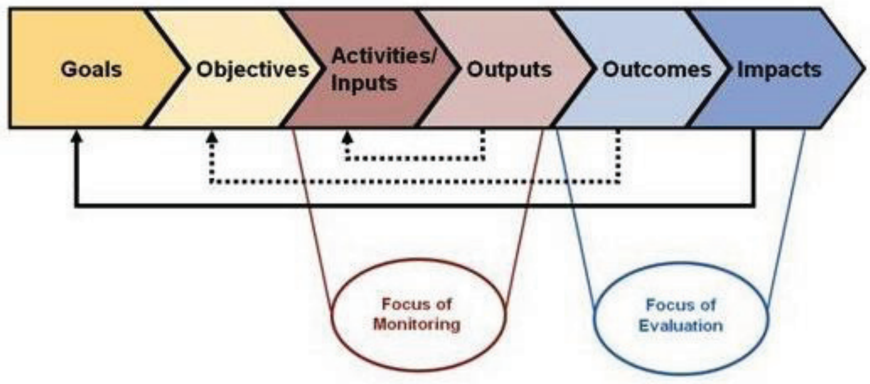
partners and communities, for example, need to know whether the activities were effective. Therefore, those responsible for monitoring and evaluation should document and disseminate the results to several target groups. Lessons can be learnt from monitoring the transition to IVM in a broad sense, supplemented with data on activities, outcomes and health impacts, if available. Aggregation of several data sources, for example by linking data on implementation to data on impact, could reveal the reasons and causes for the observed patterns.

Monitoring and evaluation are also needed to inform national decision-makers about costs and impacts to help them understand and interpret the results and guide them in deciding whether to support or modify the strategy. Monitoring and evaluation could also serve advocacy purposes by indicating policy change.

8.2.4 ROLES

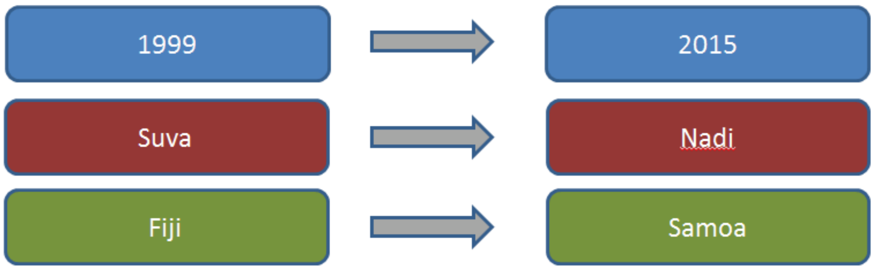
Monitoring is usually done internally by the direct stakeholders, whereas evaluation is done both internally and externally. The advantages of internal evaluation are ready availability, lower cost and knowledge about the context and operations. Internal evaluators may, however, be biased and might hide certain shortcomings because of a conflict of interest. The important advantages of external evaluators are their specialist skills and their presumed objectivity, as they are independent and can raise sensitive issues. Pressure on either internal or external evaluators to make a positive evaluation can be a barrier, obstructing the efficient identification of a programme's shortcomings and remedial action. All vector control program should have M&E Plan, including dengue control. The main functions of Monitoring and Evaluation are:

1. To guide in planning of interventions
2. To measure the effectiveness of the activities
3. To identify areas requiring improvement
4. To account for the resources used.



Methods

- Conducted longitudinally to record data over time (temporal) and space (spatial) and the fluctuation patterns within this recorded data
- Use standard indicators so results can be compared



9. Strategic and Operational (Action) Planning

9.1 Strategic Planning

Simply put, strategic planning determines where an organization is going over the next year or more, how it's going to get there and how it'll know if it got there or not. Public health organizations operate in a dynamic environment that is turbulent and unpredictable. It is necessary for these organizations to be able to develop and implement plans to take advantage of their changing environment. Strategic planning is a management technique commonly used in the private sector and has many benefits that can be applied to the healthcare and public health arenas. Health professionals (including public health workers) are beginning to formally use the strategic planning concepts and approaches that have led to success in the business sector.

The basic concept in strategic planning is to determine a plan for the organization to undertake in the coming period, based on a vision for the future. An organization prepares a strategic plan, which involves goals for several years in the future. By offering a roadmap for an organization, strategic planning provides a framework to coordinate efforts and support. Other benefits include improved decision-making and communication, as well as encouraging participation by all members and increasing motivation. Planning as a management process leads to the establishment of objectives and helps to give the organization a direction that can exist in the external environment. It is then possible to determine the methods to achieve these objectives (i.e. operational plan).

9.1.1 Formulating Strategies

Strategy formulation is process used to assess or reassess an organization's mission and vision, and to develop plans to achieve the organization's goals and objectives while preserving its mission and purpose. The major variables involved in the strategy formulation process are:

- consensus of mission and vision;
- environmental assessment (the identification of external opportunity and risk, and internal capabilities and advantages), and;
- setting goals and objectives.

Mission/Vision

A strategic plan should support the organization's vision or purpose. A clear mission is important to offer a guiding principle on which to base individual and departmental objectives. The organization's mission should address questions such as:
What is the organization's purpose? Why is this important? What will the organization do to fulfill this purpose? How will the organization benefit the community? The mission statement

should be specific, but should still allow for a diversity of programs or services to be utilized in accomplishing the vision for the future. For health services organizations, the institution must have a basic philosophy that addresses what are the health needs of the community and which will this organization best meet. Only when these questions are sufficiently answered will it be possible to set objectives and methods by which to implement them. The organization's mission and vision can then be translated into specific performance goals. It is important that the mission is clear and in agreement by all employees, donors, managers and those utilizing the services.

Environmental assessment

Public health and health care organizations are extremely susceptible to environmental influences. Analysis of external opportunities and threats and internal capacity is of primary importance in planning for the future of these organizations. An external analysis is the first step in the strategy formulation process. The focus of the analysis may involve an assessment of a number of areas of the environment including the political, economic, legal, social, and technological. All of these areas could be important in planning strategies for health care organizations. Information should be gathered through a wide variety of sources. The internal environmental assessment should involve an evaluation of the resources available or needed to perform the operations of the organization, the performance of the organization in accomplishing its services, and the process used to provide resources and services. After information about the environment has been assessed, target opportunities can be identified for the strategic plan. The opportunities should be prioritized by how consistent they are with the mission statement.

Setting Goals and Objectives

Once the strategic opportunities have been identified and potential threats taken into account, a list of specific steps that will be taken to implement the plan should be formed. Measurable outcomes are described as specific to each objective and must be determined by the mission statement. Responsibilities for implementing the goals and objectives should be established. The strategic plan organized through goals and objectives offers a set of measurable outcomes which can be evaluated.

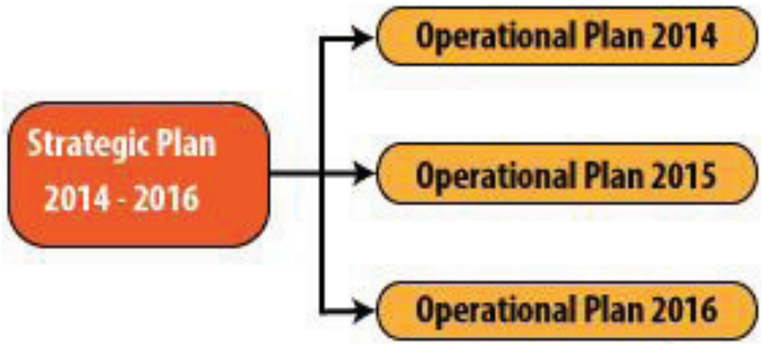
Implementation

Successful implementation of the formulated strategies is a crucial part of the planning process. Strategy implementation involves variables such as organisational structure, division of labour, resource allocation, leadership, control systems, information systems, motivation and incentives, standards and measurement. Each of these can play an

important role in the design's ability to achieve results, and the most effective way to ensure implementation of a strategic plan is through operational planning.

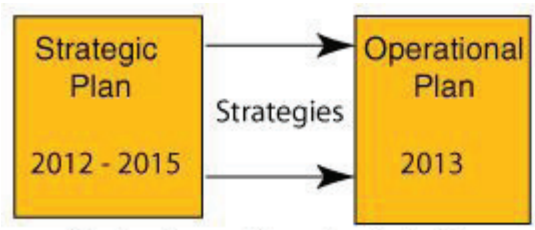
9.2 Operational Planning

It is important to understand the difference between an "operational plan" and a "strategic plan". The strategic plan is about setting a direction for the organisation, devising goals and objectives and identifying a range of strategies to pursue so that the organisation might achieve its goals. The strategic plan is a general guide for the management of the organisation according to the priorities and goals of stakeholders. The strategic plan does not stipulate the day-to-day tasks and activities involved in running the organisation. On the other hand the Operational Plan does present highly detailed information specifically to direct people to perform the day-to-day tasks required in the running the organisation. Organisation management and staff should frequently refer to the operational plan in carrying out their everyday work. The Operational Plan provides the what, who, when and how much:



- what - the strategies and tasks that must be undertaken
- who - the persons who have responsibility of each of the strategies/tasks
- when - the timelines in which strategies/tasks must be completed
- how much - the amount of financial resources provided to complete each strategy/task

The purpose of the operational plan is to provide the organisation personnel with a clear picture of their tasks and responsibilities in line with the goals and objectives contained within the strategic plan. Basically, the operational plan is a plan for the implementation of strategies contained within the strategic plan. It is a management tool that facilitates the co-ordination of the organisation's resources (human, financial and physical) so that goals and objectives in the strategic plan can be achieved.



Strategies are the end point of the Strategic Plan but the start point of the Operational Plan.

9.3 Summary: The difference between and operational and strategic plans

Strategic Plan	Operational Plan
A general guide for the management of the organisation.	A specific plan for the use of the organisation's resources in pursuit of the strategic plan.
Suggests strategies to be employed in pursuit of the organisation's goals.	Details specific activities and events to be undertaken to implement strategies.
Is a plan for the pursuit of the organisation's mission in the longer term (3 - 5 years).	Is a plan for the day-to-day management of the organisation (one year time frame).
A strategic plan enables management to formulate an operational plan.	An operational plan should not be formulated without reference to a strategic plan.
The strategic plan, once formulated, tends not to be significantly changed every year.	Operational plans may differ from year to year significantly.
The development of the strategic plan is a responsibility shared and involves different categories of stakeholders.	The operational plan is produced by the chief executive and staff of the organisation.

Conclusions

How many of you think that climate change is just a controversy and a debate? How many of you think it is a real fact and reality? How many of you reserve your opinion at the moment? Clearly, tendency is to accept climate change as fact rather than a hypothesis. It is like whether you believe in gravity. Or whether you believe world is flat or round. Human race lived for 100 thousand years, and only recently thanks to science, we know that the world is round.

Now climate change is becoming more like that. When it was first spoken 30 years ago, it was just an interesting and intimidating hypothesis. Now after 30 years, all scientists trained well in academia know without a doubt that it is a fact. It is unequivocal. Some people accept global warming, but some deny that it is from human activities. But according to scientist measurement, the components of natural warming are less than 20%, while rest is from greenhouse gas emission from human activities. It was observed that every decade became successfully warmer. How many of you know that 2014 was the hottest recorded in history? Now it seems like it is so obvious that it is not even surprising. In the Olympic, if someone breaks history, he becomes a hero. But for global warming, it does not get as much attention. Although there are so many sites for temperature measurement, on average, 2014 was the hottest year.

CO_2 emission air hit 400 ppm in 2014. Where does CO_2 come from? It does have natural origins such as volcanoes. But from past centuries, it was mostly from human activities and industrialization. Due to global warming, scientists were united for the first time. However, despite strong efforts to reduced CO_2 level and prevent global warming, best scenario is increase in 1.5 degrees by 2100 and the worst scenario is 3-4 degrees warming. Economy prediction shows that with temperature increase tropical countries are hardest hit. Sea level rise is measured in scientific way constantly. Worst scenario is 1 meter increase by 2100, and the best scenario is 50 cm rise. Sea level rise is something that cannot be reversed, and it could take even few centuries to revert. The highest point in South Tarawa in Kiribati is 3 meters, and sea level rise will soon inundate whole of South Tarawa.

Climate and weather was known to affect human even since Hippocrates, and there is a good correlation between temperature, humidity, rainfall, mosquito activities and related diseases. There are millions of people dying from various diseases and under nutrition and many of these are contributed by effects of climate change. There is also link between

climate change and NCDs where salt water intrusion causes contamination due to sea level rise, and due to difficulties in agriculture, people resort to condensed high calorie processed food.

Some studies in Fiji show good correlation between dengue fever and climate variables and time lag. If temperature and humidity were in optimal situation, then 50% of dengue may be reduced in certain areas. Also it is similar with diarrhoea. There is increase in diarrhoea in drought and flood. This is because during drought, people drink unsafe water. During flooding, toilets too close to water will contaminate drinking water well or source. Dengue fever is likely to be 5.17 times higher after drought and 10.57 times higher after flood.

If we try hard to reduce CO_2 level, and if we are more prepared to make EWS, we cannot elimination, but we may be able to reduce many cases. There are still many uncontrollable consequence of climate change, but there is also health co-benefits of mitigation.

Key message as you are key health communicators in your community. Fiji is very vulnerable to impacts of climate change including its detrimental effects on health. So many people doubt or are misinformed due to misleading politicization. Like producers of asbestos and tobacco, many people try to mislead the public for their own benefits. This occurs quite often in field of climate change. It is crucial to get substantial support from partner. This is not only because Fiji is a developing country, but because impact of climate change is not Fiji's fault. Compared to quality of life in richer countries, Fijians are living a very humble life. CO_2 produced by Fiji may be less than 10% than Americans on average. In other words, Fijians are not responsible for the issue of climate change on an average scale. Hence, why do Fijian government have to pay for problems that are not caused by them? It is not begging, but it is entitlement and righteous compensation that we are demanding.

Rich countries are not denying this. Many scientists are accepting this because it will also impact their life as well. There has been a global commitment to create a fund of 100 billion USD by 2020 to fight climate change. So far 10 billion USD has been collected, and 90 billion USD more will be collected. Half of fund will be for adaptation and the other half for mitigation. Mitigation involves establishing solar power, windmill, and other sources of renewable and sustainable energy that can replace fossil fuels, and reduce emissions of CO_2. Half of the adaptation fund will be allocated to developing world.

VBD can be prevented with timely pro-active actions. VBD can be reduced if we take timely action, and we can also minimize the "peak", which is the severity of impact from VBD.

Environmental Health Officers are crucial for public health adaptation to climate change in Fiji. This work cannot be done alone. We have to work together. I like to encourage you to be optimistic. We have all the resources to utilize and human support and capacity.

The three day workshop was not only informative in technical skills and knowledge, but also good inspiring experience empowering you in many ways. One of the concrete outputs was future strategic plan. Your inputs are very important. Many strategies and action plans are not really implemented. There are transparency plan issues and accountability issues, which means that if somebody doesn't do their job, there is no consequence. We understand that current situation, capacity, and resources are so limited that it is difficult to implement anything. We have opportunity soon. We cannot blame lack of resources and funding for not implementing. To avoid situation where we don't do our job and miss opportunity, this strategic plan was very important pro-active preparation. Strategic plan will not only be governmental document, but it may also provide concrete information for donors to prepare. Maybe by October, if good plan is made, maybe we will be prepared for the next rainy season. We appreciate your engaged participation during the meeting. I learned a lot, and I am convinced that we can make a difference if we work together.

Vinaka vakalevu

Dr Rokho Kim

Participants

Workshop group photo (by Division of Pacific Technical Support, WHO)

Sitting (left to right): Selaima Maitoga, Eseta Leawere, Penioni Matadigo, Dr Rokho Kim, Dr Domyung Paek, Mr Matthew Shortus, Kelera Oli, Hyung Soon Kim

Standing (left to right): Taniela Saturu, Josefa Tabua, Alita Goneva, Sofaia Whippy, Renivani Nene, Onisimo Sadranu, Niko Nadolo, Elia Lawena, Samuela Moiere, Sunia Ubitau, Larissa Leben