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By: Henk van den Berg
Raman Velayudhan
Mikhail Ejev

Regional framework for
surveillance and control
of invasive mosquito
vectors and re-emerging
vector-borne diseases
2014–2020



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ABSTRACT

The introduction and establishment of *Aedes* mosquito species into the WHO European Region is an emerging problem. Factors such as globalization, the increasing volume of trade and travel, continuing urbanization and environmental/climate change have contributed to this spread. *Aedes aegypti* and *Aedes albopictus* mosquitoes are effective vectors of potentially severe diseases such as dengue and chikungunya fever. Travellers returning from disease-endemic countries are increasingly introducing these diseases into the Region. In areas where these invasive mosquitoes have been established or re-established, there is a risk of local transmission of these diseases. An increasing number of outbreaks of dengue and chikungunya in the Region have been reported in the last five years. This regional framework was developed after extensive consultation with all stakeholders in order to improve the prevention, surveillance and control of the invasive mosquito vectors and re-emerging diseases in Member States.

Keywords

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Abbreviations

ECDC	European Centre for Disease Prevention and Control
EMCA	European Mosquito Control Association
EU	European Union
EC	European Commission
IHR	International Health Regulations
VBORNET	network of medical entomologists and public health experts

Glossary

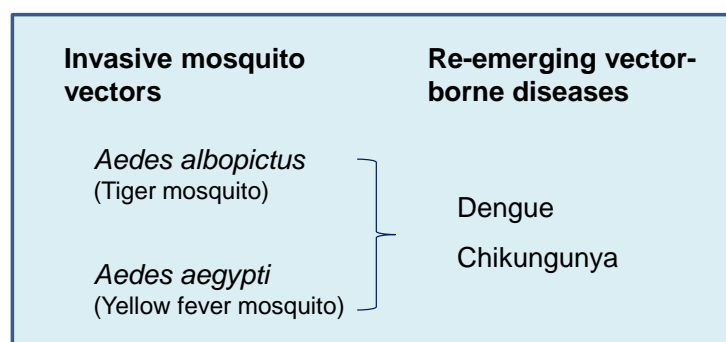
Arbovirus	Viruses transmitted by arthropods
Bridge vector	Vector that transmits a pathogen from animal hosts (such as birds) to humans
Invasive species	Species that has been introduced and that adversely affects the habitats it invades
Viraemic	Medical condition in which the virus particles circulate in the bloodstream

Summary

The introduction and establishment of *Aedes* mosquito species into the WHO European Region is a growing problem. Possible factors driving this problem are globalization, the increasing volume and pace of trade and travel, continuing urbanization and environmental challenges which include climate change. *Aedes albopictus* and *Aedes aegypti* mosquitoes are effective vectors of potentially severe diseases such as dengue and chikungunya fever. Travellers returning from disease-endemic countries are increasingly introducing dengue and chikungunya viruses into the Region. A much rarer event is the introduction of the yellow fever virus, which can also be successfully transmitted by *Aedes* mosquito species. In areas where these invasive mosquitoes have been established or re-established, there is a genuine risk of local transmission of these diseases. Indeed, an increasing number of outbreaks of dengue and chikungunya are being reported in the Region.

A regional partnership between WHO, the European Mosquito Control Association (EMCA) and the European Centre for Disease Prevention and Control (ECDC), with the involvement of the VBORNET network of medical entomologists and public health experts, has been set up to increase awareness and understanding about this growing threat and to assist countries in early detection and a prompt response. Regional meetings in 2011 and 2012 with broad participation by governments, policy-makers and experts have called for action to address the problem. In response, a regional framework has been developed in order to improve the prevention, surveillance and control of the invasive mosquito vectors and re-emerging diseases indicated in Fig. 1. The intention of the regional framework is to assist Member States in the development or updating of their own operational plans, harmonization of plans and approaches between countries, cross-border action and mobilization of resources to implement these plans.

Fig. 1. The invasive mosquito vectors and re-emerging vector-borne diseases addressed in the regional framework



The framework outlines strategic approaches and core activities. Measures to prevent the introduction of mosquitoes and to detect and contain them early are needed to prevent invasions. Where invasive mosquitoes have become established and can no longer be eliminated, the emphasis should be on integrated disease and vector surveillance, prevention of disease outbreaks and prevention of further spread of the vectors. Several enabling factors have been identified in the framework. Awareness must be raised about the threat caused by invasive mosquitoes in order to gain support at policy level and cooperation at community level. Regional coordination is needed to harmonize methods and procedures for prevention, surveillance and control across countries. Capacity-building and resource allocation is a prerequisite for the

implementation of prevention, surveillance and control activities. Moreover, basic and applied research must be conducted to understand the mosquitoes and diseases in their new environments better and to develop improved methods of control.

Re-emerging mosquito-borne diseases as regional threats

The growing problem of re-emerging vector-borne diseases

Although the number of diseases transmitted by mosquitoes in the Region is much lower than in tropical developing countries, a substantial number of these infections remain or are being brought into the Region. Outbreaks of potentially severe diseases, such as dengue and chikungunya fever, have increased in frequency in the Region, facilitated by the spread of mosquito vectors that are able to transmit these diseases (1–3). Possible factors driving the introduction and spread of vectors and disease are globalization, the increasing volume and pace of trade and travel, continuing urbanization and environmental challenges which include climate change.

Worldwide, dengue is a mosquito-borne infection of growing public health importance, found predominantly in urban and semi-urban areas in tropical and sub-tropical regions. In the past 50 years, reported dengue cases have increased 30-fold (4). WHO estimates that 50–100 million new infections occur annually in more than 100 endemic countries. The global number of dengue infections has already surpassed that for malaria (4,5), even though data for Africa are still largely lacking. Severe dengue (dengue haemorrhagic fever, dengue shock syndrome), a potentially lethal complication, affects hundreds of thousands, probably millions, of people mostly in Asian and Latin-American countries, and has become a leading cause of hospitalization and death among children in these regions.

In the past, epidemics of dengue fever occurred in southern Europe at a time when the vector *Aedes aegypti* was locally present. In 1927–1928, a large dengue epidemic caused significant morbidity and mortality in Greece (6). In the mid-20th century, the vector and the disease disappeared from the Region, but in recent years, the threat of dengue fever in Europe has increased again. The recent locally-transmitted dengue cases reported in Croatia and France in 2010 and in the autonomous region of Madeira (Portugal) in 2012 have shown that dengue transmission is possible in different areas of continental Europe where the vectors *Aedes albopictus* or *Aedes aegypti* are present. In Madeira, the costs of the dengue outbreak are likely to be substantial in terms of the resources needed for the emergency response, the burden on the health system and the adverse impact on tourism. In addition, the outbreak in Madeira has led to reports of cases imported into 14 other European countries, with implications for surveillance in those countries.

Chikungunya, another viral disease transmitted by *Aedes* mosquitoes, has shown a re-emergence during the past decade, with the potential for global expansion (7,8). The emerging chikungunya viral strain has adapted to the vector *Aedes albopictus* and, in 2005–2006, spread from the Indian Ocean to Africa, India and South-east Asia. In 2006, there was concern that it would spread to the Americas, but this did not happen (9). The outbreak of chikungunya fever in Italy in 2007 and sporadic cases in France in 2010 have proved that Europe remains vulnerable to the transmission of tropical arboviruses, and confirmed that indigenous transmission of such diseases can be established.

Yellow fever, also effectively transmitted by *Aedes* species, has become increasingly active over the past decade in endemic areas in sub-Saharan Africa and South America. In 2012, an outbreak of yellow fever in the Darfur region of the Sudan affected over 700 people, causing more than 165 deaths. In the European Region, the occasional occurrence of imported cases, for example, in Belgium and Germany (10,11), underlines the risk of yellow fever. In this context, it is worth recalling the historical outbreaks of yellow fever in southern Europe in the 19th century, such as the Barcelona outbreak in 1821 (12). Even though an effective vaccine for preventing yellow fever exists, the vaccine has limited availability in the Region.

Invasive mosquitoes in the transmission of vector-borne diseases

The introduction, establishment and spread of invasive species of mosquitoes within the European Region, assisted by globalization in trade and travel, are a cause for serious concern (13). Mosquitoes have been introduced and have successfully established themselves in new environments where they can compete with native species, transmit disease pathogens to humans, domestic animals and wildlife and cause biting nuisance and irritation among humans. The main impetus for this document, however, is the public health importance of invasive mosquitoes due to their role in the transmission of disease pathogens, notably disease viruses of tropical origin, among vulnerable human populations.

Invasive mosquitoes of the genus *Aedes* are able to disperse into new areas and adapt to new environmental conditions (13). In recent years, six *Aedes* species have been introduced into the Region, some of which have become firmly established and spread over large areas. The most invasive species, *Aedes albopictus*, has greatly expanded its range over recent decades and is now firmly established in the Mediterranean Basin. Its developmental stages, especially the eggs, are effectively transported mainly with the global trade in used car tyres and Lucky bamboo plants. Adult mosquitoes are also inadvertently transported by vehicles. This species, which is a vector of human diseases, can survive periods of coldness, and predictive models indicate that its range can expand northwards, especially in view of climate change (14–17).

A second species, *Aedes aegypti*, has become established around the Black Sea (Georgia and the Russian Federation) and in Madeira (Portugal) (13,18). This species, which is a highly effective vector of dengue, chikungunya and yellow fever viruses and closely adapted to human habitats, could re-establish itself in most of southern Europe, but due to its cold intolerance, probably not further north (17). Several other invasive species have been recorded, including *Aedes atropalpus*, *Aedes japonicus*, *Aedes koreicus* and *Aedes triseriatus*. Some of these species have been recorded locally and are spreading to other countries, but they have not yet been implicated as important vectors of human diseases.

As a consequence of the global spread of dengue and chikungunya, together with ever expanding global traffic, the number of cases among travellers into the Region has been steadily increasing in recent years (19). In particular, the recent rise in the number of dengue cases overseas might lead to an increase in infections being introduced into the European mainland, especially in view of the large numbers of travellers. The introduction of viraemic cases (persons carrying the virus) can lead to transmission wherever populations of invasive mosquito vectors, particularly *Aedes albopictus* or *Aedes aegypti*, have become locally established.

In recent years, *Aedes albopictus* has been implicated as the vector responsible for outbreaks of chikungunya in France (20) and Italy (21), and has been responsible for local transmission of

dengue in Croatia (22) and France (23). This mosquito species has also been considered as a potential bridge vector of other arboviruses (such as West Nile virus) from birds and mammals to humans (24). During the autumn of 2012, *Aedes aegypti* was the vector implicated in the outbreak of dengue in Madeira (Portugal) (25,26).

These events present a clear warning signal to the Region that the emerging disease problem may spread and intensify in the years ahead. In the absence of effective treatment or vaccines against the emerging diseases, early detection of human cases and prevention through vector control are of vital importance to protect largely vulnerable human populations. Even if vaccines against dengue or chikungunya become available in the future, they may only provide partial protection against virus serotypes and, thus, prevention and control strategies will continue to be needed (4,27).

Call for regional action

Concerns over invasive mosquitoes and their role in local transmission and outbreaks of dengue and chikungunya have prompted WHO, the European Commission (EC), EMCA and ECDC to work together to create greater awareness about the problem and to advise countries on prevention, surveillance and control activities. Additional support was provided by VBORNET, a European network of entomological and public health specialists established under the auspices of, and financed by, ECDC. VBORNET has as its main tasks to produce distribution maps of the major arthropod disease vectors and related surveillance activities, and to define priority strategic topics concerning the public health perspective of vector-borne diseases and vector surveillance (28).

Two recent meetings have addressed the concern over the continuing spread of invasive *Aedes* mosquitoes and the introduction of dengue and chikungunya fever into Europe. The first meeting, held in May 2011 in Speyer, Germany, established the basis for guidelines on vector control of invasive mosquitoes (29). At the second meeting, held in June 2012 in The Hague, the Netherlands, the countries in need and international organizations pledged their support for developing a regional framework for surveillance and control of invasive mosquitoes (30). It was concluded that action should be taken against invasive mosquitoes, but that in many countries the detection and containment of introductions and established populations are constrained by inadequate capacity and gaps in supportive legislation. The meetings formulated a number of recommendations, which constituted the starting point for development of the regional framework. The framework aims to guide countries in the development of their action plans.

In her opening address at the sixty-second session of the WHO Regional Committee for Europe, the Regional Director affirmed that the growing problem of invasive vector mosquitoes and re-emerging vector-borne diseases should be addressed properly, and that, with increased support from Member States, it was expected that a regional framework would be developed (31). With this regional framework, it is anticipated that the Regional Committee for Europe will adopt a resolution on surveillance and control of invasive vector mosquitoes and re-emerging vector-borne diseases in 2013.

Opportunities for action

The call for regional action on surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases comes at the right moment and is pertinent, given the public health concern in Member States and the inherently cross-border nature of the problem.

Governments, institutions and the general public should be aware of invasive mosquitoes and the transmission of emerging diseases so that governments can reorient their resources for surveillance, control, communication and research purposes, while complying with the existing policy agenda on vector-borne human diseases.

Substantial recent advances have been made by some leading countries and regional organizations (WHO, ECDC and EMCA) towards the development of methods for surveillance, risk assessment and information-sharing and control measures. Other countries should benefit from these developments through increased regional and bilateral collaboration and coordination. There are also opportunities at European Union (EU) level to advocate the development of and changes in policy and the harmonization of legislation to mitigate the existing problems regarding invasive mosquitoes and vector-borne diseases.

The prevention of mosquito invasions and disease emergence fulfils and complements the requirements of the International Health Regulations (IHR) for Member States to manage acute public health events and to develop and strengthen their capacities at designated ports, airports and ground crossings (32).

Several cross-border initiatives are being taken in the Region in areas relevant to emerging mosquito-borne diseases. Examples are climate change, the “one health” initiative, and travellers’ health. These themes have a bearing on the importation and transmission of disease pathogens and on the conditions for mosquito breeding. Countries should explore options for incorporating the prevention, surveillance and control of invasive mosquitoes and re-emerging vector-borne diseases into their national plans under these existing initiatives. Countries should also align the prevention, surveillance and control of invasive mosquitoes with the global and regional strategic framework on integrated vector management, which promotes the improvement of vector control through evidence-based decision-making, combinations of vector control methods, multi-disease approaches and intersectoral collaboration (33,34).

Regional framework for surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases

Goals and objectives

The goal of the regional framework is to prevent, carry out surveillance of and control re-emerging vector-borne diseases of public health importance, in particular dengue and chikungunya transmitted by invasive species of mosquitoes. The specific objectives are to:

- prevent the introduction of invasive mosquitoes into the Region;
- prevent the spread of invasive mosquitoes, especially into new areas;
- prevent outbreaks of dengue and chikungunya fever and reduce the risk of their transmission in areas where invasive mosquitoes have become firmly established;
- improve entomological surveillance and monitoring of invasive species of mosquito;
- improve surveillance and control of dengue and chikungunya viruses;
- improve disease management and thus reduce morbidity and mortality due to dengue and chikungunya.

The regional framework is expected to raise awareness of this emerging problem and to assist Member States in: (i) the development or updating of their own operational plans, (ii) the harmonization of plans and approaches between countries, (iii) cross-border action and (iv) mobilization of resources needed to implement these plans at regional and country level.

Scope and target audience

This document focuses on invasive species of *Aedes* mosquito of public health importance. Nonetheless, the burden of biting nuisance caused by these *Aedes* mosquitoes should not be underestimated (35). Invasive arthropod vectors other than mosquitoes are excluded, as are indigenous mosquito vectors of disease, such as indigenous *Anopheles* and *Culex* species which are vectors of the malaria parasite and West Nile virus, respectively (1). The basis for this narrow focus on invasive mosquitoes is the problem experienced in the Region with the rapid invasion of *Aedes* mosquitoes, the subsequent sporadic transmission and outbreaks of dengue and chikungunya by *Aedes* mosquitoes, and the availability of specific techniques for surveillance and control of *Aedes* mosquitoes (29,36).

Invasive *Aedes* mosquitoes confront Member States with a new re-emerging problem for which a consolidated framework has been lacking. It is anticipated that the framework, despite its limited scope, will benefit future programmes on any indigenous vector species and non-mosquito invasive vector species – if the activities are conducted within the framework of an integrated vector management approach (34).

The target audience for the regional framework consists of policy- and decision-makers, programme managers, research institutes, international partners, donor agencies and other stakeholders that could be involved in prevention, surveillance and control of invasive mosquitoes and the relevant vector-borne diseases.

Set of strategic approaches

A set of strategic approaches is proposed to achieve the objectives on prevention, surveillance and control of invasive mosquitoes and re-emerging vector-borne diseases (Table 1). In the technical realm, intervention is needed for prevention and control. Invasive mosquitoes should be prevented from establishing themselves in new areas. Where invasive mosquitoes have become established and can no longer be eliminated, the emphasis should be on integrated surveillance of vectors and disease and prevention of disease outbreaks.

A prerequisite for prevention, surveillance and control is that awareness of the threat of invasive mosquitoes is raised in order to gain support at policy level and cooperation at community level. As mosquito invasions and re-emerging vector-borne diseases are a cross-border problem, a mechanism for regional and bilateral coordination is vital for harmonizing methods and procedures and for preventing the further spread of the problem. Another enabling factor for the effective implementation of the framework is the development of capacity and allocation of adequate resources at country and regional level for prevention, surveillance and control of invasive mosquitoes and re-emerging vector-borne diseases. Moreover, basic and applied research must be conducted to understand the introduced mosquitoes and study methods for controlling mosquitoes and re-emerging diseases.

Table 1. Principal strategic approaches and core activities

Strategic approach		Core activity	
1. Prevention of establishment of invasive mosquitoes	1.1	Prevention of introduction of invasive mosquitoes	
	1.2	Mosquito detection at points of entry and high-risk sites	
	1.3	Prompt elimination of foci of colonization	
	1.4	Prevention of spread of established populations	
2. Integrated surveillance	2.1	Development of an integrated system of vector and disease surveillance	
3. Prevention and control of outbreaks	3.1	Preparation for disease outbreak response	
	3.2	Improvement of disease diagnosis and case management	
	3.3	Sustainable vector control to prevent transmission	
4. Awareness-raising about invasive mosquitoes and re-emerging vector-borne diseases	4.1	Generation of political support	
	4.2	Implementation of communication strategies	
5. Regional and bilateral coordination	5.1	Coordination and harmonization of prevention, surveillance and control activities	
	5.2	Coordination and harmonization of biocides registration	
6. Capacity development and resource allocation	6.1	Development of human capacity and resources for surveillance and control of vectors and disease	
	6.2	Establishment of a network of reference centres	
7. Basic and applied research	7.1	Promotion of research on entomological parameters	
	7.2	Study of methods of control of invasive mosquitoes and re-emerging disease	

Strategic approaches

The following section is numbered according to Table 1.

1. Prevention of establishment of invasive mosquitoes

Prevention should start at the source, through measures to stop the introduction of mosquitoes into new areas. When invasive mosquitoes have been introduced, the early detection of foci of introduction is critical to containing the problem from the onset. Failure to do so may allow invasive mosquitoes to establish themselves firmly in local environments and spread over wide areas, thus making species elimination difficult, if not impossible. This would also increase the risk of local transmission of re-emerging vector-borne diseases.

1.1 Core activity: prevention of introduction of invasive mosquitoes

For known sources of invasive mosquitoes, such as the importation of used tyres and Lucky bamboo, national governments and research institutes should further explore options for the prevention of accidental introduction and investigate their cost-effectiveness. Such options include restrictions on the trade in or import of high-risk goods and the preventive use of biocides (such as fumigation of at-risk shipments). The modification of conditions under which goods are shipped to reduce the presence or survival of mosquito stages should also be explored. For example, packing Lucky bamboo plants in hydrogel rather than transporting them in

standing water was reported to reduce the introduction of *Aedes albopictus* in California (37), although experience from the Netherlands suggests that *Aedes albopictus* continued to be introduced despite the transportation of plants in gels (38). When high-risk goods are imported, further preventive measures such as dry storage could curb the development of introduced egg or larval stages into adult mosquitoes.

1.2 Core activity: mosquito detection at points of entry and high-risk sites

National governments should strengthen the early detection of introduced mosquitoes through systematic monitoring at points of entry and other high-risk sites within the country (such as major ports, railway stations, rest areas along highway routes away from the Mediterranean basin) and imported goods liable to infestation with invasive mosquitoes. In and near designated points of entry, Member States have the obligation under the IHR (in Articles 19–21 and Annex 1B) to have methods and procedures in place for surveillance and control of vectors and vector breeding reservoirs (32). Two known sources of invasive mosquitoes, namely imported used tyres and Lucky bamboo plants, require systematic inspection and appropriate control (for example, in confined surroundings), supported by national legislation.

Countries should have a system in place for baseline surveillance at points of entry and high-risk sites to verify regularly the absence of invasive mosquitoes. For roughly two thirds of the land area of the Region, however, no surveillance data on invasive mosquitoes are available to date (18). Invasive species may already be present without these countries being aware of it. Resolving this paucity of information is a prerequisite for planning locally appropriate strategies of prevention or control. Countries lacking surveillance should identify local expertise to initiate and design an appropriate surveillance system. Standards and guidelines for surveillance and control developed by ECDC, EMCA and WHO are available for use by countries across the Region (29,36).

1.3 Core activity: prompt elimination of foci of colonization

In the early phase of colonization, when it is evident that invasive mosquitoes are still delimited to small foci (generally considered to be less than 1 km²), countries should carry out entomological surveillance in and around the colonized areas to guide and evaluate the intervention aiming to eliminate invasive mosquitoes (36). Hence, surveillance should be closely connected to the intervention, so that measures are implemented promptly before the invasive mosquitoes have spread. Available methods for containment of local populations of *Aedes* mosquitoes include the use of biocides targeting larval and adult mosquitoes combined with environmental methods used to create inhospitable environments for mosquitos to breed (29). In a number of countries, biocides with appropriate formulations are not currently available for use against mosquitoes. Because there is only limited experience with the elimination of invasive mosquitoes in the Region, countries should carefully evaluate and document the interventions for the benefit of future efforts.

1.4 Core activity: prevention of spread of established populations

In areas where *Aedes* mosquitoes have become firmly established, the further spread of mosquitoes to new areas or countries in the Region should be prevented where possible. In this respect, points of entry that are situated in areas with established vector populations deserve special attention. The IHR, in Annex 5, stipulate that “Parties should establish programmes to control vectors that may transport an infectious agent that constitutes a public health risk to a minimum distance of 400 metres from those areas of point-of-entry facilities that are used for

operations involving travellers, conveyances, containers, cargo and postal parcels.” Similar measures could apply to other high-risk sites.

The spread of invasive mosquitoes can also take place through the gradual expansion of the distribution of established populations, which may be difficult to prevent in areas where the local environmental conditions are favourable for the mosquitoes.

2. Integrated surveillance

2.1 Core activity: development of an integrated system of vector and disease surveillance

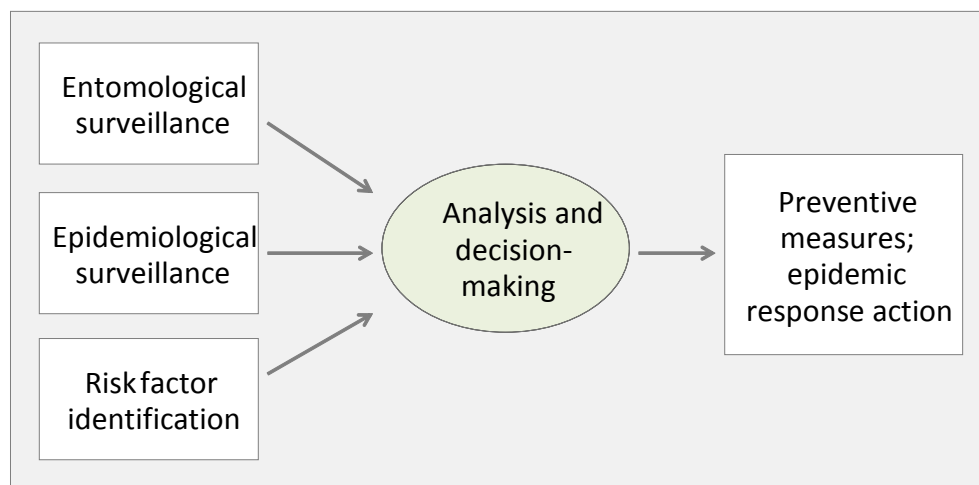
Countries should establish integrated surveillance systems for the early detection of epidemics, monitoring of vector populations and risk factors and measurement of the disease burden. Contemporary surveillance data are essential for the design and evaluation of preventive or control action.

Epidemiological surveillance of vector-borne diseases should become part of national health information systems. Surveillance methods should be standardized so that comparisons can be made between the situations in neighbouring countries.

In addition to entomological and epidemiological surveillance, an assessment of the determinants of disease transmission should assist in identifying high-risk situations and triggers for action (36,39). These determinants include entomological parameters (such as mosquito biting behaviour), human factors and environmental conditions.

Together, these three data sources – entomological surveillance, epidemiological surveillance and risk factor identification – should be analysed and used by countries for deciding on preventive measures (such as vector control when vector densities are above a certain level (29)) or epidemic response action (Fig. 2).

Fig. 2. The role of surveillance data in the planning of measures for disease prevention or epidemic response action in countries where *Aedes* mosquitoes have become established



In the European situation, where there is no endemic dengue or chikungunya, the risk of disease is related to the number of imported cases and to entomological and environmental variables which are still poorly understood. In the absence of locally-transmitted cases of disease, countries should conduct routine surveillance of vectors and other risk factors to monitor the probability of local transmission (36,40). In the event of sporadic infections, rapid case investigation is needed to determine whether the infection was imported or locally acquired (4). This should be accompanied by locally focused vector surveillance and control to limit the risk of transmission to other residents.

3. Prevention and control of outbreaks

In countries and areas where *Aedes* mosquitoes have become firmly established and elimination may no longer be feasible, it is important to minimize the risk of transmission of dengue and chikungunya virus.

3.1 Core activity: preparation for disease outbreak response

Countries in which *Aedes albopictus* or *Aedes aegypti* are established should have national preparedness plans in place, able to respond to early signs of outbreaks as soon as locally transmitted cases have been confirmed. Preparedness plans should spell out the objectives, flow of activities, roles, responsibilities and required resources. The plans – covering hospitalization plans, emergency vector control, advocacy, community mobilization, logistics, and monitoring and evaluation – should be field-tested together with partners from local government and other sectors (4,41). Countries can ask WHO, ECDC and other agencies for support in national outbreak preparedness and outbreak control or for assistance in disease control operations, for example through arrangements such as the Global Outbreak Alert and Response Network, existing reference networks or WHO collaborating centres (42–44).

Rapid communication between health authorities, local authorities and international agencies (WHO and Member States) is crucial for setting up a prompt emergency response. Cases of disease and their geo-references should be reported without delay by health workers, clinics and hospitals to enable the emergency response unit to deploy emergency vector control accompanied by vector surveillance conducted at regular intervals. In the direct vicinity of the reported cases, emergency vector control will be necessary to stop transmission. Local residents should also be mobilized (for example, by the health sector and nongovernmental organizations) to help prevent the spread of infection through source reduction campaigns and education on disease symptoms and personal protection measures.

3.2 Core activity: improvement of disease diagnosis and case management

Early and efficient diagnosis is central to achieving a successful clinical outcome of arboviral diseases such as dengue or chikungunya. Infections with dengue or chikungunya viruses show a wide range of clinical manifestations with similarities between diseases and different phases of disease (45,46). The complexity of clinical signs may lead to misdiagnosis by physicians, thus laboratory confirmation is important to exclude other diseases and to ensure proper symptomatic and supportive treatment. Molecular and serological techniques are available for detecting arboviral diseases.

Early recognition of disease, and thorough knowledge about the anticipated clinical manifestation in successive phases of disease, are the basis for effective case management (4).

The health care system should apply an appropriate front-line response to identify high-risk patients from the outset with the aim of reducing morbidity and mortality. The early notification of infections and their locations must be communicated to the emergency response unit to assist in detection and management of outbreaks.

3.3 Core activity: sustainable vector control to prevent transmission

Where populations of *Aedes albopictus* or *Aedes aegypti* are established, the proactive reduction of vector populations and human-vector contact will reduce the risk of transmission of dengue and chikungunya viruses, while also reducing biting nuisance. Experience shows that dengue vector control has mostly been reactive, that is, in direct response to increased outbreak risk and often depending on space spray applications. Reactive vector control may not be very effective at preventing outbreaks because of the long response time from infection to laboratory confirmation of dengue cases, and because asymptomatic infections resulting in silent transmission go unnoticed by passive surveillance systems (47). Proactive or sustainable approaches to vector control are not subject to these problems.

Vertical, top-down vector control programmes targeting *Aedes aegypti* have worked in the past, as shown in successful examples from Cuba and Singapore (48), but they may not be feasible or sustainable in European settings. Reports indicate that it has proved difficult to reduce populations of *Aedes albopictus* (49).

To achieve a gradual and sustainable reduction in vector breeding and human-vector contact, countries need to deploy a combination of top-down and bottom-up approaches that integrate chemical, mechanical and biological vector control methods and personal protection methods with the active participation of communities and involvement of relevant sectors and agencies. Indeed, recent experience from Spain suggests that a combination of vector control methods has been effective in reducing *Aedes albopictus* populations (50). Nevertheless, there is a paucity of information on the efficacy and effectiveness of available methods targeting *Aedes* mosquitoes (see core activity 7.2 below).

4. Awareness-raising about invasive mosquitoes and re-emerging vector-borne diseases

Invasive mosquitoes and re-emerging vector-borne diseases present a new problem to many countries. Awareness must be raised about the threat posed by this problem in order to gain support and cooperation for prevention and control action among all stakeholders, particularly policy- and decision-makers, physicians and the general public.

4.1 Core activity: generation of political support

Political commitment to tackle the problem of invasive mosquitoes and re-emerging vector-borne diseases needs advocacy at country and EU level. Such advocacy should be carried out by leading actors at the ministerial level, with the help of WHO and the EC, to put prevention, surveillance and control on national and EU policy agendas.

Advocacy should be based on contemporary surveillance data, risk analysis and data on the (potential) effectiveness of mitigation measures. Policy reform is a powerful means to ensure that prevention, surveillance and control activities are supported by legislation (for example, import/export restrictions, mandated inspection of imported goods and specific demands from

companies that trade in high-risk goods) and that the registration of biocides is authorized for professional use in mosquito control. Countries should explore the options for incorporating prevention, surveillance and control activities into existing preparedness plans for cross-border initiatives.

4.2 Core activity: implementation of communication strategies

Awareness should be raised by leading actors about re-emerging vector-borne diseases among physicians as well as the general public. Physicians should be alerted to the clinical signs and symptoms of dengue and chikungunya, which could be mistaken for other viral and parasitic diseases. The health sector, with the help of nongovernmental organizations, should inform or educate the general public through appropriate communication strategies (29), adapted to situations where an invasion of mosquito species is expected, where invasion has taken place or where local cases have been reported.

In situations where mosquito introductions are anticipated, communities can help alert authorities by spotting the arrival of new mosquitoes or daytime biting nuisance (indicative of the presence of *Aedes*). Where mosquitoes have become firmly established, communities could participate in making the peri-domestic environment less suitable for mosquitoes to breed or have human contact. Where locally transmitted cases of disease have been reported, communities must be prepared for public health interventions and should become actively involved in reducing the risks of transmission through personal protection and reducing the sources (4).

5. Regional and bilateral coordination

Invasions of mosquitoes and re-emerging vector-borne diseases are cross-border problems. Coordination between countries and at regional level is, therefore, necessary to prevent the problem spreading into new territories.

5.1 Core activity: coordination and harmonization of prevention, surveillance and control activities

A number of countries in the Region lack effective systems to detect and contain invasive mosquitoes and the disease pathogens they transmit. Other countries have developed their own systems, but the methods may not be consistent between countries. It is recommended that countries and institutions across the Region adopt standard methods of surveillance, risk assessment, vector control, case detection and outbreak response. The harmonization of methods for epidemiological and entomological surveillance will facilitate the exchange and management of data. The use of harmonized methods by countries will also enable better coordination in planning action to prevent the spread of invasive mosquitoes into new countries and the transmission of disease and to prepare for the control of cross-border outbreaks. The bilateral agreement between Azerbaijan and Georgia on the inspection of imports for invasive mosquitoes is an example of coordination between neighbouring countries.

Regional organizations, particularly WHO, ECDC and EMCA, play an important role in providing countries with technical assistance on standards and methods of surveillance and control of invasive vectors and arboviral infections. The web-based information system recently launched by ECDC is an important platform showing the geographic distribution of invasive mosquitoes, and this platform should be enhanced and combined with data on disease incidence

(28). At country level, intersectoral coordination and collaboration (for example, between public health, agriculture, local government and the private sector) are required to ensure the effective implementation of prevention, surveillance and control activities.

5.2 Core activity: coordination and harmonization of biocides registration

Biocide products play an important role in the elimination and control of invasive mosquitoes. However, a problem with the use of biocides is that in a number of countries the products are not currently registered for use against mosquitoes, leaving countries with few or no options for using biocides to, for example, eliminate foci of colonization. A new EU biocide directive will be implemented in October 2013 with the aim of increasing harmonization. This directive will stipulate that the active ingredients of biocides are registered at EU level and that biocide products are registered at national level. Even though a transition period with several provisions will be in place, the EU directive is expected to lead to the expiry of some existing biocide registrations in several EU countries, thus requiring renewed registrations.

For the specific use of biocides for mosquito control for public health purposes, countries are always dependent on biocide manufacturers or distributors and their decisions to register their products. High costs and lengthy procedures are currently stopping manufacturers and distributors from registering their products for minor use or for relatively small markets for mosquito control in individual countries. Under the new EU biocide directive, however, a biocide product registered in one EU member state can more easily be registered in other EU member states through a mechanism of mutual recognition. This will improve overall efficiency and reduce the costs of registration in EU countries. Countries should address problems with the registration of biocides with the legislative body, in this case the EC.

To further reduce costs and ease procedures, the registration of selected biocide products for mosquito control across the Region should be facilitated under the leadership of WHO and other organizations. In this regard, WHO's existing recommendations and specifications for vector control biocides and application equipment should be used as basis for the registration process.

6. Capacity development and resource allocation

The implementation of action plans ultimately depends on the existing institutional infrastructure, financial resources and human capacity at country and regional level to conduct and coordinate prevention, surveillance and control activities.

6.1 Core activity: development of human capacity and resources for prevention, surveillance and control of vectors and disease

When developing a national action plan on prevention, surveillance and control of invasive mosquitoes and re-emerging vector-borne diseases, countries should first carry out a needs assessment. As part of the needs assessment, the existing capacity that could be utilized for implementation of the action plan is identified, for example relating to laboratories, entomological and epidemiological expertise, and capacity for diagnosis and case management. The requirements in terms of additional training, staffing and infrastructure development should also be identified.

In accordance with the outcome of the needs assessment, countries should mobilize adequate human and financial resources and conduct training for optimal implementation of the national

action plan. Recommended methods and procedures for surveillance and control (4,29,36) should be adopted by countries in designing the training of trainers, in the reorientation of job descriptions and national operating procedures, and for developing and strengthening the core capacity requirements of the IHR.

6.2 Core activity: establishment of a network of reference centres

The efficiency and effectiveness of surveillance and control activities hinge upon prompt and reliable services for mosquito and pathogen identification, pathogen diagnostic tests and outbreak investigation. For example, the identification of mosquito specimens using morphological and molecular techniques is critical for differentiating between indigenous and introduced species and for determining the origin of strains of introduced species. Regional networks (such as the European Network for Diagnostics of Imported Viral Diseases (51)) exist for pathogen investigations in humans but are still lacking for entomological services. Laboratories selected as reference centres should be equipped, their expertise developed and a network between centres established to provide countries with the required specialist services. Regional organizations (such as WHO and ECDC) play an important role in the provision of technical support to reference centres and establishing or strengthening the networks between these centres.

7. Basic and applied research

To achieve the objectives of the regional framework, it is vital that national and regional research institutes and universities conduct further studies on some basic aspects of invasive mosquitoes or disease and on developing and testing methods for the early detection and control of invasive mosquitoes and re-emerging vector-borne diseases.

7.1 Core activity: promotion of research on entomological parameters

For most species of invasive mosquitoes, little is known about their mechanisms to adapt to new environmental conditions and, thus, about their potential to invade new areas. Possible mechanisms include the mosquito's ability to enter diapause, their cold hardiness and their ability to compete with indigenous mosquito species. Entomological research must be closely linked to operational requirements. In particular, studies are needed on behaviour and diapause, and on virus overwintering in *Aedes albopictus* (52). The competence of several species as vectors of human diseases still needs to be verified. Specifically, *Aedes atropalpus*, *Aedes japonicus*, *Aedes koreicus* and *Aedes triseriatus* have occasionally been introduced into the Region, but decision-making on appropriate response action depends on whether these species will be of public health importance.

In areas where *Aedes albopictus* or *Aedes aegypti* are firmly established, the potential efficiency of disease transmission (also called vectoral capacity) should be studied to assist in decision-making on the appropriate strategy of vector control or emergency response. To guide vector control operations, studies should determine the epidemic threshold, if any, of vector abundance below which transmission risk is limited. The best methods to assess adult mosquito density and biting activity need to be ascertained (52).

As well as the need for entomological studies, research should address the requirements for improved methods of diagnosis and case management of arboviral diseases.

7.2 Core activity: study of methods of control of invasive mosquitoes and re-emerging disease

The effectiveness of available methods, or combinations of methods, to eliminate foci of colonization or to suppress firmly established mosquito populations in the Region should be subjected to critical evaluation through operational research (52). Specifically, the effectiveness of chemical biocides in controlling *Aedes albopictus* and *Aedes aegypti* needs to be tested under environmental conditions that are optimal and those that are sub-optimal for the species. The susceptibility of invasive mosquitoes to the biocides used should be routinely monitored, and preventive strategies for managing insecticide resistance developed, where appropriate.

There are strong indications that the current tools for prevention, surveillance and control of invasive mosquitoes are inadequate and, therefore, new vector control tools adapted to the European context must be tested or developed (52). Methods such as the use of novel trapping devices, intelligently targeted source reduction, insecticide-treated materials, use of biological control agents and environmental management deserve increased attention in experimental studies and operational research.

In the social domain, studies are needed on the development and testing of locally tailored strategies to achieve community participation and community empowerment in vector control in the Region, drawing on the lessons learnt from dengue control in other Regions (48,53,54). In this regard, new control tools (such as trapping methods) should also be evaluated for their prospective use by the community.

The way forward

The outline of the regional framework for surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases presented in this document should assist Member States and regional organizations in developing their own action plans. It is anticipated that a resolution in support of this framework will be issued and adopted by the Regional Committee for Europe in 2013.

The Regional Office and WHO headquarters will provide technical assistance to Member States in the development of their national action plans and in strengthening their reference centres.

National action plans should specify for each of the core activities the specific activities that are planned at country level, outlining methods, defining roles and identifying capacity requirements. For each activity, the reporting requirements, milestones and timelines should also be set and products or expected outputs specified.

Countries are requested to report twice a year on the activities, challenges and shortcomings in the implementation of their action plans. The Regional Office will act as focal point to monitor progress in countries and to facilitate the sharing of information and experiences at regional level. On a biannual basis, WHO will report on regional progress to the Standing Committee of the Regional Committee and recommend action needed to address emerging issues (such as the setting up of thematic working groups or strengthening of capacity).

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**World Health Organization
Regional Office for Europe**

UN City, Marmorvej 51, DK-2100 Copenhagen Ø, Denmark
Tel.: +45 45 33 70 00 Fax: +45 45 33 70 01 Email: contact@euro.who.int
Website: www.euro.who.int