TECHNICAL REPORT

Vector control with a focus on *Aedes aegypti* and *Aedes albopictus* mosquitoes

Literature review and analysis

www.ecdc.europa.eu

ECDC TECHNICAL REPORT

Vector control with a focus on *Aedes aegypti* and *Aedes albopictus* mosquitoes

Literature review and analysis

This report was commissioned by the European Centre for Disease Prevention and Control (ECDC), coordinated by Laurence Marrama and produced by Bazian Ltd (London)

Acknowledgements
We are grateful to Ines Reulet, Herve Zeller, Marieta Braks and Alexandra Chaskopoulou for their contribution during the reviewing process, to Ana-Belen Escriva for her review of the literature search and to Teija Korhonen for her support in the management of the contract.

Suggested citation: European Centre for Disease Prevention and Control. Vector control with a focus on *Aedes aegypti* and *Aedes albopictus* mosquitoes*:* literature review and analysis of information. Stockholm: ECDC; 2017.

Stockholm, October 2017

ISBN 978-92-9498-095-3
TQ-04-17-842-EN-N
doi 10.2900/02128

Contents

Figures

Tables

Abbreviations

Bti	*Bacillus thuringiensis israelensis*
CNEV	National Centre for Vector Expertise (France)
CSI	chitin synthesis inhibitors
DGS	General Directorate for Health (France) General Directorate for Health (Portugal)
ECDC	European Centre for Disease Prevention and Control
EMCA	European Mosquito Control Association
EVD	Emerging and vector-borne diseases (programme)
GP	general practitioner
IGRs	insect growth regulators
IVM	Integrated vector management
JHA	juvenile hormone analogues
MSSI	Ministry of Health, Social Services and Equality (Spain)
RIVM	National Institute for Public Health and Environment (Netherlands)
SRAS	Regional Secretariat for Health (Portugal)
US CDC	US Centers for Disease Control
WHO EURO	World Health Organization's Regional Office for Europe

Glossary

Term	Definition
Adult mosquito control	Any intervention with or without chemical agents designed to kill adult mosquitoes, such as trapping (e.g. lethal ovitraps, Biogents (BG) traps), pyrethroid insecticides, etc.
Aedes aegypti *Ae. aegypti*	Also known as the yellow fever mosquito, a mosquito that is invasive to Europe. It is a vector for chikungunya, dengue and a potential vector for Zika viruses, among other pathogens.
Aedes albopictus *Ae. albopictus*	Also known as the tiger mosquito, a mosquito that is invasive to Europe. It is a vector for chikungunya, dengue and Zika viruses among other pathogens.
Bacillus thuringiensis israelensis (Bti)	A bacterium with insecticidal crystal protein, used as microbial larvicide (i.e. a form of bacteria that kill larvae).
Chitin synthesis inhibitors (CSI)	An insect growth regulator (see IGR below) that prevents chitin - an essential component of insects' exoskeleton – formation so when the insect molts and a new exoskeleton cannot form properly, the insect dies.
Insect growth regulators (IGR)	Chemicals that inhibit the life cycle of an insect.
Integrated vector management (IVM)	Integrated vector management is the use, in combination, of all available methods needed to control mosquito populations. It is specific for the targeted region and mosquito species.
Invasive species	A species originating from elsewhere, that establishes and proliferates within an ecosystem, having a negative impact on the environment, human health and potentially the economy.
Juvenile hormone analogues (JHA)	A hormonal IGR that mimics or inhibits the juvenile hormones to disrupt egg and larvae development, causing death.
Larval control	Any intervention with or without chemical agents designed to kill mosquito larvae, such as source reduction, the use of IGRs, bacterial insecticides, etc.
Lysinibacillus (Lsph, formerly Bs)	A bacterium with insecticidal crystal protein, used as microbial larvicide, (i.e. a form of bacteria that kill larvae).
Source reduction	Removing and preventing potential mosquito breeding sites (sources).

Executive summary

Background

The global movement of goods and people, and climate change have contributed to the spread of the 'invasive' mosquitoes *Aedes aegypti* and *Aedes albopictus* into Europe. Rather than simply being a nuisance the presence of these mosquitoes represents a major risk to public health. This literature review collects, summarises and analyses current international, national and sub-national technical documents, guidance and recommendations on control methods against invasive mosquitoes.

Methods

The literature review was performed by searching bibliographic databases, internet sources and the websites of relevant authorities. Searches were not limited to English language sources or documents, but were limited by date to 2006 onwards. The bibliographic database search strategies were reviewed by a literature search expert from the European Centre for Disease Prevention and Control (ECDC). A call for evidence was launched by ECDC's emerging and vector-borne diseases (EVD) programme to collect further technical materials, which may not have been published by the EU Member States. Once identified, documents were sifted using inclusion and exclusion criteria. Data was extracted into tables using headings based on ECDC's pre-specified areas of interest. These headings form the basis of the analysis, with additional themes reported in the findings section.

Findings

The literature review included 29 guidance documents and 18 technical/evaluative documents. The main gaps identified were in relation to evaluation, sustainability and community engagement.

Although many of the documents described evaluation as part of integrated vector management, it was unclear how the outcomes were integrated into practice and contributed to the continuous improvement of integrated vector management (IVM) programmes. Ensuring the continuing effectiveness of current control methods ensures in turn that programmes are sustainable. Approaches to help conserve the longevity of chemical control methods were restrained use, monitoring of localised resistance and the incorporation of the data into practice. According to many of the documents sourced, communities had a vital role to play since the effectiveness of control measures implemented in public spaces could be greatly improved by extending them to residential and commercial private property.

Discussion and conclusions

This review identified key areas where there is a lack of information and where opportunities exist to further enhance vector control across Europe. Publishing or otherwise sharing evaluations of vector control programmes would facilitate knowledge exchange and contribute to the creation of a European evidence base. Research into alternative control methods could increase the range of tools available, to improve the sustainability of the chemical products currently available. There is scope for further evaluation of the best methods for communicating with communities to encourage their participation in mosquito control which, in turn, could inform evidence-based practice.

Further monitoring and evaluation would facilitate evidence-based practice which could potentially increase the effectiveness and sustainability of control methods. There is scope for European-wide guidance to support this activity and ensure best practice.

1. Introduction

In recent years 'invasive' species of mosquitoes have begun to contribute to the nuisance and public health threat posed by mosquitoes in Europe. Current surveillance indicates that the two most prevalent species representing a public health in Europe are *Aedes aegypti* and *Aedes albopictus*. These mosquitoes are able to transmit chikungunya and Zika viruses, for which there is currently no vaccine, and dengue fever, for which the vaccine is still under evaluation in the field. However, all three of these diseases have no disease-specific treatment. In addition, *Aedes albopictus* has the potential to act as a bridging vector between animals and humans for some pathogens [1]. In this context, vector control is an important mechanism for disease prevention [2].

Previously chikungunya, dengue fever and Zika were characterised as 'imported' diseases, where infected people had returned from travel to endemic regions and then been treated in Europe, sometimes leading to further transmission of the disease by local vector mosquitoes before appropriate infection control measures could be put in place. As of January 2017, *Aedes albopictus* is recorded as having established itself in several European countries and its ability to survive the winter in those countries highlights the risk of potential spread to other countries within Europe [1,3]. In 2007, an outbreak of chikungunya in the Emilia-Romagna region of Italy caused by a local population of *Aedes albopictus* mosquitoes marked a turning point in Europe [4]. Since then several locally acquired cases have be detected in France (both dengue and chikungunya) and Croatia (dengue cases). Surveillance in recent years has shown that eggs of *Aedes albopictus* are able to survive in a dormant state (diapause) during European winters and hatch when climatic conditions are right, leading to population establishment [5-8]. In western Europe, *Aedes aegypti* is only established in Madeira – an archipelago in the North Atlantic which is an autonomous region of Portugal – however, intense trade and movement of people means that introduction via Madeira is a risk for other countries within continental Europe. *Aedes aegypti* was previously established in Europe up until the early 20th century and it can shelter indoors to potentially survive European winters [8]. So far *Aedes albopictus* has not established itself outside of the greenhouse areas where it has been detected in northern Europe [8]. Two key routes for the import of *Aedes albopictus* eggs into Europe are in tyres and lucky bamboo. Since the eggs can survive out of water, conventional measures to reduce sources by drying out reservoirs of water may not eradicate this risk and additional insecticide use may be required [8,9]. The situation with imported mosquitoes evolves quickly, requiring constant vigilance and preparedness. Moreover, when these imported mosquito vectors carry resistance mechanisms, as has already been evidenced for *Aedes albopictus*, there is a real concern that existing insecticides will decline in efficacy [8a].

There are numerous ways in which 'invasive' species of mosquitoes can be introduced to an area. International trade cargo, in particular flowers/plants or used tyres that contain dry, resistant eggs, are a well-known potential source [1,5]. In 2011, World Health Organization (WHO) stated that national regulation of the used tyre trade was urgently needed [10]. However, restrictions on imports without other surveillance and control measures would be insufficient for preventing species introduction and potential establishment [5]. By way of example, in the Netherlands the Minister of Health, Welfare and Sport has been working with the tyre industry body to create regulations to reduce the inadvertent transportation of mosquito eggs [11]. The emphasis is on the need for inter-disciplinary cooperation between organisations responsible for infectious disease control and others who can contribute to the effective control of mosquitoes. Transport vehicles are also important routes of importation for invasive mosquitoes, whether by road, air or sea [8].

Aedes albopictus and *Aedes aegypti* are both prolific daytime biters. This increases the risk of humans being bitten because it is harder to take personal protective measures during the daytime than at night, when measures such as bed nets are effective against evening/night-time biting mosquitoes. *Aedes aegypti* seeks out human blood meals from multiple individuals in short periods of time, greatly increasing their ability to spread disease [8]. European Decision No. 1082/2013/EU highlighted Member States' responsibility for establishing effective surveillance, monitoring, early warning and response measures to prevent the spread of cross-border threats [12]. Therefore, there is a need for effective vector control measures to limit the spread of invasive mosquitoes, control their numbers and prevent disease outbreaks. Although it is possible to learn from previous experience of controlling species native to Europe, the invasive species have dry, resistant eggs that can survive and be moved in large numbers over long distances. Therefore the applicability of lessons learned may be somewhat limited. Climate change and urbanisation have also contributed to creating habitats suitable for invasive mosquitoes [1,13]. Given that these species are also spreading elsewhere, such as the United States of America, it may be possible to learn lessons from strategies that have proved successful elsewhere and can be adapted to the European environment.

WHO has highlighted that there is a need for additional information about the efficacy and effectiveness of control methods for *Aedes sp.* [1]. In addition to learning from other regions where mosquito species have already become established, there is a possibility for cross-disciplinary learning. In particular, WHO describes the lessons that integrated vector management can learn from integrated pest management in agriculture [2]. However, there are differences, such as the fact that farmers can see immediate economic benefits from pest management, whereas they can be more difficult to measure in vector management where the burden is more dispersed across healthcare services, tourism, trade, etc.

As the viability and spread of the 'invasive' mosquitoes increases in Europe, their control becomes a more immediate and everyday challenge, rather than a response to small imported populations. ECDC has produced guidance for surveillance of native and invasive mosquito species, designed to harmonise and improve the effectiveness of surveillance practice across Europe [14,15]. This guidance recommends the implementation of an integrated invasive mosquito control programme in all countries where mosquito-borne disease surveillance and invasive mosquito population surveillance indicate that there is a risk of mosquito-borne diseases [14]. The European Mosquito Control Association (EMCA) and WHO's European Regional Office produced mosquito control guidance in 2011, and WHO produced a regional framework for the surveillance and control of invasive mosquito species [1,10]. However, in 2016 EMCA highlighted the need for guidance focused on controlling invasive mosquito species populations [16].

There remains a lack of up-to-date, clear recommendations and guidance on the implementation of cost-effective biological, chemical and environmental management vector control measures, focusing on invasive mosquito species, in the European context [2]. Therefore, ECDC commissioned this literature review to collect, summarise and analyse what information is required to implement vector control with a focus on *Aedes aegypti* and *Aedes albopictus*. This involved reviewing sub-national, national and international technical documents, guidance and recommendations on invasive mosquito control methods, as well as journal articles for relevant information. The focus is on applied vector control measures, the operational use of vector control and background strategy. The literature review also aimed to identify information gaps on vector control measures in European countries.

The main research question that this literature review aims to answer is: what are the currently recommended vector control measures in Europe against *Aedes aegypti* and *Aedes albopictus* (keeping in mind that a combination of methods would certainly be required)?

2. Methods

Searching

A literature search was performed for current European technical documents, guidance and reports that give advice or recommendations on vector control and journal articles, with a focus on *Aedes aegypti* and *Aedes albopictus*.

This literature review used a multi-pronged approach to pragmatically identify key literature and relevant documents, whilst minimising the possibility that important documents would be missed.

The sources for the literature review included bibliographic databases (Embase.com, PubMed), grey literature sources (such as Google Advanced search and key institutional websites) and a call for evidence by ECDC to the Emerging and Vector-borne Disease focal points of the Member States.

Search strategies

The searches combined the concepts within the scope of this project: the European geographical area, the concept of control strategies/programmes, specific control methods (such as insecticides), and the two specific invasive mosquito species. These concepts were combined to maximise the proportion of relevant results retrieved, without excessively reducing the ability of the search strategy to retrieve all relevant results. This included the use of proximity operators to search for words located near to each other within sentences and focusing on words appearing in titles and abstracts.

Embase.com and PubMed

The search terms were identified through background reading including the documents cited in the request for proposal sent out by ECDC, a thorough reading of the American Centers for Disease Control and Prevention's (US CDC) guidance on mosquito control and in consultation with ECDC experts and Bazian's expert advisor.

While developing the search strategies, we scanned the retrieved results to determine whether the search strategy was effective in identifying relevant records. Search strategies were iteratively revised and refined to maximise the number of relevant results retrieved, by reviewing a selection of the retrieved results ordered by relevance. The search strategy was further revised in response to a detailed peer review by ECDC.

The search was restricted to European countries using a search filter. The initial filter included Europe as a keyword and indexing term to focus the geographical scope of the search, but it was agreed that this was too restrictive. Therefore, the filter was revised to include keywords and subject headings, related to Europe and all EU Member States. The records retrieved by the searches included national and local documents, indicating that the filter was successful in retrieving a broad range of documents.

The search strategies for Embase.com and PubMed are given in Annex 1.

Grey literature searches

Grey literature searching used the following types of sources:

- Google advanced search to search for mosquito control guidance from international agencies and individual European countries.
- Key websites of relevant international agencies (such as WHO, ECDC and EMCA), and national organisations responsible for infectious disease control (such as Ministries for Health, Ministries for Public Health, the Robert Koch Institute[1] and research institutes such as Denmark's Statens Serum Institut[2]) were searched and browsed.
- The documents found were also used to identify websites for further searching.

The searches in these grey literature sources followed the same principles as the bibliographic database searching – combining the different concepts relevant to the project.

The search interfaces of grey literature sources are less sophisticated than bibliographic databases and require a different search approach. Therefore, multiple, simplified versions of the Embase.com search strategy were performed to search these sources. After running each search we iteratively refined the search strategy based on the results retrieved. For example, if many irrelevant results were retrieved, we tried different combinations of terms or different keywords in the next iteration of the search. However, if we retrieved many relevant results, we

[1] http://www.rki.de/EN/Home/homepage_node.html
[2] http://www.ssi.dk/

added new search terms to the search strategy based on those contained in the retrieved documents. The process was therefore iterative, developing search strategies based on the results of previous searches.

The searches used English keywords and phrases such as 'mosquito control' and 'mosquito guideline', translated into relevant languages, for example 'controllo delle zanzare' (Italian) and 'sivrisinek kontrol rehberi' (Turkish, for documents from Cyprus) to retrieve non-English language documents. These English keywords and phrases were also combined with other concepts such as country keywords (e.g. Malta mosquito control.) Another iteration of these searches restricted them to specific sites or internet domains (e.g. 'guía de control de mosquitos' limited to Spain), excluding irrelevant internet domains (e.g. 'mosquito control' filetype:pdf -.gov -.org – which would remove results from US-based websites). Where phrases did not retrieve relevant results, we also experimented with top level searching, such as searching simply for the word mosquito (in the relevant language) on individual websites or restricted to a specific website (e.g. komár [the Czech word for mosquito] restricted to the site:mzcr.cz).

This iterative approach is an effective way to construct search strategies for sources. It enables the searcher to be flexible and respond to the results that are retrieved, rather than running all pre-chosen iterations of search strategies, regardless of their effectiveness. The iterative nature of searching and the range of sources searched means that it is not feasible to record every iteration of the search strategy used in every source. The description above is designed to illustrate the approach taken as clearly as possible.

The reference lists of included papers were also scanned to check for references that had not been previously identified.

Call for evidence

ECDC contacted the Emerging and Vector-borne Disease Focal Points in each Member State country to call for evidence. This step was planned from the outset, to increase the probability that the project would include the key European technical documents and to potentially form the basis for a repository of these documents accessible by all European countries in order to support the exchange of good practices between countries.

Additionally, the documents identified in this review were compared against the contents of the Global Vector Hub (under development)[3] which will collect guidance, technical and training documents for vector control.

Sifting

When sifting the results retrieved from Embase.com and PubMed, two reviewers independently sifted 10% of the database records to test and refine the inclusion and exclusion criteria. The reviewers then compared their sifting decisions and used the discussion to refine the inclusion and exclusion criteria. The results of grey literature searching were initially sifted on-the-fly, due to difficulties in downloading references from these sources. A two-step sifting process was used, based initially on title and abstract screening, then full text. The full texts of documents received via the call for evidence were uploaded and sifted in Endnote. The same criteria were used to sift records from all sources.

[3] see https://zikaplan.tghn.org/news/newsletter/newsletter-april-2017/global-vector-hub/

Inclusion criteria

- Documents must specifically include *Aedes aegypti* and *Aedes albopictus* mosquitoes, these can be included in documents that cover all mosquito species in a country.
- Any form of biological, chemical and environmental management that controls the mosquito population, regardless of the purpose of control (e.g. minimising nuisance, control of disease-transmitting mosquitoes).
- Guidance documents describe the control methods used at an international, national or local level.
- Technical and evaluative documents should describe strategies and/or evaluations of strategies - including technical, practical input for vector control implementation.
- Systematic reviews of control methods or mosquito resistance.
- Articles must either have been published in academic literature (e.g. journals such as Eurosurveillance) or be produced/used by national, sub-national or supra-national authorities, non-governmental organisations or other official agencies.
- Searches were limited to 2006 onwards. This decision was taken following discussions between Bazian, ECDC and our expert adviser, which concluded that in this fast-moving area documents published prior to this date may not be relevant to today's context. There was a possibility of extending the date range, but the reviewers felt that the volume of material included was sufficient, so this step was not required.
- In Europe, although focusing on EU Member States.

Exclusion criteria

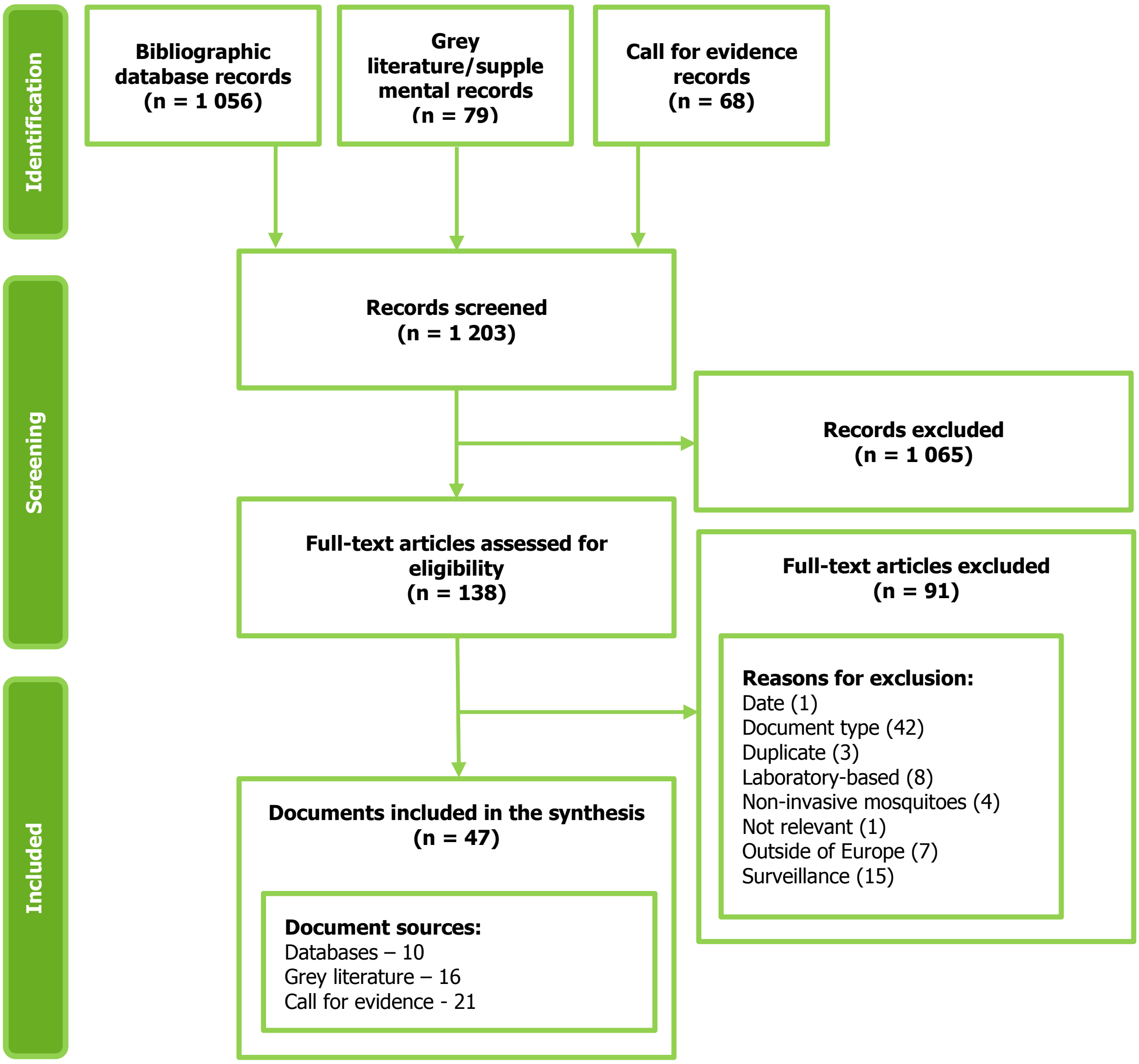
- Non-mosquito pest control.
- Vector control outside of Europe.
- Surveillance – documents focused on surveillance, not as part of a control programme. This is covered by ECDC guidance.
- Personal protective measures – this literature review specifically focuses on controlling the vector population as an upstream control measure, rather than personal measures such as spray repellent.
- Descriptive – where documents were classified as reviews, cost effectiveness studies or evaluations of vector control (rather than guidance), they were excluded if they described a vector control programme without including outcome information to constitute an evaluation of the effectiveness of the programme.
- Setting – studies based in laboratories or using captured mosquitoes were excluded.

Many documents considered for inclusion were excluded because they did not provide guidance, technical instruction or evaluation. Often they described methods that had been used, without providing either guidance or evaluation upon which guidance could be derived. There were also guides aimed at the general public, travel advice, steps that could be taken to reduce mosquito breeding and the prevention and treatment of mosquito bites. Evaluation of the effectiveness of different control mechanisms, including some innovative approaches to performing controlled studies, were excluded where they did not contribute to guidance or form the basis of a control plan. Regulations concerning the use of chemical control were only included as part of an integrated plan, not the regulations in and of themselves.

Originally, there was an option to include guidance outside of Europe – such as guidance produced by the US CDC – in the event of there being insufficient documents or gaps in information from Europe. Based on the documents retrieved, the decision was taken not to include guidance from outside of Europe in the analysis. However, CDC guidance and draft WHO guidance have been included in the discussion section of this report as a benchmark to European practice [17,18].

The flow of documents through the search and sift process is shown in the PRISMA diagram (Figure 1). The literature review included 47 documents in total (see complementary information about the excluded document in Annex 3). This comprised 29 guidance documents, 10 of which were identified through grey literature searching and 19 via the call for evidence. Of the 18 reviews and evaluations, six were identified through grey literature searching, two via the call for evidence and 10 through database searching. Scanning the reference lists of included papers and cross-checking against the Global Vector Hub did not identify any additional records for inclusion.

Figure 1. Prisma diagram



Analysis

Data was extracted into tables under the following headings:

- Type of document
- Organisation producing document (author/publisher)
- Objective of the control strategy
- Control methods used:
  - Biological
  - Chemical
  - Physical
- Inspections at borders (of imported goods, travellers and vehicles)
- Criteria for implementation of the control programme
- Organisation and management at a national and sub-national level
- Cost of the control programme
- Evaluation methods
- Economic considerations (including cost-effectiveness assessment of control methods)
- Community involvement
- Surveillance
- Risk assessment
- Resistance.

Technical documents and reports were analysed and summarised to find current information and advice from European countries and agencies. We identified information gaps by scanning the tables, to highlight priority areas where technical information appeared to be lacking.

3. Findings

This literature review included 29 guidance documents. One set of guidelines that focused on resistance management in France has not been included in the main data extraction tables because it did not contain relevant information [19]. It is included in the section on resistance.

The literature review also identified 18 documents that have been grouped under the heading Reviews, cost effectiveness assessments and evaluations of vector control.

This section presents results from the guidance and reviews, cost effectiveness assessments and evaluation documents under the pre-specified heading. There is a separate section containing emergent findings that did not fit within these headings.

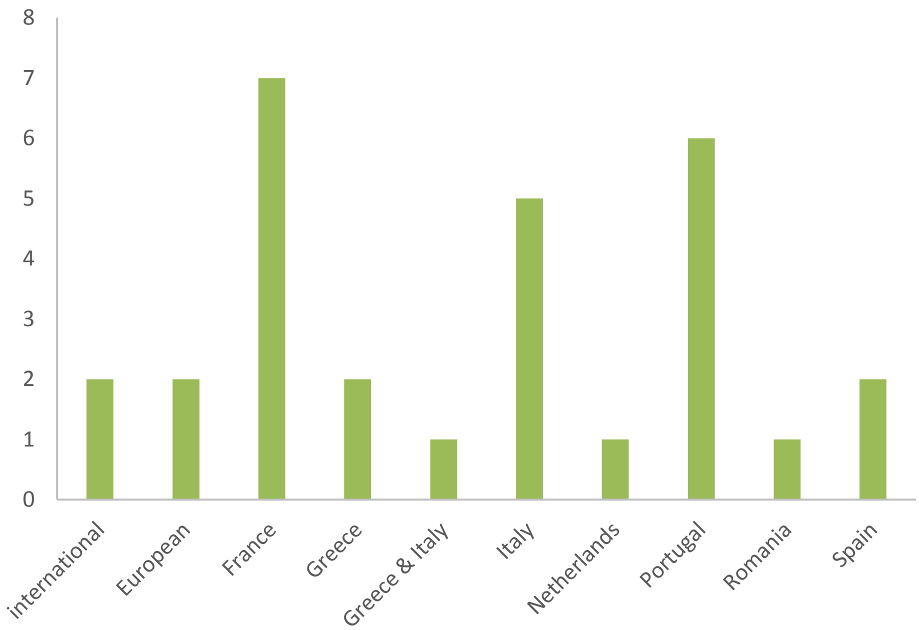
3.1 Organisation producing document (author/publisher)

Guidance

International and European guidance

WHO produced two of the included guidance documents [2,20]. WHO's Regional Office for Europe, in collaboration with EMCA, produced guidance on controlling mosquitoes representing a public health risk [10]. WHO's Regional Office for Europe also produced guidance on surveillance and control of invasive mosquitoes and re-emerging vector-borne diseases [1]. The remaining guidance documents were produced by national, regional or local authorities responsible for public health.

Figure 2. Number of included documents by organisation producing the guidance



National guidance

- France [22-28]
- Greece [29,30]
- Italy [5,31]
- Greece and Italy [29,30
- The Netherlands [9]
- Portugal [33]
- Romania [34]
- Spain [35].

Regional and local guidance

- Italy [21,36,37]
- Portugal [38-42]
- Spain [44].

Reviews, cost-effectiveness assessments and evaluations of vector control

These documents include two European-focused systematic reviews [8,45], three European cost studies [46-48], and 11 evaluations of vector control programmes within Europe [49-60]. Two of the included documents describe the same evaluation, therefore these two documents have been extracted as a single study [46,47].

Table 1. Geographical setting: country scope considered in the reviews, cost-effectiveness and evaluation documents

Reference (country abbreviation)	Country scope	Country code
Baldacchino F, Caputo B, Chandre F, et al (EU).[45]	European	EU
Medlock JM, Hansford KM, Schaffner F, et al (EU).[8]	European	EU
Rivas Morales S (IT).[46, 47]	Italy	IT
von Hirsch H, Becker, N (DE).[48]	Germany	DE
Abramides GC, Roiz D, Guitart R, et al (ES).[49]	Spain	ES
Baldacchino F, Bussola F, Arnoldi D, et al (IT).[50]	Italy	IT
Bellini R, Albieri, A, Carrieri, M, et al (IT).[51]	Italy	IT
Bellini R, Medici A, Puggioli A, et al (IT).[52]	Italy	IT
Caputo B, Ienco A, Cianci D, et al (IT).[53]	Italy	IT
Caputo B, Ienco A, Manica M, et al (IT).[54]	Italy	IT
Englbrecht C, Gordon S, Venturelli C, et al (IT).[55]	Italy	IT
Flacio E, Engeler L, Tonolla M, et al (CH).[56]	Switzerland	CH
Manica M, Cobre P, Rosa R, Caputo B (IT).[60]	Italy	IT
Marini L, Baseggio A, Drago A, et al (IT).[57]	Italy	IT
Scholte EJ, Den Hartog E, Dik M, et al (NL).[58]	Netherlands	NL
Scholte EJ, Dik M, Ibanez-Justicia A, et al (NL).[59]	Netherlands	NL
SRAS (PT).[43]	Portugal	PT

3.2 Target species

The majority of the included guidance and other reviews, cost effectiveness assessments and evaluations of vector control documents focused on tackling invasive mosquitoes as a group or individual invasive mosquito species [1,8,9,21-23, 25-28, 30-32, 34-43, 45,46,48,58].

3.3 Objectives

Guidance

The objectives of the various guidance documents varied, depending on the country in question, the region and local priorities (see Table 2). Overall, disease prevention was the most common objective, following by mosquito population reduction, prevention of mosquito establishment and disease outbreak response, then nuisance reduction and the detection of a new invasive species.

The guidance included in this review varied in objectives, depending on the local entomological situation. For example, in the autonomous region of Madeira, where *Aedes aegypti* is established, measures focus on maintaining the population at safe and manageable levels [42]. The authorities in Madeira have accepted that preventing outbreaks of diseases such as dengue is not always possible, which reinforces the need for vector control and appropriate response measures to suspected cases [42]. Whereas in the Netherlands, where invasive species are primarily imported through international trade, control measures focus around ports of entry and imports to eliminate mosquitoes introduced into the area and prevent their further spread [9].

Most guidance focused on preventing the import of vectors. However, two guidance documents in Madeira and France specified an objective of preventing the spread and export of invasive mosquitoes to other regions, especially within Europe [24,42]. Again, this emphasises the impact that local context has on the objectives of control programmes. The large, well-established invasive mosquito populations in these countries create a high risk of their spreading through Europe. The objectives of the included guidance are summarised in Table 2.

Table 2. Type of organisations producing guidance, target species and objectives of the activities presented in the guidance documents under review

Reference (country abbreviation)	Organisation producing guidance	Target species	Nuisance reduction	Prevention of establishment	Population reduction	Disease prevention/ control	Outbreak response	Detection of invasive species
WHO.[2]	International	All vectors				•		
WHO.[20]	International	All vectors						
EMCA (EU).[10]	European	All mosquitoes	•	•	•	•	•	•
van den Berg H, Velayudhan R, Ejov M (EU).[1]	European	Invasive mosquitoes	•	•	•	•	•	•
CNEV (FR).[23]	National	Invasive mosquitoes	•	•	•	•	•	
CNEV (FR).[24]	National	All mosquitoes				•	•	
CNEV (FR).[25]	National	*Ae. albopictus*	•			•	•	
DGS (FR).[22]	National	*Ae. albopictus*				•		
DGS (PT).[33]	National					•		
DGS (FR).[26]	National	*Ae. albopictus*		•	•	•	•	•
DGS (FR).[28]	National	*Ae. albopictus*		•	•	•	•	•
DGS (FR).[27]	National	Invasive mosquitoes	•		•	•	•	•
Institutul Cantacuzino (RO).[34]	National	*Ae. albopictus*						
LIFE CONOPS (EL).[30]	National	*Ae. albopictus*		•	•			
LIFE CONOPS (EL).[32]	National	*Ae. albopictus*		•	•	•	•	
MS (IT).[31]	National	Invasive mosquitoes				•	•	
MSSI (ES).[35]	National	Invasive mosquitoes	•	•	•	•	•	
RIVM (NL).[9]	National	*Ae. albopictus*		•	•	•		
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT).[5]	National	All mosquitoes	•	•	•		•	
Υπουργείο Υγείας (EL).[29]	National	All mosquitoes	•	•	•	•		
Comunidad de Madrid (ES).[44]	Regional	All vectors						
Regione del Veneto (IT).[21]	Regional	*Ae. albopictus*		•	•	•		
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT).[37]	Regional	*Aedes aegypti*				•	•	
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT).[36]	Regional	*Ae. albopictus*	•		•	•	•	
SRAS (PT).[39]	Regional	*Ae. aegypti*			•	•	•	
SRAS (PT).[38]	Regional	*Ae. aegypti*						
SRAS (PT).[40]	Regional	*Ae. aegypti*		•	•			
SRAS (PT).[42]	Regional	*Ae. aegypti*			•	•	•	
SRAS (PT).[41]	Regional	*Ae. aegypti*			•	•		

Country abbreviations: EL - Greece, FR - France, IT - Italy, NL - Netherlands, PT - Portugal, RO - Romania, ES - Spain. EU - Europe

Organisation abbreviations: EMCA European Mosquito Control Association, CNEV Le Centre National d'Expertise sur les Vecteurs (The National Center for Vector Expertise), DGS (FR) La Direction Générale de la Santé (Directorate General for Health), DGS (PT) Direção-Geral da Saúde (Directorate-General for Health), LIFE CONOPS (a joint Greek-Italian project to devise IVM programmes), MSSI Ministerio de Sanidad, Servicios Sociales e Igualdad (Ministry of Health, Social Services and Equality), RIVM Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment), Υπουργείο Υγείας (Ministry of Health), SRAS Secretaria Regional da Saúde (Regional Secretariat for Health).

Note: blanks in tables (denoted iin pink) indicate that information is not included or is not applicable

3.4 Vector methods recommended

This section describes the control methods recommended in the guidance documents included. Table 3 gives an overview of the control methods recommended. Subsequent sections describe the recommended control methods in greater detail.

Table 3. Control methods overview – guidance

Reference	Biological	Methods: Chemical	Methods: Larvicide - products	Methods: Adulticide - products	Methods: Physical
WHO [2]	Yes	Unclear*	No details reported.	No details reported.	Yes
WHO [20]	Not reported	Not reported	No details reported.	No details reported.	Not reported
EMCA (EU).[10]	Yes	Larvicide & Adulticide	IGRs*: CSI† (diflubenzuron) or JHA* (methoprene, fenoxycarb and pyriproxyfen).	Pyrethrins and pyrethroids	Yes
van den Berg H, Velayudhan R, Ejov M (EU) [1]	Yes	Larvicide & Adulticide	Any approved substance	Any approved substance	Yes
CNEV (FR) [23]	Yes	Larvicide & Adulticide	IGRs (diflubenzuron, pyriproxyfen).	Pyrethroids (deltamethrin).	Yes
CNEV (FR) [24]	No	Larvicide & Adulticide	No details reported.	No details reported.	Yes
CNEV (FR) [25]	No	Unclear	No details reported.	No details reported.	Yes
DGS (FR) [22]	No	Larvicide & Adulticide	Any approved substance	Any approved substance	Yes
DGS (PT) [33]	Yes	Larvicide & Adulticide	No details reported.	No details reported.	No
DGS (FR) [26]	No	Larvicide & Adulticide	Any approved substance.	Pyrethroids or organophosphates. Permethrin and d-phenothrin (for aircrafts)	Yes
DGS (FR) [28]	No	Larvicide & Adulticide	Any approved substance.	Natural pyrethrum (low risk scenarios) Pyrethroid - deltamethrin (higher risk scenarios)	Yes
DGS (FR) [27]	No	Larvicide & Adulticide	No details reported.	No details reported.	Yes
Institutul Cantacuzino (RO) [34]	No	Larvicide	No details reported.	No details reported.	Yes
LIFE CONOPS (EL) [30]	Yes	Larvicide & Adulticide	Microbial larvicides (see biological).	Diflubenzuron	Yes
LIFE CONOPS (EL) [32]	Yes	Larvicide & Adulticide	IGRs.	Any approved substance.	Yes
MS (IT) [31]	Yes	Larvicide & Adulticide	IGRs.	Pyrethroids – cyflutrina, cypermetrina, deltamethrin, etofenprox, permethrin, and tetramethrin.	Yes
MSSI (ES) [35]	Yes	Larvicide & Adulticide	Any approved substance	Any approved substance	Yes
RIVM (NL) [9]	Yes	Larvicide & Adulticide	Microbial larvicides (see biological).	Deltamethrin (Aqua-K-Othrine®).	Yes
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5]	No	Larvicide & Adulticide	IGRs (diflubenzuron, methoprene, piryproxifen)	Pyrethrins, pyrethroids (bifenthrin).	Yes
Υπουργείο Υγείας (EL) [29]	No	Larvicide & Adulticide	IGRs (diflubenzuron) ; microbial larvicides (BTi).	Deltamethrin; lambda-cyhalothrin; permethrin; alpha-cypermethrin; cyfluthrin; tetramethrin + pbo; bendiocarb; etofenprox; tetramethrin; piperonyl butoxide; cypermethrin; 1R-trans phenothrin.	Yes
Comunidad de Madrid (ES) [44]	No	Unclear	No details reported.	No details reported.	Yes
Regione del Veneto (IT) [21]	Yes	Larvicide & Adulticide	IGRs (diflubenzuron, pyriproxyfen).	First generation pyrethroids for quick knock-down. Second or third generation photo-stable pyrethroids with good residual action.	Yes

Reference	Biological	Methods: Chemical	Methods: Larvicide - products	Methods: Adulticide - products	Methods: Physical
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) [37]	Yes	Larvicide & Adulticide	IGRs (diflubenzuron, pyriproxyfen, S-methoprene).	Pyrethroids, pyrethrum.	
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36].	Yes	Larvicide & Adulticide	IGRs (diflubenzuron, pyriproxyfen).	Pyrethroids.	Yes
SRAS (PT) [39]	No	Unclear	No details reported.	No details reported.	No
SRAS (PT) [38]	No	Larvicide	No details reported.	No details reported.	Yes
SRAS (PT) [40]	No	Unclear	No details reported.	No details reported.	No
SRAS (PT) [42]	No	Larvicide & Adulticide	No details reported.	No details reported.	Yes
SRAS (PT) [41]	No	Unclear	No details reported.	No details reported.	Yes

** Note: unclear means that the document discussed the use of chemical controls but no further information was provided.*

† Abbreviations used: IGRs – insect growth regulators are divided into CSI – chitin synthesis inhibitors and JHA – juvenile hormone analogues.

3.4.1 Integrated vector management

Guidance

WHO recommends integrated vector management (IVM), which applies a multi-disease control approach rather than disease-specific strategies. It combines a range of interventions, using evidence-based decision-making to design and adapt control strategies, and a multi-sectoral approach among public health entities, other relevant agencies/organisations and the community [2]. IVM also aims to improve the cost-effectiveness, ecological soundness and sustainability of disease vector control [2]. The guidance included in this review followed the principles of IVM.

Figure 3. Overview of IVM methods used in included guidance

Source: Bazian

It was recommended that the effectiveness of control methods should be monitored and evaluated during and after implementation of control measures.

This approach, recommended by WHO, is borne out in the included guidance documents. Although not all documents specifically refer to IVM, it is clear that this is the generally accepted approach [9, 10, 23-27, 29, 33, 35, 36, 39-42].

Integrated control strategies combine chemical, physical, biological, and cultural control measures [61]. In particular, there was an emphasis on the prevention of mosquito breeding through simple measures such as site reduction at municipal level (e.g. good sewer management and encouraging the public to dispose of standing water, to reduce the need for insecticide use) [44,62, 63]. Control activities must be carried out by registered and qualified companies [28,44].

Reviews, cost effectiveness assessments and evaluations of vector control

A review of invasive mosquito control in Europe found that in larger areas with a recently established population – parts of France, Italy, Greece and Spain - control was much more challenging [8]. Madeira has struggled to control its large and well-established invasive mosquito population, despite a concerted integrated vector management programme [8].

However, there have been successes, such as the autonomous region of Catalonia in Spain, where an IVM programme significantly reduced the number of *Aedes albopictus* eggs in an area where they were already well-established [8, 49]. The programme comprised source reduction through a door-to-door community intervention; granular form *Bacillus thuringiensis israelensis* (Bti) applied to seasonal streams; monthly larvicide (diflubenzuron) treatment of selected vegetation, scuppers, water tanks and street drains and adulticide (Fastac®, active ingredient alfacipermetrin) applied once in 2008 and four times in 2009 [49]. This study provided evidence of the effectiveness of these strategies in achieving short-term reductions in the mosquito population, which is especially relevant for areas where these mosquitoes are well-established and eradication is no longer a realistic objective. During the study period the overall number of eggs increased, suggesting that the mosquito population is continuing to rise in this area.

In southern Switzerland, an IVM programme was implemented to tackle *Aedes albopictus* in the region of Switzerland bordering Italy [56]. This involved a community education programme to encourage source reduction and Bti use, larvicide treatment using monthly applications of diflubenzuron or weekly Bti in public spaces over 20 weeks, and permethrin use reserved for high-risk areas or where a disease case is confirmed. Ovitraps were used to assess the effectiveness, with untreated areas having 2.26 times more *Aedes albopictus* eggs.

3.4.2 Biological

Guidance

The guidance documents included varied in terms of whether they recommended use of biological vector control methods. Some methods, such as fish and crustaceans that eat mosquito larvae, were not commonly recommended for use (see Table 4) [9, 10, 21, 23, 30-32,36]. Whereas others, such as Bti and Lsph (formerly known as Bs) are more commonly recommended [5,9,10,21,23,29-32,36,37]. Bti and Lsph are bacteria with insecticidal crystal protein, used as microbial larvicide (i.e. a form of bacteria that kill larvae.)

Biological vector control methods were acknowledged as a potentially useful tool, especially in the context of increasing insecticide resistance. The threat to human health and ecology that pesticides present is also a consideration, with biological methods particularly popular for use in containers such as animal troughs that cannot be emptied.

However, some of the fish used to control mosquito larvae – such as mosquitofish (*Gambusia affinis*) - are not native to Europe. Hence EMCA/WHO and French guidance recommend that native fish species are used rather than invasive species that may disturb the local ecosystem [10,23]. EMCA/WHO guidance excludes the introduction of non-native fish, whereas French and Italian guidance recommends that non-native fish species are only used in isolated bodies of water where they cannot escape into the local ecosystem [21,23,31,36,37].

Guidance for mosquito control in Greece and Italy recommend that sterilised mosquito males can be released in areas that are inaccessible to other control methods [30,32].

Table 4. Biological methods for vector control– guidance

Reference	Recommended biological methods					
	Native fish	Other fish	Copepods	Genetically modified mosquitoes	Bti	Bti & Lsph
WHO.[2]						
WHO.[20]						
EMCA (EU).[10]	•				•	•
van den Berg H, Velayudhan R, Ejov M (EU).[1]						
CNEV (FR).[23]	•	•			•	
CNEV (FR).[24]						
CNEV (FR).[25]						
DGS (FR).[22]						
DGS (PT).[33]						
DGS (FR).[26]						
DGS (FR).[28]						
DGS (FR).[27]						
Institutul Cantacuzino (RO).[34]						
LIFE CONOPS (EL).[30]			•	•	•	•
LIFE CONOPS (EL).[32]			•	•	•	•
MS (IT).[31]		•			•	•
MSSI (ES).[35]						
RIVM (NL).[9]		•	•		•	•
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT).[5]					•	
Υπουργείο Υγείας (EL).[29]					•	
Comunidad de Madrid (ES).[44]						
Regione del Veneto (IT).[21]	•	•			•	
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT).[37]		•			•	•
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT).[36]		•	•		•	
SRAS (PT).[39]						
SRAS (PT).[38]						
SRAS (PT).[40]						
SRAS (PT).[42]						
SRAS (PT).[41]						

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

Reviews, cost effectiveness assessments and evaluations of vector control

The use of biological methods for controlling invasive mosquitoes were described in 10 out of the 18 technical, review or evaluation documents included in this review (see Table 5) [45,8,46,47,48,49,50,51,52, 57,59].

Table 5. Biological methods for invasive mosquito control- reviews and evaluations

Reference	Document type	Target species	Biological
Baldacchino F, Caputo B, Chandre F, et al (EU).[45]	Review	Aedes (all subspecies)	Bti/Lsph Entomopathogenic fungus - potential, but so far has only been tested outside of Europe. Copepods - semi-field trials in Italy showed favourable results, worth studying in greater depth in Europe. Spinosad – a bacterial compound not available in Europe. Appears effective, but its effect on non-target species requires further study. Wolbachia-infected adults - the effectiveness of this as a strategy remains unclear, as does its sustainability.
Medlock JM, Hansford KM, Schaffner F, et al (EU) [8].	Review	All invasive mosquitoes	As part of IVM
Rivas Morales S (IT) [46,47].	Cost study	*Ae. albopictus*	Cyclopoids micro crustaceans (copepods) – in public fountains.
von Hirsch H, Becker, N (DE) [48].	Cost study	*Ae. albopictus*	Bti (on private land)
Abramides GC, Roiz D, Guitart R, et al (ES) [49].	Technical/ evaluation	Mosquitoes	Bti
Baldacchino F, Bussola F, Arnoldi D, et al (IT) [50].	Technical/ evaluation	*Ae. albopictus*	Bti - granular Bti (1.2%, 1 g/m2) applied to seasonal streams as part of IVM – no specific results attributable to Bti.
Bellini R, Albieri, A, Carrieri, M, et al (IT) [51].	Technical/ evaluation	*Ae. albopictus*	Bti - granular Bti/Lsph (Vectomax) applied every 4–6 weeks June-September to catch basins (10g catch basin−1). Residents used one larvicide tablet per catch basin every 10 days. Significant reduction in the quantity of mosquito larvae in catch basins and plant saucers between the two door-to-door interventions, there was no significant difference between other container types.
Bellini R, Medici A, Puggioli A, et al (IT) [52].	Technical/ evaluation	*Ae. albopictus*	Sterile males – in Italy releasing sterile males significantly reduced fertility in the local population. Two out of five areas experienced significant reductions in egg density (50–70%).
Manica M, Cobre P, Rosa R, Caputo B (IT) [60].	Technical/ evaluation	*Ae. albopictus*	Not applicable
Marini L, Baseggio A, Drago A, et al (IT) [57].	Technical/ evaluation	*Ae. albopictus*	Bti - applied weekly in public spaces, pellets for private property. Results for overall IVM programme, not attributable solely to Bti.
Scholte EJ, Dik M, Ibanez-Justicia A, et al (NL) [59].	Technical/ evaluation	*Ae. aegypti* & *Ae. albopictus*	Bti - Bti space spray or granules were added to water containers in a 500m perimeter once every two to three weeks, until the first week of November. Results not reported in detail.

Bti has only short-term residual activity, whereas Lsph is recycled through infected larvae and affects slightly different mosquito species – so they can be combined to maximise effectiveness [45]. Field evaluations have shown that Bti/Lsph are more effective when applied using motorised misters - either backpacks or vehicle mounted – to reach hard-to-access breeding sites. Bti has been effective in Europe as an aerial spray in coastal or wetland areas of France and Greece, applied to imported tyres in the Netherlands, in road drains in Spain and in Germany's Rhine Valley, but is primarily used to treat catch basins in residential areas [48-50, 58,59]. An IVM programme in Catalonia, Spain, used granular Bti in seasonal streams. In the Emilia-Romagna region of Italy Bti is recommended for residential settings because its low toxicity makes it suitable for use by the public [46,47]. It is distributed via door-to-door visits and at public events, however local municipalities can also arrange with pharmacies to sell it directly to citizens.

Copepods have been effective at reducing and even eradicating mosquito populations outside of Europe, but there have only been small, semi-field trials in Europe itself – although these reported favourable results [45]. An evaluation of mosquito control in the Italian region of Emilia-Romagna suggested such larval predators be considered as an option in vector control, but these biological methods were not included in the current programme and have therefore not been evaluated. Consequently, there is a need for further studies to assess their effectiveness in Europe [45]. Copepods feed mainly on the most juvenile forms of larvae and therefore the effectiveness of this strategy may be increased by combining it with Bti – which is harmless to copepods – in order to kill other larval stages [45].

Entomopathogenic fungi – which disable or kill mosquito - show potential as a method for vector control, especially given that they have been judged not to pose a toxicity risk to humans. However, so far these fungi have only been tested in laboratory or semi-field experiments, and outside of Europe [45].

Releasing mosquitoes infected with strains of the bacteria *Wolbachia pipientis* has been studied as a method for controlling mosquito populations. However, the effectiveness of this as a strategy remains unclear, as does its cost and sustainability (males are dead-end hosts) [45].

The release of male mosquitoes sterilised using radiation has also been trialled in pilot sites in urban Italy for *Aedes albopictus* [52]. The results were mixed, with two areas experiencing significant reductions in egg density (50–70%) while the remaining three experienced small, non-significant changes [52]. In these pilot studies a laboratory in Austria supplied large quantities of sterile males. As with any other control method, authorities would need to consider supply of the control medium prior to implementation. Countries and local authorities considering this technique could collaborate to jointly purchase larger volumes of sterile mosquitoes from a single supplier to create economies of scale.

There are other novel techniques such as interfering with mosquito DNA, which are still in development and have not been field tested in Europe or elsewhere [45].

3.4.3 Chemical

Guidance

Chemical methods were also commonly used, these included larvicides alone, and larvicides and adulticides in combination (see Table 6) [1–5, 9,10,21–24, 26–38,42]. Adulticides are applied directly on vegetation or other known mosquito resting harbourages in the form of residual treatments or in the form of space sprays using Ultra Low Volume (ULV) application technologies against the flying adult mosquitoes. Where use of adulticides was permitted, they were recommended only in extreme circumstances, such as when the adult mosquito population had reached such high levels that there was a significant risk to public health (epidemic risk) or in cases of an outbreak, rather than as a routine part of vector management [5,10,21–24, 27–29, 31, 32, 36,37,42]. The threshold for epidemic risk was not clearly defined in any guidance. Adulticide treatments are usually applied via ground applications in Europe, with aerial application only for ULV in exceptional circumstances. ULV applications are generally restricted [37,45].

Table 6. Chemical control methods – guidance

Reference	Larvicide					Adulticide				
	Larvicide	Any approved substance	Insect growth regulators	Chitin synthesis inhibitors	Juvenile hormone analogues	Adulticide	Any approved substance	Pyrethrins	Pyrethroids	Organophosphates
WHO [2]	Unclear*					Unclear				
WHO [20]										
EMCA (EU) [10]	•		•	•	•	•		•	•	
van den Berg H, Velayudhan R, Ejov M (EU) [1]	•	•				•	•			
CNEV (FR) [23]	•		•			•		•		
CNEV (FR) [24]	•					•				
CNEV (FR) [25]	Unclear					Unclear				
DGS (FR) [22]	•	•				•	•			
DGS (PT) [33]	•					•				
DGS (FR) [26]	•	•				•		•	•	•
DGS (FR) [28]	•	•				•		•	•	
DGS (FR) [27]	•					•				
Institutul Cantacuzino (RO) [34]	•									
LIFE CONOPS (EL) [30]	•					•				
LIFE CONOPS (EL) [32]	•		•			•	•			
MS (IT) [31]	•		•			•			•	
MSSI (ES) [35]	•	•				•	•			
RIVM (NL) [9]	•					•			•	
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5]	•		•			•		•	•	
Υπουργείο Υγείας (EL) [29]	•		•	•		•			•	
Comunidad de Madrid (ES) [44]	Unclear					Unclear				
Regione del Veneto (IT) [21]	•		•	•		•			•	
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) 37]	•		•	•	•	•			•	
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36]	•		•	•		•			•	
SRAS (PT) [39]	Unclear					Unclear				
SRAS (PT) [38]	•									
SRAS (PT) [40]	Unclear					Unclear				
SRAS (PT) [42]	•					•				
SRAS (PT) [41]	Unclear					Unclear				

** Note: unclear means the document indicated that chemical controls can be used, but no further information was reported. Blanks in tables (denoted in pink) indicate that information is not included or is not applicable.*

Reviews, cost effectiveness assessments and evaluations of vector control

Table 7. Chemical control overview – reviews and evaluations

Reference	Target species	Larvicides				Adulticides								
		IGRs	Pyriproxyfen	Diflubenzuron	JHA	Pyrethroids	Xylene	Toluene	Alfacipermetrin	Permethrin	Deltamethrin	Tetramethrin	Bendiocarb	Fenitrothion
Baldacchino F, Caputo B, Chandre F, et al (EU) [45].	Aedes (all)	•	•	•	•	•								
Medlock JM, Hansford KM, Schaffner F, et al (EU) [8]	Invasive mosquitoes													
Rivas Morales S (IT) [46,47]	*Ae. albopictus*													
von Hirsch H, Becker, N (DE) [48]	*Ae. albopictus*		•	•		•	•	•						
Abramides GC, Roiz D, Guitart R, et al (ES) [49]	Mosquitoes													
Baldacchino F, Bussola F, Arnoldi D, et al (IT) [50]	*Ae. albopictus*			•		•			•	•	•			
Bellini R, Albieri, A, Carrieri, M, et al (IT) [51]	*Ae. albopictus*													
Bellini R, Medici A, Puggioli A, et al (IT) [52]	*Ae. albopictus*		•	•										
Caputo B, Ienco A, Cianci D, et al (IT) [53]	*Ae. albopictus*													
Caputo B, Ienco A, Manica M, et al (IT) [54]	*Ae. albopictus*		•											
Englbrecht C, Gordon S, Venturelli C, et al (IT) [55]	*Ae. albopictus*			•						•	•			
Flacio E, Engeler L, Tonolla M, et al (CH) [56]	*Ae. albopictus*													
Manica M, Cobre P, Rosa R, Caputo B (IT) [60]	*Ae. albopictus*									•		•		
Marini L, Baseggio A, Drago A, et al (IT) [57]	*Ae. albopictus*			•						•	•	•		
Scholte EJ, Den Hartog E, Dik M, et al (NL) [58]	*Ae. albopictus*										•			
Scholte EJ, Dik M, Ibanez-Justicia A, et al (NL) [59]	*Ae. aegypti* & albopictus										•			
SRAS (PT) [43]	*Ae. aegypti*					•							•	•

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

Larvicides

A review of invasive mosquito control in Europe found that larvicides were effective in reducing the mosquito population in certain settings, such as used tyre yards in France and recently colonised greenhouses in the Netherlands [8]. The chemical larvicides most commonly reported in use were diflubenzuron and pyriproxyfen (see Table 7 for a summary of the chemicals used). The details of the methods used to apply larvicides are set out in Table 8.

Insect Growth Regulators (IGR) are the most commonly used mosquito chemical control, these products interfere with insect larval development so that they do not reach maturity and therefore cannot breed, some IGRs also inhibit egg hatching [45].

An evaluation of four IGR formulations implemented in 2008/2009 in the Emilia-Romagna region of Italy found that three diflubenzuron-based formulations were all effective and long-lasting, with 100% effectiveness up to 3–4 weeks post-treatment [51]. Following treatment, there was a steady decline of effectiveness over time. The formulation DEVICE® SC-15 was recommended by the authors because it can be delivered via backpack pumps, making it particularly effective and suitable for applying to road drains and road hopper windows – both of which are common in Italian towns. Pyriproxyfen (SUMILARV 0.5G®) at the recommended doses did not deliver satisfactory effectiveness and persistence. Diflubenzuron was equally effective for both *Aedes albopictus* and the native *Culex pipiens*. However, pyriproxyfen was slightly less effective with *Aedes albopictus* than *Culex pipiens*. This provides further evidence to strengthen the case for using diflubenzuron-based formulations to target invasive species. A subsequent IVM programme in the same region involved five larvicidal treatments (using diflubenzuron and pyriproxyfen) of public road drains during the breeding season, which were repeated if heavy rainfall or strong winds might adversely affect effectiveness [46,47].

Another study applied one treatment of IGR (Flubex, 2g tablets with 2% of diflubenzuron) every second week (from May) to catch basins [54]. Three types of traps were used to measure the number of mosquitoes reaching maturity and emerging as adults, Catch Basin Traps (CBT), Mosquito Emergence Trap (MET) and Sticky Traps (ST). The Mosquito Emergence Trap (MET) can be placed next to treated sites, such as catch basins, to measure the number of mosquitoes reaching adulthood and therefore the effectiveness of larvicidal treatment. This evaluation used a newly designed (in 2012) MET that can distinguish between mosquitoes that have emerged from catch basins or other nearby breeding sites. Three of the four quadrants had almost no adult mosquitoes emerging, whereas one quadrant (in a botanical garden) had rates of adult emergence comparable to untreated sites. This may have been due to rainfall or debris reducing the effectiveness of the insecticide treatment. Sticky traps proved particularly effective at attracting *Aedes albopictus*.

Several *Aedes sp.* prefer breeding in smaller water containers, which can make it difficult to identify and physically reach breeding sites – either to remove or treat them [45,53]. *Aedes albopictus* and *Aedes aegypti* females lay eggs from a single reproductive cycle in multiple locations, the innovative larvicide delivery method 'auto-dissemination' exploits this behaviour by luring them onto surfaces treated with larvicide, which they then spread to other breeding sites [53]. It was effective in Italy using pyriproxyfen (5%), killing 50–70% of *Aedes albopictus* pupae, compared to <2% mortality at untreated sites [45,53]. Auto-dissemination has the potential to spread larvicide to otherwise untreated, hard-to-reach breeding sites. Pyriproxyfen's good residual action means that larvicide-treated lure sites do not need frequent maintenance. This potentially makes it a cost-effective larvicidal delivery method. One challenge for auto-dissemination is ensuring that the larvicide adheres to the surface of the adult mosquito, and approaches such as combining oil and pyriproxyfen powder may increase the effectiveness of autodissemination [45]. Auto-dissemination could be combined with other agents, such as funghi, to also target adult mosquitoes or distributed using sterilised males (the sterile insect technique), to potentially increase the impact of those individual control methods [45,53]. More field trials are needed to understand the real-world factors affecting the effectiveness of the technique. An evaluation of the Dengue action plan in Madeira described the use of larvicides, without specifying the compounds used.

Adulticides

All included documents reported using pyrethroids to control adult mosquito populations (see Table 7 for a summary of the chemicals used). The details of the methods used to apply adulticides are given in Table 13.

In a built-up area of Rome, Italy, a vehicle-mounted, cold, low-volume application of permethrin and pyrethrum (0.5% TERBUTIN, droplet size <50μm, vehicle speed 15km/hour) applied as a space spray 60–90 minutes before sunset was effective in reducing *Aedes albopictus* abundance by 80–87% [54].

An evaluation in north-eastern Italy compared the effectiveness of two adulticide formulations for controlling *Aedes albopictus* [57]. Microsin combines the pyrethroids cypermethrin (10%) and tetramethrin (2%) with the synergist piperonyl butoxide (15%). Etox comprised the nonester pyrethroid etofenprox (20%) and the pyrethroid tetramethrin (3%) with the synergist piperonyl butoxide (15%) [57]. The formulations were applied using both a mist sprayer and a stretcher power sprayer. The mounted mist sprayer used 8-bar pressure to apply insecticide at a dose of 0.37 litres per m^2, the operator speed was 6–8 km per hour. The stretcher power sprayer pressure was 20 bar and applied a dose of 0.063 litres per m^2 with an operator speed of 3–4 km per hour. Applications followed manufacturer's instructions, using the recommended concentration of active ingredient (0.4% for Microsin and 0.5% for Etox). Insecticide application to vegetation occurred in clear, dry conditions, with little to no wind at 18:30. Both insecticides had a dramatic impact on mosquito population (close to 100% reduction), with this reduction decreasing to around 50% after 14 days. The stretcher sprayer had around 60% population reduction after 14 days, whereas the mist sprayer had only around 40%. The authors speculate that this may be due to the stretcher's higher pressure, enabling the insecticide to penetrate further into vegetation. The best combination of insecticide and application method was the stretcher power sprayer and microsin.

Another evaluation in Rome investigated adulticide spraying in the immediate vicinity of residential property [60]. A hand-held sprayer applied microsene (100g contains 15g permethrin, 2.5 tetramethrin, 5g piperonyl butoxide), mixed either with water or carbonoxide (a liquid additive), to both sides of a hedge and inside the perimeter of the study area. Spraying had an immediate effect on adult population (-86% the next day), but adult populations quickly recovered even after a second treatment – there was a population recovery time of 10 days to pre-treatment levels. However, carbonoxide increased the immediate knock-down effect and population recovery time, and therefore may be a useful emulsifier.

An evaluation of the dengue action plan in Madeira described resistance testing for a range of adulticide products used in 2013 but did not provide details of application methods or concentrations, etc. [43] The products tested were a carbamate insecticide (Bendiocarb), an organophosphate (Fenitrothion) and a pyrethroid (Cyfluthrin).

Table 8. Chemical control details – reviews and evaluations

Reference	Document type	Target species	Larvicide used	Adulticide used	Methods: Chemical - techniques used	Chemical methods results
Baldacchino F, Caputo B, Chandre F, et al (EU) [45].	Review	*Aedes* (all sub-species)	IGR	Pyriproxyfen, methoprene, diflubenzuron. Pyrethroids	Larvicide - treatment of catch basins. Adulticide – using pyrethroids under high-risk circumstances. Generally ground applications are used in Europe, aerial application only in exceptional circumstances.	Larvicide - treating catch basins reduced *Aedes albopictus* adult emergence, diflubenzon more effective than pyriproxyfen (Italy). Pyriproxyfen auto-dissemination effective at killing pupal mosquitoes of albopictus (Italy). Adulticide - spraying alpha-cypermethrin on vegetation in parks was effective; in another study ULV deltamethrin achieved higher mortality and residual effect than alpha-cypermethrin (Spain). In Italy LV permethrin and pyrethrum was effective in reducing abundance.
Medlock JM, Hansford KM, Schaffner F, et al (EU) [8].	Review	All invasive mosquitoes	As part of IVM	As part of IVM	Not reported.	No pesticide-specific results reported.
Rivas Morales S (IT) [46,47].	Cost study	*Ae. albopictus*	Not reported	Not reported	Not reported.	Cost outcomes reported.
von Hirsch H, Becker, N (DE) [48].	Cost study	*Ae. albopictus*	Diflubenzuron Pyriproxyfen (public drains)	Pyrethroids of lower impact (xylene, toluene)	Larvicide - Five treatments of public road drains during the breeding season. Treatments repeated if climactic conditions affect effectiveness. The process should be documented. Adulticide - three consecutive nights, 100m radius of the residence of suspected or confirmed cases, 300m radius of a cluster of cases. Apply droplets <50μm to vegetation up to 4m high on public and private land. Portable or vehicle-mounted sprayers, depending on the accessibility of the treatment area. Repeat if heavy rain occurs and postpone in winds of >3m per second. Treatments should be timed to avoid the presence of humans or animals, using appropriate safety equipment. The process should be documented.	Cost outcomes reported.
Abramides GC, Roiz D, Guitart R, et al (ES) [49].	Cost study	Mosquitoes	N/A (biological larvicides used)	N/A	N/A	N/A
Baldacchino F, Bussola F, Arnoldi D, et al (IT) [50].	Technical/ evaluation	*Ae. albopictus*	Diflubenzuron	Pyrethroid (Alfacipermetrin)	Larvicide - (2% diflubenzuron, 1 g/hl) in scuppers, water tanks and street drains containing stagnant water in the intervention areas. Adulticide - (10% alfacipermetrin 50 cc/hl) applied monthly July to October to the vegetation of some public gardens.	Significant reduction in numbers of mosquito eggs in treated areas compared with untreated areas in 2008 and 2009.
Bellini R, Albieri, A, Carrieri, M, et al (IT) [51].	Technical/ evaluation	*Ae. albopictus*	N/A (biological larvicides used)	N/A	N/A	N/A
Bellini R, Medici A, Puggioli A, et al (IT) [52].	Technical/ evaluation	*Ae. albopictus*	Diflubenzuron Pyriproxyfen	N/A	Larvicide - Diflubenzuron was sprayed into road drains using a backpack pump (25 ml/drain sprayed over three seconds). Pyriproxyfon 0.5g increased to 4 g/catch basin.	All diflubenzuron formulations achieved 100% effectiveness up to 3-4 weeks post treatment. The DEVICE® SC-15 was considered the best as the backpack pumps make it suitable for applying to inaccessible areas. Pyriproxyfen did not deliver satisfactory effectiveness at recommended doses. Diflubenzuron was more effective than pyriproxyfen in targeting *Ae. albopictus*.
Caputo B, Ienco A, Cianci D, et al (IT) [53].	Technical/ evaluation	*Ae. albopictus*	N/A	N/A	N/A	N/A
Caputo B, Ienco A,	Technical/ evaluation	*Ae. albopictus*	Pyriproxyfen	N/A	Auto-dissemination - 5% and 0.5% concentration pyriproxyfen powder	5% formulation was most effective, killing 50–70% of *Aedes albopictus*

Reference	Document type	Target species	Larvicide used	Adulticide used	Methods: Chemical - techniques used	Chemical methods results
Manica M, et al (IT) [54].					used in modified sticky traps. Adult mosquitoes are lured in, contaminated with the larvicide which they then spread to breeding sites.	pupae, compared to <2% mortality at untreated sites.
Englbrecht C, Gordon S, Venturelli C, et al (IT) [55].	Technical/ evaluation	*Ae. albopictus*	Diflubenzuron	Permethrin	Larvicide - Catch basins treated with one tablet of diflubenzuron (2%, 2 g tablets) every second week, including dry catch basins. Adulticide - vehicle-mounted cold low-volume spraying (droplet size < 50 µm, 1.5 g pyrethrum 50% extract; 8 g permethrin, 2.64 g piperonyl butoxide for 100 g of product) 60–90 minutes before sunset.	Three of the four treated areas had almost no adult mosquitoes emerging, whereas one quadrant (in a botanical garden) had rates of adult emergence comparable to untreated sites. This may have been due to rainfall or debris reducing the effectiveness of the insecticide treatment in the catch basins. After the second application of adulticide the estimated percentage of control was 80–87% for *Aedes albopictus*.
Flacio E, Engeler L, Tonolla M, et al (CH) [56].	Technical/ evaluation	*Ae. albopictus*	N/A	N/A	N/A	N/A
Manica M, Cobre P, Rosa R, Caputo B (IT) [60].	Technical/ evaluation	*Ae. albopictus*	N/A	Microsene – contains permethrin and tetramethrin.	Adulticide – sprayed onto vegetation and around houses within the study area.	Adulticide spraying had an immediate effect on adult population, but adult populations quickly recovered (even after a second treatment). Population recovery time of 10 days to pre-treatment levels. Carbonxide increased the immediate knock-down effect and extended population recovery time compared to emulsifying with water.
Marini L, Baseggio A, Drago A, et al (IT) [57].	Technical/ evaluation	*Ae. albopictus*	Diflubenzuron	Permethrin	Larvicide - Diflubenzuron monthly. During the main breeding season. Adulticide - permethrin spraying where disease cases are confirmed or in high-risk areas such as school yards.	Results for overall IVM programme - untreated areas had 2.26 times more *Aedes albopictus* eggs.
Scholte EJ, Den Hartog E, Dik M, et al (NL) [58].	Technical/ evaluation	Aedes albopictus		Two pyrethroid formulations.	Two formulations - 0.4% of active ingredient: cypermethrin 10%, tetramethrin 2%, synergist piperonyl butoxide 15%; - 0.5% active ingredient: nonester pyrethroid etofenprox 20%, tetramethrin 3%, synergist piperonyl butoxide 15%. Adulticide - using a mounted mist sprayer (8 bar pressure, 0.37 litres per m2 dose, 6–8 km per hour) and a stretcher power sprayer (20 bar pressure, 0.063 litres per m2, 3-4km per hour). Application to vegetation in clear, dry conditions, with little to no wind and at 6:30 pm.	Both insecticides had a dramatic impact on mosquito population (close to 100% reduction), after 14 days this reduction decreased to around 50%. The stretcher sprayer had around 60% population reduction after 14 days, whereas the mist sprayer had only around 40%.
Scholte EJ, Dik M, Ibanez-Justicia A, et al (NL) [59].	Technical/ evaluation	*Ae. aegypti, Ae. albopictus*	N/A (biological larvicides used)	Deltamethrin	Not reported in detail.	Not reported in detail.
SRAS (PT) [43].	Technical/ evaluation	*Ae. aegypti*	Not reported	Bendiocarb, Fenitrothion, Cyfluthrin	Not reported	Not reported

3.3.4 Physical

Guidance

Physical methods for preventing and destroying potential breeding sites – such as emptying or covering water tanks, using mosquito netting (see below for an expanded list) – were the most commonly used control methods (see Table 9) [1,2,5,9,10,18-27,29-34,36-38,40,42,44,64]. These interventions reflect the urban settings to which most guidance applied and the habits of the mosquitoes in question. In Italy, there was guidance tailored to rural settings, where the emphasis was on land maintenance (e.g. filling ditches in fallow land) and drainage maintenance, demonstrating the need for control measures that suit the specific landscape and environment in which they are being applied [37].

In documents where one or more method was used as part of an integrated vector management programme, physical methods were used as the first-line control method, and other methods were used if physical methods were not feasible or did not work.

Table 9. Physical methods - guidance

Reference	Methods: Physical
WHO [2]	•
WHO [20]	
EMCA (EU) [10]	•
van den Berg H, Velayudhan R, Ejov M (EU) [1]	•
CNEV (FR) [23]	•
CNEV (FR) [24]	•
CNEV (FR) [25]	•
DGS (FR) [22]	•
DGS (PT) [33]	
DGS (FR) [26]	•
DGS (FR) [28]	•
DGS (FR) [27]	•
Institutul Cantacuzino (RO) [34]	•
LIFE CONOPS (EL) [30]	•
LIFE CONOPS (EL) [32]	•
MS (IT) [31]	•
MSSI (ES) [35]	•
RIVM (NL) [9]	•
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5]	•
Υπουργείο Υγείας (EL) [29]	•
Comunidad de Madrid (ES) [44]	•
Regione del Veneto (IT) [21]	•
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) [37]	•
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36]	•
SRAS (PT) [39]	
SRAS (PT) [38]	•
SRAS (PT) [40]	
SRAS (PT) [42]	•
SRAS (PT) [41]	•

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

Reviews, cost effectiveness assessments and evaluations of vector control

The documents included described the following key activities as physical methods for controlling invasive mosquitoes (see Table 10):

- Emptying temporary water containers
- Covering immovable water containers
- Indoor storage of water containers
- Indoor storage of tyres
- Cleaning up landfill sites and other rubbish
- Treating landfill sites
- Treating tree cavities
- Maintaining canals and riversides to avoid stagnation
- Using biological control in public fountains that cannot be emptied
- Lethal traps
- Mapping breeding sites
- House-to-house visits - to identify breeding sites and provide information on treatment
- Public awareness campaign to provide information on breeding sites and their treatment.

The *Aedes albopictus* control programme in the Emilia-Romagna region of Italy included mapping non-removable potential breeding sites (to inform control measures), emptying and cleaning water containers, indoor tyre storage, treatment of tree cavities and maintaining canals and riversides to prevent stagnation [46,47]. As this was an integrated vector management programme including multiple control methods, it was not possible to assess the effectiveness of the physical control methods in isolation. The evaluation did include the costs for some activities relating to physical control, such as door-to-door interventions and site inspections. Again, as these activities did not purely relate to physical control, it is not possible to infer the cost of physical control methods alone.

The IVM programme in the Trento province of northern Italy used door-to-door visits by local authority staff to identify potential breeding sites on residential property and inform residents about how to control mosquitoes on their property and supply them with larvicides [50]. These visits were effective in getting residents to implement control measures – more effective than a passive education programme consisting of information leaflets. Three months after the door-to-door visits, the number of catch basins positive for larvae had been reduced by a factor of three, whereas small positive containers had increased by a factor of three. However, the authors suggest that the latter result does not discredit the effectiveness of this intervention, because recent heavy rainfall could have created these breeding sites and the first visit was at the start of the breeding season when there were fewer breeding sites anyway. The door-to-door visits were very time-consuming and costly, constituting around half of the total cost of the programme. To reduce costs and make programmes more sustainable, the authors suggest that local authorities could consider using trained volunteers to undertake the visits or target 'hot spots' where surveillance indicates the mosquito population is high [50].

In Spain, door-to-door visits were also used to inform residents about source reduction, and enter properties – with permission – to identify sources within the residential property and help with source reduction – by either emptying or treating water containers with larvicide [49]. This IVM programme also targeted physical control methods at non-residential sites, such as the removal of waste at municipal sites and the disposal of illegally dumped material to eliminate breeding sites. The evaluation of this programme revealed that the number of containers with stagnant water containing mosquito larvae or pupae was 9% higher in 2009 than in 2008. However, this could be attributed to increased inspections. For example, visits to private property could only occur with residents' permission, and as the programme progressed there was greater citizen involvement which may, in turn, have translated into greater willingness to allow these inspections.

Traps are usually used for mosquito population surveillance. However, lethal ovitraps or BG Sentinel traps have also been used as a successful control method in one field study in Italy and several countries outside of Europe [45,55]. In Italy, test sites were 150 and 350m^2 with 7–8 traps each placed 5–10 metres apart. Traps were emptied daily so mosquitoes could be identified, sexed and counted. Biogents (BG) sentinel traps reduced nuisance biting by 87% and the number of eggs laid in ovitraps was reduced by 64% [55].

In Madeira, the government has devised a multi-pronged public education campaign to mobilise the community in their response to *Ae. Aegypti* [43]. This includes presentations to schools, public institutions, companies, parishes and flyers/posters to raise public awareness. The government created an online tool called 'NÃO! MOSQUITO' where residents could report mosquito presence and obtain up-to-date information on the level of mosquito populations in their area through 'heat maps'. Door-to-door visits were made to houses that had reported mosquitoes via the platform. These visits identified and treated mosquito-positive containers and potential breeding sites, as well as informing the public on how to prevent and treat containers in the future.

Source reduction relies on cooperation from residents as breeding sites require regular cleaning and/or treatment. The effectiveness of municipal activities may be undermined if this level of activity is not matched by individual and collective community efforts. Hence public education is considered a 'basic' part of IVM – even though it does not always elicit the desired behaviour [45].

Table 10. Physical methods - reviews and evaluations

Reference	Document type	Target species	Physical
Baldacchino F, Caputo B, Chandre F, et al (EU) [45].	Review	*Aedes* (all subspecies)	First-line control method Emptying temporary water containers Covering immovable water containers Lethal traps
Medlock JM, Hansford KM, Schaffner F, et al (EU) [8].	Review	All invasive mosquitoes	As part of IVM
Rivas Morales S (IT) [46,47].	Cost study	*Ae. albopictus*	Treating landfill sites Emptying temporary water containers Indoor storage of water containers Indoor storage of tyres Treating tree cavities Mapping breeding sites Maintaining canals and riversides to avoid stagnation Using biological control methods in public fountains that cannot be emptied.
Abramides GC, Roiz D, Guitart R, et al (ES) [49].	Technical/ evaluation	*Ae. albopictus*	Cleaning up landfill sites and other rubbish House-to-house visits - to identify breeding sites and inform about treatment Treating water containers with larvicide Emptying temporary water containers.
Baldacchino F, Bussola F, Arnoldi D, et al (IT) [50].	Technical/ evaluation	*Ae. albopictus*	House-to-house visits - to identify breeding sites and inform people of treatment methods.
Englbrecht C, Gordon S, Venturelli C, et al (IT) [55].	Technical/ evaluation	*Ae. albopictus*	Lethal traps
Flacio E, Engeler L, Tonolla M, et al (CH) [56].	Technical/ evaluation	*Ae. albopictus*	Public awareness campaign to inform people about breeding sites and their treatment.
Scholte EJ, Dik M, Ibanez-Justicia A, et al (NL) [59].	Technical/ evaluation	*Ae. albopictus, Ae. atropalpus*	Emptying temporary water containers.
SRAS (PT) [43].	Technical/ evaluation	*Ae. aegypti*	Public education to support source reduction.

3.5 Vector control at borders

Guidance

Vector control at points of entry for goods and people was specifically included in some of the guidance material (see Table 11) [1,5,9,10,21,23,24,26-28]. In the case of France there is specific guidance for mosquito control at entry points [24,27].

Guidance included best practice for physical and chemical control of mosquitoes in and around airports and ports, such as removing waste where water may collect and spraying water sites that cannot be removed. Disinfestation of cargo from at-risk areas and measures to reduce the likelihood of vector transportation (such as transporting lucky bamboo in gel rather than water) were also considered, but the practical constraints of such approaches were acknowledged [1,28]. In some countries there were local initiatives, but a lack of national guidance [5]. However, there has been progress, for example in the Netherlands where regulation of high-risk imports was previously lacking and has now been introduced since the guidance was published [9,11].

Table 11. Import monitoring and control – guidance

Reference	Imports
WHO [2]	
WHO [20]	
EMCA (EU) [10].	•
van den Berg H, Velayudhan R, Ejov M (EU) [1].	•
CNEV (FR) [23].	•
CNEV (FR) [24].	•
CNEV (FR) [25].	
DGS (FR) [22].	
DGS (PT) [33].	
DGS (FR) [26].	•
DGS (FR) [28].	•
DGS (FR) [27].	•
Institutul Cantacuzino (RO) [34].	
LIFE CONOPS (EL) [30].	
LIFE CONOPS (EL) [32].	
MS (IT) [31].	
MSSI (ES) [35].	
RIVM (NL) [9].	•
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5].	•
Υπουργείο Υγείας (EL) [29].	
Comunidad de Madrid (ES) [44].	
Regione del Veneto (IT) [21].	•
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) [37].	
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36].	
SRAS (PT) [39].	
SRAS (PT) [38].	
SRAS (PT) [40].	
SRAS (PT) [42].	
SRAS (PT) [41].	

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

Reviews, cost effectiveness assessments and evaluations of vector control

Only three of the documents included described inspections at borders [43, 58,59]. In the Netherlands tyre importers premises are routinely inspected for invasive mosquitoes, as tyre imports provide a route for the mosquitoes into the country and a means for dispersing them [58,59]. The publications did not include precise statistical information on the effectiveness of such measures [43, 58,59].

3.6 Criteria for implementation

Guidance

Most of the guidance had defined criteria for implementation of control measures (see Table 12) [1,5,10,18-24,26-33,35,36,39,41,42,64]. The criteria used depended on the country. Generally there was an assessment of the risk posed by the mosquitoes and a disease outbreak. The risk posed by the mosquito was informed by whether the invasive mosquito species was considered established (reproducing and overwintering) or introduced (sporadic introduction, without establishment) [3]. For example, in countries where these 'invasive' mosquitoes are well-established, preventive control measures were implemented year-round, every year to reduce the mosquito population and disease risk [5,21,24,27-29,32,36,42]. Meanwhile other countries would only implement control measures when surveillance indicated an increase in mosquito populations, nuisance complaints or an autochthonous case [5,10,21-24,36-28,30,32,33,35,36,39,42].

Guidance material from France, Portugal and Spain provides detailed risk assessment levels defining the control measures that should be implemented [22,23,26-28,33,35]. These criteria are summarised in Table 12 below.

Table 12. Criteria for implementation - guidance

Reference	Invasive mosquito species detected	Animal cases	Human cases - imported	Human cases - autochthonous	Human cases - epidemic	General public bite complaints	Peri-residential mosquito habitats	Mosquito density	Favourable climate for mosquito activity
CNEV (FR) [23].			•	•		•	•		
DGS (FR) [22].		•	•						
DGS (FR) [26].	•		•	•	•				
DGS (FR) [28].	•		•	•	•				
DGS [27].				•				•	
DGS (PT) [33].	•			•	•				
MSSI (ES) [35].	•		•	•	•				•

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

In other guidance the thresholds for moving between different risk levels were less clear (for example at what point the mosquito population goes from being a 'nuisance' to an 'epidemic risk'.

Reviews, cost effectiveness assessments and evaluations of vector control

A review of the costs of *Aedes albopictus* control activities in the Emilia-Romagna region of northern Italy concluded that an environment with a mosquito population below epidemic risk level or nuisance threshold (or both) can be considered a 'public good' [46,47]. When this 'public good' is damaged by a population in excess of the appropriate thresholds, it has an impact on other 'public goods' - e.g. enjoyment of parks and green spaces in urban areas, a direct economic impact in the form of medical and veterinary costs, and an indirect economic impact on activities that are dependent on an environment with an acceptable mosquito population (e.g. outdoor activities). The author suggests that the value attached to maintaining this 'public good' and mitigating the negative impact of excessive mosquito populations informs municipal and individual decision-making concerning expenditure on mosquito control [47].

As with guidance, the criteria for implementing or escalating vector control activities according to an assessment of the risk level is not always clear. Combining surveillance data with citizen reports of mosquito nuisance could help to create an objectively-defined nuisance threshold, above which additional measures would be implemented [54]. Combining surveillance and risk assessment could also prevent population densities from reaching epidemic risk levels.

The methods implemented should also be tailored to the desired outcome - e.g. reducing the mosquito population or responding to a disease outbreak – depending on whether the desired outcome is long-term or immediate [45].

3.7 Organisation and management at national and subnational level

Guidance

Most of the guidance documents set out organisational structures for managing control measures. Many included detailed descriptions, flowcharts demonstrating the roles and responsibilities of different institutions, and the legislative and regulatory frameworks governing these relationships [9,20,22,25,26,28,29,33,35,36,39,41,42]. The need for effective multi-sectoral collaboration was stressed in several guidance documents, and specifically the role of clearly defined working arrangements in order to facilitate this collaboration [10,20,28,35,42].

WHO recommends that European countries potentially exposed to invasive mosquito species should produce programmes for surveillance and control of mosquitoes and vector-borne diseases [10]. WHO also recommends that although control measures may be administered locally, the final accountability should lie with national authorities [2,20].

WHO highlights that health system reform, in particular decentralisation and local empowerment, potentially complicates vector control but also presents opportunities for effective and regionally-specific approaches on a bottom-up basis [1,2].

WHO's handbook for integrated vector management provides an organisational framework for national and local level vector management [20]. It recommends that vector management policy is co-ordinated at a national or ministerial level by an intersectoral steering committee on IVM. Decision-making is then decentralised to local authorities who can formulate vector control programmes that reflect the local context and are responsive to the continually changing environment. However, a key prerequisite for decentralising vector control is that staff working at local level have the skills and capacity to make these decisions.

Reviews, cost effectiveness assessments and evaluations of vector control

Coordination of activities indirectly contributes to the effectiveness of control programmes. The 'weakest-link' in the chain is where the effectiveness of one programme is undermined by a neighbouring authority not implementing effective measures, resulting in the continued reintroduction and proliferation of mosquitoes in both territories [46,47,56]. This applies to coordination both within and between countries, arguably making the case for larger, regional entities to produce guidance on co-ordinating activities, which individual countries and their municipalities can then implement [46,47]. Coordination can also support smaller municipalities or countries, which may have fewer resources available for these activities, reducing their risk of becoming the 'weakest-link' [46]. Area-wide integrated pest management is an alternative phrase to integrated vector management, preferred by some because including the term 'area-wide' conveys the need for international, national and subnational coordination [46,47].

Coordination between neighbouring municipalities could also lead to cost-savings. For example, sharing 'back-office' functions such as staff who write tenders and manage contractors [46,47]. In addition, it may be possible to achieve economies of scale through the joint procurement of pesticides.

A review of control methods in Europe against *Aedes sp.* concluded that successful implementation was contingent on cooperation between the various stakeholders involved [45]. This includes cooperation at the planning stage – including stakeholders such as politicians, public authorities (e.g. health, environment and education services), scientists and the general public. Cooperation in implementation is also vital - for example putting the community at the centre of source reduction measures.

3.8 Cost of the control programme

Guidance

The cost of control programmes was rarely discussed in the guidance documents included [23,29,35,40]. One guideline recommended that the cost of implementing vector control programmes should be borne by the authority implementing the programme [29]. This cost may be directly covered by that authority or paid to a contractor undertaking the control activities.

WHO's handbook states that transforming existing vector control programmes into IVM programmes may require some start-up funds [20]. Multi-sectoral involvement can help raise funds from other sectors affected by the vectors, including non-health public sector organisations, the private sector, the tourist industry and/or civil society. In some settings donor funding is an option, especially to cover up-front costs.

Several of the guidance documents included practical support for authorities planning to contract out work, such as examples of tenders [21,23,36]. One guideline recommended designing programmes for the long term, to reduce the administrative burden and cost involved in appointing contracts [29].

Another guideline discussed diversifying the workload of staff involved in mosquito control, to work on other projects outside of the mosquito breeding season [23]. This ensures that their workload remains constant throughout the year and prevents the need to hire seasonal staff to cover the busy periods.

No guidance described the actual cost of the control programme or the budget allocated.

Reviews, cost effectiveness assessments and evaluations of vector control

An evaluation of the *Aedes albopictus* control programme in the Emilia-Romagna region of Italy (population 4.5 million) includes a detailed breakdown of expenditure for different control activities [46,47]. The programme saw its costs reduced from EUR 7.6 million in the first year of the integrated control programme, to EUR 3.1 million in 2015. This is partly explained by simple changes in accounting practice and the one-off costs involved in establishing the infrastructure and standardising practice for vector control – hence 2008 is considered a 'partial emergency' year. In Emilia-Romagna, larvicidal treatments make up the bulk of expenditure – 48% in 2008 and 67% in 2015. However, there were overall budget reductions, representing a decline in actual expenditure on larvicides from EUR 3.6 million to EUR 2 million between 2012 and 2015. The second largest expenditure overall was on door-to-door interventions – including awareness raising, site inspections and some larvicide procurement. Vector surveillance costs fell substantially between 2008 and 2009 because a technical innovation meant that traps could be used every other week instead of on a weekly basis, which reduced costs. From then onwards expenditure remained broadly stable. The cost of quality control also decreased over time, but at the same time the number of areas within the region carrying out quality control activities declined – so the reduced cost reflects reduced activity. So although expenditure on education in primary schools decreased in real terms between 2009 and 2015, the percentage of the overall budget allocated to this programme remained relatively stable at around 3%.

The expenditure on and coverage of these programmes was not clearly detailed by the municipalities within the region, so the reported figures are estimates. Overall expenditure on the vector control programme decreased between 2008 and 2015, however, the distribution of this decrease varied for different areas within the region without a clear pattern or explanation. As regional funding has been reduced, the proportion of overall funding provided by the local areas has also changed – one area increased its funding by over 100%, while another reduced it by 1.2%. However, once again there was no clear pattern and further investigation is therefore recommended. Per capita funding of vector control programmes decreased in all regions between ~30% and ~70% – actual per capita funding was between EUR 4.70 and EUR 1.10 in 2008, falling to between EUR 1.19 and EUR 0.25 in 2015.

Many of the guidance documents in this review recommend that authorities using contractors should employ due diligence processes, such as seeking multiple quotes from different contractors to assess, compare and identify the best value for money, without necessarily providing further information. Including indicative costs in guidance documents would help support municipalities in making assessments and assist with resource allocation and planning. Where municipalities receive reimbursement from regional or national governments for vector control activities, guidance could provide an 'acceptable range of expenditure' eligible for reimbursement to encourage and support municipalities in seeking value for money [46,47]. An evaluation of vector control costs in one region of Italy suggests the correlation between the number of residents and the cost of the larvicide treatment as a possible measurement of costs [46,47]. This cost assessment concluded that the programme had been technically effective and efficient as the costs had decreased over time without reducing effectiveness [46,47].

3.9 Evaluation methods

Guidance

Procedures for monitoring vector control programmes were described in the majority of the guidance documents included (see Table 13). There were also recommendations on the monitoring of control measures implemented by contractors and authorities [20-24,29,31,33,36,37,39,41,44]. This included recommending that the effectiveness of activities be assessed [1,2,5,9,10,20,21,23,24,26,28-32,37,39,41,42]. Some guidance defined a population reduction of 80–90% as 'effective' [31,37].

WHO's handbook on vector management contains a detailed framework for assessing vector control methods, as well as specific indicators for evaluating all stages of the process when designing and executing vector control programmes [20]. Generating and strengthening the evidence base is important. In particular, WHO recognises the need to understand local parameters that may impact on the effectiveness of interventions.

Italian guidance recommends that effectiveness evaluation is incorporated into contracts with companies providing services, so that poor performance can potentially lead to sanctions [21,37]. Daily monitoring is recommended to assess whether repeat treatments are needed [21]. It recommends verifying that pyriproxyfen-based products and diflubenzuron have been applied correctly by taking 500 cc samples three times from treated bodies of water, then monitoring the captured larvae over 24–48 hour intervals to record the rates of pupae and larvae death. The recommended method for Bti is to take three 500 cc samples and visually inspect them for larvae at 24 and 48 hour intervals, the treatment can be considered effective if no live larvae are observed.

The communication plan produced by the health authority in Madeira includes a recommendation to specifically evaluate the effectiveness of methods for communicating with the general public [40].

France's National Centre for Vector Expertise (CNEV) contained a standard structure for annual reports that local authorities should supply to CNEV, including a description of the human and material resources used, monitoring data, adverse events, the control measures implemented and communication materials required in order to ensure consistency [24]. In its guidance on invasive mosquito species surveillance, ECDC recommends collection methods for mosquito larvae and adults, including appropriate risk reduction measures [14].

Some guidance stipulated that the monitoring and evaluation should be carried out by an organisation other than that performing the activities to ensure impartiality [20,21,23,29,31,33,37]. WHO's handbook recognises the potential disadvantages of internal evaluation, but also that external evaluation can be costly [20]. Its pragmatic solution is a 'cross-wise' evaluation, whereby different local authorities within a country can evaluate each other's vector control programmes.

WHO recognises that personnel within local authorities may not have the necessary skills to evaluate their vector control programmes [20]. It recommends partnering with research institutions to support evaluation activities and ensure that research is relevant to problems in the field.

Table 13. Evaluation methods - guidance

Reference	Target species	Evaluation	Evaluation methods - details
WHO [2]	All vectors	Yes	Monitor efficacy - impact on vector population and disease transmission.
WHO [20]	All vectors	Yes	All stages of policy development, communication and implementation should be evaluated. Baseline and final measures are needed. Data should be collected in a standardised format. Linking with research institutions can provide the skills and capacity for evaluation. Internal evaluation is less resource-intensive but may not be as impartial as external evaluation. Cross-wise evaluation is where authorities evaluate each other's programmes. The findings of evaluations account for the resources used, provide lessons learned and inform future policy design. Evaluation is also an important advocacy tool.
EMCA (EU) [10]	All mosquitoes	Yes	Baseline surveillance data required for evaluation, including geographical information systems (GIS) mapping. Incorporate evaluation into control programmes to assess the risk of disease transmission.
van den Berg H, Velayudhan R, Ejov M (EU) [1][1]	Invasive mosquitoes	Yes	Document and evaluate interventions to inform future programmes – including social aspects like community participation (not just scientific aspects). Surveillance should guide and evaluate the programme. Research and surveillance should also include vector behaviour, not just population.
CNEV (FR) [23]	Invasive mosquitoes	Yes	Evaluation should assess the effectiveness of the activities in the programme. Private companies should be monitored to ensure the quality and completeness of work.
CNEV (FR) [24]	All mosquitoes	Yes	Annual evaluative reports. Interim reports may also be requested. All activities must be recorded in the annual monitoring report alongside a balance sheet. The report should include: human and material resources used, activities undertaken (biocides used, areas treated, doses, precautions taken, efficacy evaluation), a record and description of events requiring additional measures - e.g. adverse event reporting forms, description and examples of communication activities (e.g. information materials).
CNEV (FR) [25]	*Ae. albopictus*	Yes	The Health Impact Assessment (HIA) assesses risk to health. Assessing the health impact of vector-borne disease can help in lobbying for resources prior to implementation.
DGS (FR) [22]	*Ae. albopictus*	Yes	Local authorities have to report on the control measures used.
DGS (PT) [33]	All mosquitoes	Yes	Research should be incorporated into the design, monitoring and evaluation of the strategy. The evaluation approach should be designed with all stakeholders (national, local and international) involved and should be carried out by experts. (p.12)
DGS (FR) [26]	*Ae. albopictus*	Yes	Surveillance is used to monitor the effectiveness of control measures, such as biocides.
DGS (FR) [28]	*Ae. albopictus*	Yes	Surveys carried out to identify and physically remove breeding sites, where possible on public and private land. Surveillance used to monitor the effectiveness of control measures, such as biocides.
DGS (FR) [27]	Invasive mosquitoes	No	Not reported.
Institutul Cantacuzino (RO) [34]	*Ae. albopictus*	No	Not reported.
LIFE CONOPS (EL) [30]	*Ae. albopictus*	Yes	Quality control to measure effectiveness.
LIFE CONOPS (EL) [32]	*Ae. albopictus*	Yes	Evaluation is two-fold - quality controls on the extent of treatments and ovitraps to measure the effectiveness of the treatment.
MS (IT) [31]	Invasive mosquitoes	Yes	Evaluation to measure the extent of treatment (compliance of contractors) and larvae/adult monitoring to assess the effectiveness of interventions. Should be carried out by an independent person.
MSSI (ES) [35]	Invasive mosquitoes	No	Not reported.
RIVM (NL) [9]	*Ae. albopictus*	Yes	Surveillance should be intensified during the active season to evaluate the effectiveness of control measures. The measures can be considered effective if no further mosquitoes are identified. This intensified monitoring should continue at the start of the breeding season in case any mosquitoes survive the winter.
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5]	All mosquitoes	Yes	Control measures should be stopped or stepped down to maintenance levels once surveillance indicates that they have been successful.

Reference	Target species	Evaluation	Evaluation methods - details
Υπουργείο Υγείας (EL) [29]	All mosquitoes	Yes	Monitor the application of mosquito control programmes and evaluate their effectiveness, using independent organisations. An end-of-year report is submitted, detailing the methods used, any observations or problems in implementation. The report should also include entomological data on the effectiveness, any resistance observed and safety checks (e.g. water checks). The data should be kept by the local regional administration for ten years.
Comunidad de Madrid (ES) [44]	All vectors	Yes	Requires companies to perform control measures to evaluate the treatments carried out.
Regione del Veneto (IT) [21]	*Ae. albopictus*	Yes	Evaluation of effectiveness should be incorporated into contracts with companies providing services and carried out by an external agency. Regular monitoring of treatment sites to check the extent (e.g. have all sites been treated) and effectiveness of treatments (e.g. are repeat treatments required). Verify that pyriproxyfen-based products and diflubenzuron have been applied correctly by taking 500 cc samples three times from treated bodies of water to sample third or fourth stage larvae. Monitor the captured larvae over 24–48 hour intervals to record the rates of pupae and larvae death, number of nymphs emerging as adults. Observations are repeated until all pupae and larvae are dead. The effectiveness of Bti treatments should be evaluated by taking three 500 cc samples and visually inspecting for larvae. It can be considered effective if no living larvae are observed.
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) [37]	*Ae. aegypti*	Yes	Evaluation of post-treatment larval mortality is used to improve the application technique and dose of larvicides in real time, to ensure efficiency and high quality. Recommends pre-treatment larval population assessment, then further testing 48 hours after larvicide application. Because different larvicides affect different parts of the life cycle, it recommends Pyriproxyfen or S-Methoprene evaluation after 10 days, diflubenzuron on the 10th and 14th day of treatment. Treatments that do not reach effectiveness thresholds may be indicative of poor contractor performance and can lead to sanctions.
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36]	*Ae. albopictus*	Yes	Even if an external organisation is employed to perform vector control, municipalities should monitor the quality and effectiveness of treatments.
SRAS (PT) [39]	*Ae. aegypti*	Yes	Evaluate the extent (compliance) and effectiveness of control measures implemented.
SRAS (PT) [38]	*Ae. aegypti*	No	Not reported.
SRAS (PT) [40]	*Ae. aegypti*	Yes	The communication plan will be evaluated via email, in terms of complaints and by means of direct contact with the public.
SRAS (PT) [42]	*Ae. aegypti*	Yes	Internal and external evaluation are used to monitor the activities undertaken and measure their effectiveness and efficiency. Evaluating the extent and effectiveness of implemented control measures.
SRAS (PT) [41]	*Ae. aegypti*	Yes	The plan is in place for two years, after which it will undergo evaluation. Quarterly reports on the measures implemented and any deviations from planned treatments, to inform whether the plan needs to be adapted.

Reviews, cost effectiveness assessments and evaluations of vector control

This project is mainly based on evaluations that have been made available in the public domain (published in journals or online), so there may be additional unpublished evaluations. Based on the documents retrieved, the systematic evaluation of vector management programme effectiveness in Europe appears to be a neglected part of the IVM cycle.

Evaluation of vector management programmes contributes towards their continuous improvement during and after implementation and helps improve knowledge concerning the effectiveness of different strategies by sharing of information and experience [45]. The lack of documents may be due to the complexity of evaluation, meaning that authorities do not have the capability to carry out such evaluations, or because evaluation is overlooked and therefore resources are not allocated [54]. In one example from Madeira, the raw numbers of positive traps were published for one year. Continuing to publish this data would enable a simple year-on-year comparison to be made [43].

The reviews, cost effectiveness assessments and evaluation documents included in this review provide a sufficient level of detail on the control methods used to enable others to learn from the research or replicate the approaches. However, the lack of information on evaluation methods is still a significant shortcoming.

3.10 Economic considerations

Guidance

Where cost effectiveness was discussed, it was included as an overarching consideration when designing control programmes, rather than detailed recommendations or specifications as to how this should be achieved [1,2,9,10,23,24,35]. WHO emphasised that this evidence was required, but equally recognised that the authorities may not have the financial and technical resources needed to undertake cost effectiveness evaluations, despite their future cost-saving potential [20].

Reviews, cost effectiveness assessments and evaluations of vector control

A review of control methods identified that theoretical modelling could be used to estimate the costs of control strategies and that cost effectiveness analyses could compare strategies to inform policy decisions and shape control strategies prior to implementation [45]. Modelling could also help to predict the environmental factors that may have an impact on the effectiveness of control measures when implemented.

3.11 Community involvement

Guidance

Because invasive mosquitoes tend to proliferate in small, often man-made bodies of water, community engagement was a key part of many of the plans reviewed (see Table 14). The actions of individual citizens to reduce mosquito breeding sites on their private property are an integrated part of the wider fight against mosquitoes. Guidance focused on preventive activities (particularly removing potential breeding sites), therefore community involvement is important because many of these sites are located on private property [1,2,5,9,10, 20-37, 39-42,44]. Indeed, WHO concludes that integrated vector management can only be achieved through community involvement [2,20]. The only guideline that did not stress community involvement focused on measures that construction firms can take to prevent the creation of mosquito breeding habitats on construction sites [38]. One guideline even recommended that authorities should consider how control methods could be used by the community when planning intervention (e.g. trapping methods that are unsuitable for widespread municipal use may still be useful for individual residences) [1].

France's Direction Générale de la Santé (DGS) produced guidance specifically for communities wanting to implement control measures against mosquitoes, which includes involving the general public in surveillance activities – referred to as 'citizen science' [23,25]. This guideline stressed the idea of 'social mobilisation', making the community active participants in prevention and control measures, rather than simply using personal protective measures [26]. Community engagement requires long-term commitment and ongoing activities in order to build and maintain capacity, which can then be effectively activated during an epidemic [25].

WHO suggests that raising awareness and improving community engagement may have an impact on the effectiveness of control measures beyond their efficacy as measured in trials [1]. For example, raising awareness among the general public so that they can alert authorities to the appearance of invasive mosquitoes, using 'citizen science' as a resource [1].

Table 14. **Community action – guidance**

Reference	Source reduction	PPE (e.g. preventing bites)	Door-to-door interventions	Communication methods	Schools	Reporting invasive species/nuisance/disease
WHO [2].						
WHO [20]						
EMCA (EU) [10]	•	•				
van den Berg H, Velayudhan R, Ejov M (EU) [1]	•	•				•
CNEV (FR) [23]			•	•		
CNEV (FR) [24]	•			•		
CNEV (FR) [25]	•	•	•	•	•	
DGS (FR) [22]	•	•				
DGS (PT) [33]				•		
DGS (FR) [26]	•	•		•		
DGS (FR) [28]	•	•		•	•	
DGS (FR) [27]	•			•		•
Institutul Cantacuzino (RO) [34]						
LIFE CONOPS (EL) [30]	•		•	•		
LIFE CONOPS (EL) [32]	•		•	•		
MS (IT) [31]	•	•	•		•	•
MSSI (ES) [35]	•	•				
RIVM (NL) [9]		•		•		
Roberto Romi L, Toma FS, Marco Di Luca, et al (IT) [5]	•	•				
Υπουργείο Υγείας (EL) [29]	•	•		•		
Comunidad de Madrid (ES) [44]	•					
Regione del Veneto (IT) [21]	•					
Servizio Sanitario Regionale Emilia-Romagna [Arbovirus] (IT) [37]	•	•	•			
Servizio Sanitario Regionale Emilia-Romagna [Tiger mosquitoes] (IT) [36]				•	•	
SRAS (PT) [39]	•					
SRAS (PT) [38]						
SRAS (PT) [40]				•	•	•
SRAS (PT) [42]	•			•		
SRAS (PT) [41]				•		

Note: blanks in tables (denoted in pink) indicate that information is not included or is not applicable.

The authorities in Madeira have placed particular emphasis on providing effective information to the public and relevant multi-sectoral professionals by producing specific communication plans [40,42]. The challenge is knowing what and how to communicate, given that technical information may be difficult for the general public to understand [25]. Messages delivered to encourage community engagement also have to be appropriate to the level of risk, so that community action is channelled towards activities that will effectively and proportionately control the mosquito population [25]. For example, before disease cases are confirmed, it is not necessary to encourage the population to monitor signs and symptoms because that would potentially overwhelm the public health system and not necessarily improve case detection due to the generic nature of many of the symptoms [25].

One guideline recommends the best method for mass communication as being a compromise between short and powerful messages that potentially convey little information, and longer and more detailed messages that may be less engaging and have less impact [25]. The guidance documents included recommend communicating with the public via materials such as flyers and posters, broadcasts on local media, social media and online resources, information telephone lines, informative talks, attending community meetings and having stalls at community fairs [9,20,23-27,29,30,32,35,36,40-42]. One guideline concluded that materials such as leaflets were more effective when combined with interpersonal interventions such as face-to-face talks, rather than delivered on their own [25]. Only four guidance documents recommended door-to-door interventions because they were so resource-intensive [23,25,30,32].

Widening the concept of 'community' to include business owners may also contribute to the fight against mosquitoes. For example, encouraging garden centres to sell sand to fill plant pot saucers to prevent them accumulating water for mosquitoes to breed in [25]. Health professionals are another group of local actors who can engage in the fight against mosquitoes, and a lack of engagement can be an issue – for example, if general practitioners (GPs) are not sufficiently engaged to identify and report cases or advise appropriate treatment (e.g. isolation) [25].

Reviews, cost effectiveness assessments and evaluations of vector control

In evaluations of vector control programmes, community involvement seems to be considered a success factor, which is probably due to the high number of potential breeding sites located on private property [49,50]. An assessment of the cost effectiveness of the vector control programme in Emilia-Romagna, Italy, concluded that the area with the most potential for development was on private land where most breeding sites are located. This would necessitate greater community engagement to generate community-based action [46,47].

Community engagement programmes can be a victim of their own success – in Catalonia (Spain) citizen cooperation increased by 16% year-on-year, subsequently increasing workload [49]. However, there is potential for using the public as volunteers to reduce personnel costs [50]. The evidence from evaluative studies suggests that passive educational materials – such as printed leaflets – were not as effective as active methods, such as door-to-door interventions [50]. However, door-to-door interventions are very resource-intensive [50]. Attendance at community meetings was also poor – with fewer than 2% of community members attending – suggesting a need to identify ways to encourage people to participate [50].

The 'weakest-link' problem also applies to community involvement [46,47]. As such, it is important that definitions of 'community' include all stakeholders – for example local businesses and building managers who can implement measures on private, non-residential property, as well as members of the public [46,47].

School children have been identified as potential disseminators of mosquito control information, raising awareness among their family members [25,36,46,47]. In the case of Emilia-Romagna, the engagement of schoolchildren was intensified by running a competition to design the logo for the following year's anti-mosquito campaign [46,47]. The full reimbursement of primary school mosquito education programmes by the regional health body reflects the importance placed upon this activity [46,47]. However, the effectiveness of this approach was not formally evaluated.

In the Swiss region bordering Italy, a public awareness campaign was conducted using multiple channels – media, internet and leaflets – to inform citizens about possible breeding sites and their elimination, as well as larvicidal treatment. However, it was not possible to evaluate the effectiveness of this approach within the integrated programme [56]. Providing larvicide treatments to the public for use on private property may help to complement and amplify the effectiveness of other larvicidal activities [50]. Public awareness and education campaigns may take time to have an impact, therefore it is useful to secure long-term funding for such initiatives [49].

In Madeira, the public is involved in various education and citizen science projects [43]. Awareness among the public was raised using presentations in various public institutions, flyers and posters. The government also used an online tool 'NÃO! MOSQUITO' to involve and inform residents about the mosquito fight in their area. Door-to-door visits were used to inform the public of how to prevent and treat mosquito-breeding within and around the home.

Public involvement has been effective in Europe - however it is dependent on a culture that is willing and able to volunteer, which may make relying on volunteers a risky strategy [45]. One option is to use a mixed approach, where volunteers support and supplement the work of paid workers [45]. Variations in the effectiveness of interventions in different areas may be attributed to socioeconomic and cultural factors, as well as environmental variations [49]. Where action is required by the general public, authorities may want to consider legislative mechanisms to motivate this [49].

3.12 Surveillance

Guidance

This literature review recorded whether surveillance was listed as an integrated activity within vector control programmes. Surveillance as a separate activity is covered by ECDC guidance and does not come within the scope of the literature review [14,15].

Surveillance was an integrated part of mosquito control programmes in most of the guidance included in this review, but the ways in which surveillance activities were incorporated into control programmes varied. In most cases, surveillance data directly informed the design of control mechanisms [1,5,9,10,20-33, 35-37, 39-42]. WHO emphasises the need to have baseline surveillance data in order to inform the evaluation of vector control programmes [20]. In some cases surveillance data was used to inform how, where and whether control mechanisms should be implemented during active periods to maximise effectiveness [9,20,26,28,29,32,35-37,42]. Furthermore, surveillance may be used in 'real time' so that plans can be adapted to maximise effectiveness [5,20,31,37].

Reviews, cost effectiveness assessments and evaluations of vector control

Mapping can be used to identify 'hot spots' where there is a concentration of potential breeding sites, in order to focus control activities [50,54, 46,47,65].

In Madeira, the public could report mosquito presence and also see the results of surveillance via 'NÃO! MOSQUITO' [43]. This was designed to help the public adapt their behaviour according to the risk and enable health authorities to discover additional breeding sites/activities. Surveillance also included mapping possible breeding sites such as gutters – noting their location and condition and the presence of mosquito larvae/pupae.

3.13 Other impacts of vector control

Guidance

Many of the guidance documents assessed the potential risks (to human health, environment, etc.) associated with control programmes, but the amount of detail varied hugely [9, 21, 26, 35 5, 21, 27, 36 29 5, 21-26, 28, 32, 35-37, 44]. For example, WHO discusses the environmental and ecological impact throughout, but does not make specific recommendations or state that assessments should be carried out [2,10]. On the other hand, several guidance documents recommended that implementing authorities should undertake impact assessments [5, 21-26, 28, 32, 35-37, 44].

Others provide greater detail, such as:

- details of the impact assessment that should be included [9,21,26,35]
- safe storage [23]
- protective wear for staff [5, 21, 27, 36, 37]
- measuring environmental residual levels [29]
- potential environmental impact on non-target species [37,63]
- potential impact on human health [5,44].

Some guidance stated that the environmental impact, potential for contamination, bioaccumulation in wildlife and impact on human health, such as neurological damage, should also be considered when designing and implementing vector control programmes [5,44]. The use of insecticides requires an assessment of the potential impact, for example on bees, and appropriate steps to reduce risk [37,63].

Reviews, cost effectiveness assessments and evaluations of vector control

No relevant findings identified in the documents included.

3.14 Resistance

Guidance

Consideration of resistance was mentioned in many of the reviewed guidance [22, 23, 27, 28, 30, 32, 35, 39, 42]. WHO states that resistance testing is one of the central principles of IVM – which many of the guidance claimed to follow. It is therefore disappointing that many simply referred to resistance as something to consider rather than recommending specific action [20,66].

Resistance is exacerbated by the low number of pesticides approved for use in Europe, combined with excessive use in the past and in agriculture. [79] To overcome resistance, most of the guidance documents recommended non-pesticide-based control measures as the first-line and major component of any vector control programme. Furthermore, adulticide treatments, where resistance is a major issue, should only to be used in emergencies where there is a threat to public health or a disease outbreak [5, 10, 21-24, 27, 29, 32, 36, 42].

Ongoing monitoring of resistance was recommended in some of the guidance documents [22, 28, 30, 32, 39, 42]. The practical issues involved in testing for resistance were discussed, in particular the range of methodological approaches available and a lack of studies on the epidemiological consequences of resistance [42]. Some guidance discussed the need to consider resistance – especially where there is localised resistance – when selecting products for use [23, 27, 35, 42].

France's National Centre for Vector Expertise (CNEV) produced guidance focusing on preventing and managing insecticide resistance [19]. This recommends a more nuanced approach to risk-benefit assessments that considers how the product will be used (e.g. by registered professionals), especially when considering the differences between vector control for nuisance reduction or disease prevention [19]. This guideline highlights the 'social demand' for insecticidal products by the public to reduce nuisance and the risk of biting, which is a less well-controlled aspect of insecticide management. Pesticide companies are recommended to keep records of the types of customers they supply, but it is unclear how well this has been done [19]. CNEV views resistance monitoring as part of the evaluation process for assessing the effectiveness of the various control measures in their different delivery mechanisms during and after use [19].

Alternating between different insecticides with various mechanisms or using different combinations of insecticides is one approach to managing and preventing resistance [19]. Novel combinations of insecticides may require registration and approval – even where constituent ingredients are approved – because of the potential consequences of their combination [19]. This may incur further cost and bureaucracy. The mosaic approach treats one area with one insecticide, then uses another in adjacent areas to avoid localised resistance [19]. Although this approach may be beneficial in terms of effectiveness, it is complicated to administer and organise. There may also be financial consequences as it is impossible to achieve the economies of scale possible when purchasing large amounts of a single substance. Creating 'refuges' is another approach, where insecticides are not administered in selected areas to enable these breeding mosquitoes to reintroduce sensitive alleles into the general population and prevent the emergence of resistance [19]. This is contingent on having affected areas that are suitable for non-treatment that will not pose a threat to human health or comfort, which may be harder to find in the urban areas affected by *Aedes aegypti* and *Aedes albopictus*. Such approaches are only really applicable to larvicides where there are multiple products and combinations available. However, in the case of adulticides only pyrethroids are approved for use.

In 2016, the European Council produced a report on the sustainable use of biocides, stressing that the key to sustainability is ensuring the long-term effectiveness of the agents currently available and supporting research and development to identify new agents [64]. The principle activities to maintain effectiveness are restricting the use of biocides to situations where they are strictly necessary and using the most effective application techniques (based on evidence). This best practice needs to be disseminated across Europe to ensure consistency across all countries. In particular, the report encourages countries to speed up the evaluation process for biocides (without compromising rigour) and encourage research into innovative agents (including alternatives to biocides). Research and development in vector biocides is not always perceived as attractive by industry because the market is relatively small (1.3% of the overall insecticide market). Moreover, there is often little government finance to support research costs and regulatory complications. Hence many agents currently in use originate from the more lucrative agrochemical market [19].

WHO has produced guidance on testing for resistance in malaria mosquito vectors and the same principles can be applied to invasive species [66]. Insecticide resistance, like antimicrobial resistance, requires a global and unified approach [66-68].

Reviews, cost effectiveness assessments and evaluations of vector control

In Madeira, resistance testing carried out in 2009 and 2013 identified only the organophosphate, Malathion[4], as meeting the WHO threshold for not showing resistance (98–100% mortality) [43]. The other products tested ranged between 29% and 78% effectiveness and showing a high degree of resistance. No relevant findings were identified in the other documents included.

[4] According to international chemical nomenclature = 2-(dimethoxyphosphinothioylthio)butanedioic acid diethyl ester

4. Emergent findings

This section focuses on the emergent findings that did not fit within the pre-specified headings. These findings emerged from guidance documents, as well as reviews, cost effectiveness assessments and evaluations of vector control.

4.1 Multi-sectoral involvement

As part of IVM, WHO and other agencies producing the documents included in this review emphasised the need for multi-sectoral involvement in the planning and execution of vector control programmes [2, 10, 20, 28, 35, 40, 42, 43, 46, 47, 56]. There are opportunities to learn from other professions such as marketing and advertising. Many of the included documents addressed multi-sectoral involvement in their specifications as to how vector control programmes should be organised and managed (see 5.7) [10, 20, 28, 35, 42].

A consistent campaign should be designed, using recognisable features, logos, graphics and slogans that can build 'brand recognition', as commercial organisations do [25,28].

4.2 Ensuring control measures are appropriate for the setting

Not all invasive species of mosquitoes have the same reproductive behaviour, habitat preferences and biting habits, and therefore different approaches are required [5]. The range of preferred habitats also require multi-sectoral approaches to vector control, because the mosquitoes are equally happy to breed in small reservoirs of water, tyres in industrial yards, manhole covers on pavements or plant pot trays in residential gardens [5]. ECDC recognises this and recommends that preparedness planning and responses to vector-borne diseases take the form of multi-sectoral activities [69]. Therefore, control programmes should be informed by the habits of the target mosquitoes to ensure effectiveness and prevent overuse of pesticides, leading to resistance and a potentially negative impact on human and animal health, and ecology.

4.3 Human factors

Some non-technical challenges involved in effective vector control include the limited financial and human resources; the complex variety of individuals and organisations involved and the difficulty in mobilising various partners and the general population to take preventive action against an unrecognised risk [25]. This last point is especially difficult, because these practices have to be integrated into everyday routines in order to be effective [25]. However, their effectiveness could potentially lead to complacency as the threat perception lowers. Therefore there is a need for continuous reinforcement and adaptation of the public health messages to ensure consistent public engagement.

4.4 Legislative and regulatory approaches

WHO considers legislation to be one of the key components of IVM [2,20]. In Italy and Madeira, a potential barrier to implementing control measures is the lack of legislative compulsion [5,42]. In contrast, France's strong legislative framework provides this support and enables authorities to force certain actors to comply [26]. WHO describes legislation and regulation as key policy instruments that can be used to help implement vector control programmes [20]. However, it is unclear how often such mechanisms are used and whether they are effective. Given the time and effort involved in passing such legislation or regulatory mechanisms, it is important to understand whether or not they are effective. If employing legislative or regulatory mechanism, municipalities also need to consider the negative impact on good will and social capital, by forcing people to comply.

Principles of vector management can be integrated into town planning processes as proactive, preventive measures. This would encourage or compel architects and developers to design buildings and spaces that do not create mosquito habitats, potentially reducing the future need for vector control [21,35,36]. Similarly, construction firms (and other high-risk companies such as garden centres) could be compelled to incorporate vector control into their health and safety measures, and potentially monitored for compliance, to ensure that they do not create breeding sites during building construction [24, 27, 35, 38]. Madeira, which is particularly affected by *Aedes aegypti*, has produced a poster with guidance specifically for construction firms that can be displayed on site [38]. This is especially important when considering the sustainability of vector control measures, because invasive mosquito species are likely to become more prevalent across wider areas of Europe. Another even more upstream measure suggested by CNEV in France is to attempt to influence people's architectural tastes towards mosquito-proof designs [25].

Regulation could also be used as a mechanism to standardise processes according to best practice, where there are variations in practice that are not evidence-based [46,47,64]. Incorporating IVM principles into existing policy and regulatory frameworks may increase the likelihood of their being implemented [9].

4.5 Finance

WHO recommends that countries need to allocate sufficient human and financial resources to enable plans to be fully implemented [1]. The National Institute for Public Health and the Environment in the Netherlands (RIVM) points out that, technically speaking, it is possible to prevent the establishment of invasive mosquitoes if there are sufficient human, financial and material resources [9]. However, limited financial support or incentives for participation may hamper the implementation of control measures [5,25].

4.6 Activities outside of the active breeding season

For many countries, vector control measures are implemented year-round. Disease outbreaks can provide an opportunity for reflection and the identification of lessons learned to improve preparedness and responses for the future [42]. Greece is the only country to have described identifying potential breeding sites during winter and treating them with larvicide [29]. Given the increasing ability for mosquito eggs to overwinter and survive in desiccated states, this control measure may become increasingly important in other countries as well.

4.7 Economic impact

Poor vector management has the potential to create a negative economic impact, in terms of direct and indirect medical costs associated with an outbreak, but also a potential impact on tourism if there is either a perceived risk of disease in the region or if vectors reach nuisance levels which may put off tourists [23,42].

Measuring the economic impact may help with advocacy activities – both in terms of lobbying for more funds and to encourage people to participate in activities [25]. However, measuring the economic impact of mosquitoes is very challenging.

5. Discussion

The documents included in this review suggest a good level of consistency between what is recommended in guidance and what is happening in reality. However, there were some gaps in information and practice identified.

WHO has published a draft framework for a global vector response, however this has not been included in the formal data extraction part of this project because it was an unapproved draft at the time of writing [18]. Nevertheless, the recommendations are incorporated into the discussion below. Similarly, the findings of this review have been benchmarked against CDC guidance to give an indication of how European practice compares [17].

The areas where this review identified gaps in information and opportunities for action are in:

1. Population thresholds
2. Evaluation and knowledge sharing
3. Cost and cost effectiveness
4. Resistance
5. Biological methods
6. Inspections at borders
7. Maintaining action
8. Encouraging innovation & research.

5.1 Population thresholds

Criteria for the implementation of specific control methods are often defined in relation to the mosquito population level. For example, whether population levels constitute either an epidemic risk or exceeded nuisance thresholds. However, these population thresholds are not clearly defined. This may lead to variations in practice, which can have an impact on the effectiveness of the control methods implemented.

ECDC guidelines on the surveillance of invasive mosquito species in Europe provide guidance on how to assess the risk posed by different mosquito species, placing this activity at the heart of risk assessment to inform the design and implementation of prevention and control measures [14]. The guidance includes a comparison of different ways of measuring mosquito populations (population abundance, female biting, etc.), exploring the information each approach provides, as well as the strengths and weaknesses of each measurement. It also recommends appropriate methods for pathogen screening in invasive mosquitoes where there is an imported disease case, a locally established invasive mosquito population or a widely-established population. ECDC has also produced surveillance guidance which focuses on native mosquitoes [15].

CDC guidance provides several thresholds for population abundance to inform epidemic risk assessment, but stresses that these thresholds are not universal to all arboviruses, may not apply to all settings and may need to be tailored to local requirements [17]. It suggests that the larval population threshold necessary to prevent yellow fever transmission is less than 5% of houses with at least one positive container (House Index, HI); less than 10% of water containers positive for larvae/pupae (Container Index, CI) and a rate of five positive containers per 100 houses (Breteau Index, BI). It also reported a study in Taiwan where for dengue *Aedes aegypti* population thresholds were 1% HI, 1.8% CI and 1.2 BI [70]. The CDC guidance did not identify pupal population thresholds relevant to chikungunya or Zika, but did identify a modelling study estimating that dengue transmission required a mosquito population of between 0.5 and 1.5 *Aedes aegypti* pupae per person, assuming a temperature of 28° Celsius (82°Fahrenheit) and a human population immunity of 0–67%. If measuring egg density, then a population of less than two eggs per house was necessary to stop dengue transmission. The CDC guidance reported that two or more adult females per ovitrap per week were associated with dengue cases, whereas one or less was a safe level. For chikungunya less than two adult females per trap halted transmission. The CDC concluded that at present it is not possible to use adult mosquito infection rates as a threshold for arboviruses.

It is also possible to quantitatively define tolerable and intolerable nuisance thresholds, based on adult abundance and the general public reporting the frequency of bites 71]. Such threshold definitions could well be included in surveillance guidance documents, which are outside the scope of this review and may explain the apparent information gap. However, including population thresholds in vector control guidance or links to these definitions could help to standardise practice and ensure that best practice is followed.

5.2 Evaluation and knowledge sharing

According to guidance, evaluation is often integrated into the IVM process. However, based on the low number of published evaluations identified, it appears that the evaluations are not necessarily being shared publicly. The findings from vector control programme evaluations can also be useful evidence in advocacy activities to lobby for funding or changes to policy [20]. Coordinated information sharing has already proved useful in improving invasive mosquito surveillance.

Much of the published literature on controlling invasive mosquito species is from the United States of America, which may provide some useful lessons learned but there are differences in the types of habitats and control measures required. Hence, the focus here has been on reviews, cost effectiveness analyses and evaluations undertaken in Europe. WHO has identified the evaluation of interventions for vector management as a key 'pillar of action' to support the reduction of vector-borne diseases [18].

By not publishing evaluations, there is a missed opportunity for countries to share experience, lessons learned and best practices tailored to the European context.

There is also a need to ensure that evaluation is a continuous process within vector management, rather than a stand-alone activity at the end of the annual active control period. Continuous evaluation would enable authorities to modify and improve control programmes in real time based on this intelligence. WHO has also identified a need to strengthen and integrate health information systems into vector management to guide programmes [18].

Standardising evaluation methods, for example across Europe, could improve the consistency of data collected [20]. This could enable comparisons between countries and also facilitate the application of findings from one country to another.

5.3 Economic considerations and cost effectiveness

There is a general lack of information in the literature about how much these vector control programmes do or should cost. There was also little information on ways to manage costs, however where this was included (e.g. annualising staff time) it was clear that there are potential gains in information sharing [23,29].

There were no guideline recommendations regarding the cost effectiveness evaluation methods to use. Several cost-based evaluations of vector control programmes were identified, which indicate that it is possible to evaluate the cost of these programmes, and several guidance documents specified that costs are recorded.

Therefore, there is an information gap in relation to the cost of vector control programmes and best practices for measuring their cost effectiveness. Sharing information about the cost would enable countries to benchmark costs to ensure that their programme represents value for money. Information about cost effectiveness measures might encourage more countries to undertake the activity as uncertainty about methods could be a barrier. The results of cost-effectiveness analyses should then be shared publicly to make the most of this information.

5.4 Resistance

Resistance is mentioned as a concept in many of the included documents, but rarely in detail. France has produced national guidance on resistance management, which recommends that resistance testing should be integrated into IVM strategies [19]. Localised resistance would reduce the effectiveness and increase the cost of vector control programmes, which may encourage authorities to implement it. Monitoring of resistance is often a stand-alone activity that is not linked to the evaluation of the effectiveness control programmes or the development of control guidance 72]. By way of comparison, the US CDC recommends that resistance monitoring and management is integrated into all control programmes and provides guidance on resistance testing procedures [17,73].

Resistance is also an issue that requires a supranational response, which is why WHO has produced guidance on resistance testing [66]. The lack of actionable information or recommendations in the literature reviewed in this project suggests that resistance testing is an area which needs further work.

5.5 Biological methods

Biological control methods – such as microbes, crustaceans or fish that eat mosquito larvae – are recommended in some of the included guidance documents. There is some evidence from the literature that biological control measures could be a worthwhile addition to IVM programmes however, it is challenging to isolate the impact of a particular component.

The US CDC recommends the use of the biological larvicide Bti, copepods and larvivorous fish – although the latter two may be less effective against *Aedes aegypti* and *Aedes albopictus* because of their preference for small temporary containers that may entirely dry out [17]. These containers are often numerous and when identified, it can be better to remove them than to treat them.

Biological methods could offer a sustainable alternative to chemical control methods to overcome the challenge of mosquito resistance. Increased use of biological methods could displace some chemical methods and, where resistance is an issue, could help to increase the longevity of these chemicals and the sustainability of IVM programmes overall. However, implementing biological control requires careful planning to ensure that there are no adverse environmental effects, especially when using non-native species.

5.6 Inspections at borders

Not many of the guidance or other documents described control methods around points of entry for people and vehicles, and imported goods. Although environmental changes contribute to the spread and increased settlement of invasive mosquitoes in Europe, the import of larvae remains a key source of introduction [8].

The scientific evidence suggests that invasive mosquito larvae can survive in a desiccated state and through winter. Surveillance and control of imports is therefore a potentially useful component of IVM that is being overlooked. Given that this literature review focused on vector control, surveillance of imports may be addressed by surveillance-focused guidance that is beyond the scope of this review (e.g. WHO guidance on surveillance at points of entry) [74].

5.7 Maintaining action

Community involvement appears to be an important factor in the successful and comprehensive implementation of IVM programmes. It requires the public to be educated about mosquitoes and the associated risks and involves motivating people to change their behaviour and take small, regular steps to contribute to reducing breeding sites. This action needs to be maintained throughout the breeding season and for people to incorporate it into their behaviour on a long-term basis. *Aedes albopictus* has also the ability to lay eggs and bite indoors which means that community action is even more important [8]. Germany, the Netherlands, Spain and the UK have all also harnessed the power of 'citizen science' to complement conventional mosquito surveillance activities [15]. The US CDC recommends a community-wide source reduction campaign and education campaigns which start before the mosquito breeding season begins, to reduce breeding opportunities for mosquitoes and establish good habits that will last through the breeding season, reinforced by continued public education campaigns [17].

Therefore, it would be useful for specific evaluations of different community engagement programmes to identify best practice (in communication methods, incentives, etc.) which guidance could incorporate to achieve behavioural change. WHO has also recommended that national plans are devised to co-ordinate community engagement and mobilisation [18]. However, there appears to be little evidence underlying such recommendations. It is unclear what community activities are most effective, therefore there is a risk of an opportunity cost with community effort and resources being channelled towards potentially ineffective methods. A study in Madeira showed the value of understanding community knowledge of mosquitoes – risk perception, their habits, how to prevent breeding and biting – to inform the design of future education interventions to target particular myths or gaps in knowledge [75].

Legislation and regulation can be used to compel community action and are identified by WHO as an enabling factor for action in vector control [18]. However, it is unclear how effective this method has been in Europe and whether this route would achieve the desired effect. There is always a risk that such compulsion could create community resentment, leading to disengagement.

There is a shortage of information on best practices in achieving and sustaining community behaviour change to support IVM. Community initiatives are being widely implemented, without evidence to support the type of activity or the methods for motivating communities.

5.8 Encouraging innovation and research

Research activity is important to ensure that there are different types of control methods to achieve effective vector control, to work around increasing resistance to current pesticides and investigate innovative control methods. There is also a need for open-mindedness. For example, studies in Madeira found that flushing storm drains with salt water was effective and low-cost, this has now been implemented [76,77]. There is also a need for more research to understand mosquito behaviour, in order to design effective control programmes [78]. WHO's draft framework recommends enhancing basic and applied research to understand the current situation and to monitor improvement [18].

In particular, there is an opportunity for greater mutually beneficial collaboration between the authorities implementing vector control and research institutions [20]. Research into monitoring and evaluation of vector control methods benefits the authorities by enabling the continuous improvement of their control programmes, potentially increasing the efficiency of individual methods and ensuring that funding is invested into only the most effective measures. Similarly, research institutions can benefit from gathering data for their research activities, particularly as these programmes are already ongoing and therefore may not involve direct costs for the research institution, unlike experiments or field studies. For example, an evaluation of four larvicide treatments was sponsored by a chemical manufacturers' association and hosted by local authorities in Italy – both stakeholders were interested in determining the most effective pesticide so it made sense to collaborate and pool resources 51]. Another similar example involved the collaboration of government institutions, academia and industry to evaluate the efficacy and non-target impacts of two adulticiding products applied aerially as a space sprays against *Aedes*, *Culex* and *Anopheles* species. Data were approved for Good Efficacy Practice (GEP) and were used to shape guidelines for applications of these products, taking into account not only efficacy but environmental compatibility. [80].

5.9 Limitations of literature review

This pragmatic literature review used systematic methods with the aim of identifying and describing key guidance and technical documents within Europe. As with all literature reviews, there is a chance that some relevant documents may not have been identified and included. The process was designed to mitigate this by combining different approaches to identifying documents – searching, a call for evidence and following up references in the documents included. Although the risk cannot be entirely eliminated, we are confident that if documents have been excluded, they are unlikely to affect the overall findings of this pragmatic review.

A formal analysis of the relative efficacy, effectiveness or safety of different chemical products, was beyond the scope of this literature review. Guideline producers should review the efficacy, effectiveness and safety of the products mentioned in this review before any recommendations are made.

6. Conclusions

There is a significant opportunity for improved evaluation of the effectiveness and cost of IVM programmes to provide data to inform evidence-based practice and continuous improvement. This would allow countries to share such evaluations, so that lessons can be learned and knowledge exchanged across Europe.

The problem of invasive mosquitoes will not go away. Therefore, IVM programmes need to be sustainable. This means that greater attention should be paid to monitoring resistance and incorporating this data into practice, evidence-based approaches should continue to be applied in pesticide use, and research should continue into alternative or new control methods to increase the range of tools available.

Communities play a potentially important role in implementing control measures on private property, as business owners and in voluntary roles with regard to public spaces. Legislative and regulatory routes may provide the legitimacy and mechanisms for compelling community action, but the potential benefits and drawbacks should be carefully assessed. There is an opportunity to learn from other areas of public health information and behaviour change, to encourage greater community engagement and action.

7. References

1. van den Berg H, Velayudhan R, Ejov M. Regional framework for surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases 2014-2020. Copenhagen: 2012. Available from: http://www.euro.who.int/__data/assets/pdf_file/0004/197158/Regional-framework-for-surveillance-and-control-of-invasive-mosquito-vectors-and-re-emerging-vector-borne-diseases-20142020.pdf?ua=1
2. WHO. Global strategic framework for integrated vector management. Geneva: World Health Organization, 2004. Available from: http://apps.who.int/iris/bitstream/10665/68624/1/WHO_CDS_CPE_PVC_2004_10.pdf.
3. ECDC. Mosquito maps [Internet]. Stockholm: European Centre for Disease Prevention and Control; [updated January 2017; cited 24/04/17]. Available from: http://ecdc.europa.eu/en/healthtopics/vectors/vector-maps/Pages/VBORNET_maps.aspx.
4. ECDC. Mission report: chikungunya in Italy. Stockholm: European Centre for Disease Prevention and Control, 2007. Available from: http://ecdc.europa.eu/en/healthtopics/documents/0709_chikungunya_fever_mission_report.pdf.
5. Roberto Romi L, Toma FS, Marco Di Luca, Daniela Boccolini MG, et al. Linee guida per il controllo di Culicidi potenziali vettori di arbovirus in Italia [Guidelines for the control of *Culicidae* potential vectors of arboviruses in Italy] Rome: 2009. Available from: http://www.iss.it/binary/publ/cont/09_11web.pdf.
6. Collantes F, Delgado JA, Alarcon-Elbal PM, et al. First confirmed outdoor winter reproductive activity of Asian tiger mosquito (*Aedes albopictus*) in Europe. Anales de Biología. 2014;36:71-6.
7. Deblauwe I, Demeulemeester J, De Witte J, et al. Increased detection of *Aedes albopictus* in Belgium: no overwintering yet, but an intervention strategy is still lacking. Parasitology Research. 2015;114(9):3469-77.
8. Medlock JM, Hansford KM, Schaffner F, et al. A review of the invasive mosquitoes in Europe: ecology, public health risks, and control options. Vector-Borne and Zoonotic Diseases. 2012;12(6):435-47.

8a. Grigoraki L, Pipini D, Labbe P, Chaskopoulou A, Weill M, Vontas J. Carboxylesterase gene amplifications associated with insecticide resistance in *Aedes albopictus:* Geographical distribution and evolutionary origin. PLoS Negl Trop Dis. 2017. 11(4): e0005533. Available at: http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0005533

9. RIVM. Preventie en bestrijding van exotische muggen in Nederland [Prevention and control of exotic mosquitoes in Netherlands]. Bilthoven: 2012. Available from: http://www.rivm.nl/dsresource?objectid=611e7e10-f8f7-4d17-bbcf-bce397c2411f&type=org&disposition=inline.
10. EMCA. Guidelines for the control of mosquitoes of public health importance in Europe. Speyer: 2011. Available from: http://www.emca-online.eu/assets/PDFs/EMCA_guidelines_Speyer_2011.pdf.
11. Officiële bekendmakingen. Convenant voorkomen of beperken van herhaalde insleep van exotische muggen bij bedrijven die handelen in gebruikte banden [Covenant preventing or limiting repeated introduction of exotic mosquitoes companies trading in used tyres]. Amsterdam: Officiële bekendmakingen, 2013. Available from: https://zoek.officielebekendmakingen.nl/stcrt-2013-18303.pdf.
12. European Parliament. Decision no 1082/2013/EU of the European Parliament and of the Council of 22 October 2013. Official Journal of the European Union. 2013;5.11.2013:L293/1-/15.
13. Roiz D, Neteler M, Castellani C, et al. Climatic factors driving invasion of the tiger mosquito (*Aedes albopictus*) into new areas of Trentino, Northern Italy. PLoS ONE. 2011;6(4).
14. ECDC. Guidelines for the surveillance of invasive mosquitoes in Europe. Stockholm: 2012. Available from: http://ecdc.europa.eu/en/publications/Publications/TER-Mosquito-surveillance-guidelines.pdf.
15. ECDC. Guidelines for the surveillance of native mosquitoes in Europe. Stockholm: 2014. Available from: http://ecdc.europa.eu/en/publications/Publications/surveillance-of%20native-mosquitoes%20-guidelines.pdf.
16. EMCA. Resolution taken at EMCA symposium, Speyer, 13-15 March 2016. Speyer: 2016. Available from: http://www.emca-online.eu/assets/PDFs/Resolution_EMCA2016_Zika.pdf.
17. CDC. Surveillance and control of *Aedes aegypti* and *Aedes albopictus* in the United States. Atlanta (GA): Centers for Disease Control and Prevention, 2015. Available from: https://www.cdc.gov/chikungunya/pdfs/Surveillance-and-Control-of-Aedes-aegypti-and-Aedes-albopictus-US.pdf.
18. WHO. Global vector control response 2017-2030: fourth draft. Geneva: 2016. Available from: http://www.who.int/malaria/areas/vector_control/Draft-WHO-GVCR-2017-2030.pdf?ua=1.
19. CNEV. Utilisation des insecticides et gestion de la résistance [Use of insecticides and resistance management]. Montpellier: 2014.
20. WHO. Handbook for integrated vector management. Geneva: 2012. Available from: http://apps.who.int/iris/bitstream/10665/44768/1/9789241502801_eng.pdf.
21. Regione del Veneto. Linee operative per la lotta all zanzara: manuale per gli operatori [Anti-mosquito guidelines: manual for operators]. Venice: Regione del Veneto, 2009.
22. DGS. Circulaire interministerielle no DGS/RI1/DGALN/DGAL/2012/360 du 1er Octobre 2012 relative aux mesures visant à limiter la circulation du virus West Nile en France métropolitaine [Interministerial circular no. DGS / RI1 / DGALN / EB / 2012/360 of 1 October 2012 on measures to limit the circulation of West Nile virus in metropolitan France]. Paris: Ministère des affaires sociales et de la santé: Direction Générale de la Santé, 2012.
23. CNEV. Guide à l'attention des collectivités souhaitant mettre en oeuvre une lutte contre les moustiques urbains vecteurs de Dengue, de Chikungunya et de Zika [Guide to communities wishing to implement a fight against the urban mosquito vectors of Dengue, of Chikungunya and Zika]. Montpellier: Centre National d'Expertise sur les Vecteurs, 2016. Available from: http://www.cnev.fr/images/pdf/notes_et_avis/gbp%20version%20longue%20a4%20.pdf.

24. CNEV. Guide méthodologique: surveillance et contrôle des moustiques aux points d'entrée ouverts au trafic international [Methodological guide: surveillance and mosquito control at points of entry open to international traffic]. Montpellier: 2012.
25. CNEV. La mobilisation sociale contre *Aedes albopictus:* cléments pour la définition d'une stratégie [Social mobilization against *Aedes albopictus*: elements for defining a strategy]. Montpellier: 2016.
26. DGS. Guide relatif aux modalités de mise en œuvre du plan anti-dissémination du Chikungunya et de la Dengue en métropole [Guide to the implementation of the anti-spread of chikungunya and Dengue plan in metropolitan France]. Paris: 2013. Available from: http://social-sante.gouv.fr/IMG/pdf/Guide_annexe_a_l_instruction_DGS_RI_2013.pdf.
27. DGS. Mise en place des programmes de surveillance et de contrôle des vecteurs au niveau des points d'entrée: guide méthodologique [Implementation of programs monitoring and control vectors at the level entry points]. Paris: 2014. Available from: http://social-sante.gouv.fr/IMG/pdf/SurveillanceControle_des_vecteurs_V2_BD.pdf.
28. DGS. Instruction no DGS/RI1/2015/125 du 16 avril 2015 mettant à jour le guide relatif aux modalités de mise en oeuvre du plan anti-dissémination du Chikungunya et de la Dengue en métropole [Directive no DGS / RI1 / 2015/125 of 16 April 2015 updating the guide on the implementation of the anti-spreading plan for Chikungunya and Dengue fever in metropolitan France]. Paris: 2015. Available from: http://social-sante.gouv.fr/IMG/pdf/Instruction_et_Guide_chik_dengue_16_avril_2015.pdf.
29. Υπουργείο Υγείας. [Mosquito control programme, relative information and protection of the public for the year 2016]. Athens: Υπουργείο Υγείας, 2016.
30. LIFE CONOPS. Σχέδιο Διαχείρισης για το *Aedes albopictus* στην Ελλάδα [Management plan for *Aedes albopictus* in Greece] [Internet]. Kifissia: LIFE CONOPS. Available from: http://www.conops.gr/management-plans/aedes-albopictus-2/.
31. MS. Piano nazionale di sorveglianza e risposta alle arbovirosi trasmesse da zanzare (*Aedes* sp.) con particolare riferimento a virus Chikungunya, Dengue e virus Zika-2016 [National surveillance plan and response to mosquitoes (*Aedes* sp.) with particular reference to Chikungunya virus, Dengue virus and Zika-2016 virus]. Rome: Ministero della Salute, 2016. Available from: http://www.trovanorme.salute.gov.it/norme/renderNormsanPdf;jsessionid=cGZ+MFsh5d1dsg1Yb+yeYQ__.sgc4-prd-sal?anno=2016&codLeg=55229&parte=1%20&serie=null.
32. LIFE CONOPS. Management plan for the *Aedes albopictus* in Greece and Italy [Internet]. Kifissia: LIFE CONOPS. Available from: http://www.conops.gr/management-plan-for-aedes-albopictus-in-greece/?lang=en.
33. DGS. Estratégia: plano nacional de prevenção e controlo de doenças transmitidas por vetores [National plan for the prevention and control of vector-transmitted diseases]. Lisbon: Direção-Geral da Saúde, 2016.
34. Institutul Cantacuzino. Informatii si propuneri privind tinerea sub control a populatiei de tantari din specia invaziva *Aedes albopictus* in Bucuresti [Information and suggestions on keeping under control the population of mosquitoes *Aedes albopictus* in Bucharest invasive species]. Bucharest: Institutul Cantacuzino, 2015.
35. MSSI. Plan nacional de preparación y respuesta frente a enfermedades transmitidas por vectores: parte I Dengue, Chikungunya y Zika [National plan for preparedness and response to vector-borne diseases: part I Dengue, Chikungunya and Zika]. Madrid: Ministerio de Sanidad, Servicios Sociales e Igualdad, 2016.
36. Servizio Sanitario Regionale Emilia-Romagna. Zanzara tigre e altri insetti pericoli pubblici: line guida per gli operatori dell'Emilia-Romagna [Tiger mosquito and other public hazards insects: guidelines for the Emilia-Romagna operators]. Bologna: 2016. Available from: http://www.salute.gov.it/imgs/C_17_opuscoliPoster_156_ulterioriallegati_ulterioreallegato_0_alleg.pdf.
37. Servizio Sanitario Regionale Emilia-Romagna. Piano sorveglianza arbovirosi 2016 [Arbovirus surveillance plan]. Bologna: Servizio Sanitario Regionale Emilia-Romagna, 2016.
38. SRAS. Mosquito *Aedes aegypti:* boas práticas de prevenção na construção civil [Good prevention practices in construction: mosquito *Aedes aegypti]*. Madeira. Available from: http://www.iasaude.pt/attachments/article/931/Boas_pr%C3%83%C2%A1ticas.pdf.
39. SRAS. Dengue: boas práticas na construção civil [Dengue: good practices in construction]. Madeira. Available from: http://www.iasaude.pt/mosquito/attachments/article/100/Plano_a%C3%83%C2%A7%C3%83%C2%A3o_para_dengue.pdf.
40. SRAS. Plano de comunicação para a prevenção e control do *Aedes aegypti* [Communication plan for the prevention and control of *Aedes aegypti]*. Madeira: 2012. Available from: http://doc.iasaude.pt/mosquito/attachments/article/84/PLANO%20DE%20COMUNICA%C3%83%E2%80%A1%C3%83%C6%92O%20PARA%20A%20PREVEN%C3%83%E2%80%A1%C3%83%C6%92O%20E%20CONTROLO%20DO%20AEDES%20AEGYPTI.pdf.
41. SRAS. Plano municipal de combate ao mosquito vetor de transmissão da Dengue [Municipal mosquito control plan Dengue transmission vector]. Madeira: 2012. Available from: http://www.cm-funchal.pt/images/stories/destaques/2012/11/planoMunicipalCombateMosquito/PlanoCombateMosquito.pdf.
42. SRAS. Plano de contingência para o surto de Dengue [Contingency plan for the Dengue outbreak]. Madeira: 2013. Available from: http://www.iasaude.pt/mosquito/attachments/article/83/Plano%20conting%C3%83%C2%AAncia%20dengue.pdf.
43. SRAS. Plano de ação para Dengue. Madeira: 2013. Available from: http://www.iasaude.pt/mosquito/attachments/article/100/Plano_a%C3%83%C2%A7%C3%83%C2%A3o_para_dengue.pdf.
44. Comunidad de Madrid. Control de vectores y plagas manual de buenas prácticas introducción [Vector and pest control good practices manual introduction] Madrid: Comunidad de Madrid. Available from: http://www.madrid.org/cs/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-disposition&blobheadername2=cadena&blobheadervalue1=filename%3DControl+vectores+y+plagas+-+Manual+buenas+practicas.pdf&blobheadervalue2=language%3Des%26site%3DPortalSalud&blobkey=id&blobtable=MungoBlobs&blobwhere=1352907764881&ssbinary=true.

45. Baldacchino F, Caputo B, Chandre F, et al. Control methods against invasive *Aedes* mosquitoes in Europe: a review. Pest Management Science. 2015;71(11):1471-85.
46. Regione Emiliana Romagna. Controllo della zanzara-tigre: analisi dei costi sostenuti dagli enti locali [Control of mosquito-tiger: analysis of the costs incurred by local authorities]. Bologna: 2012. Available from: http://salute.regione.emilia-romagna.it/documentazione/rapporti/contributi/contributi_73_zanzara_tigre.pdf/view.
47. Rivas Morales S. Economics of vector-borne diseases prevention: the case of the tiger mosquito control and Chikungunya and Dengue prevention plan in the Emilia-Romagna region (Northern Italy) Bologna: University of Bologna; 2016.
48. von Hirsch H, Becker, N. Cost-benefit analysis of mosquito control operations based on microbial control agents in the upper Rhine valley (Germany) European Mosquito Bulletin. 2009;27:47-55.
49. Abramides GC, Roiz D, Guitart R, et al. Effectiveness of a multiple intervention strategy for the control of the tiger mosquito (Aedes albopictus) in Spain. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2011;105(5):281-8.
50. Baldacchino F, Bussola F, Arnoldi D, et al. An integrated pest control strategy against the Asian tiger mosquito in northern Italy: a case study. Pest Manag Sci. 2017;73(1):87-93.
51. Bellini R, Albieri, A, Carrieri, M, Colonna, R, Donati, L, Magnani, M, Pilani, R, Veronesi, R, Chiot, G, Lanza, N. Efficacy and lasting activity of four IGRs formulations against mosquitoes in catch basins of northern Italy European Mosquito Bulletin. 2009;27:33-46.
52. Bellini R, Medici A, Puggioli A, et al. Pilot field trials with *Aedes albopictus* irradiated sterile males in Italian urban areas. Journal of Medical Entomology. 2013;50(2):317-25.
53. Caputo B, Ienco A, Cianci D, et al. The "auto-dissemination" approach: a novel concept to fight *Aedes albopictus* in urban areas. PLoS Neglected Tropical Diseases. 2012;6(8).
54. Caputo B, Ienco A, Manica M, et al. New adhesive traps to monitor urban mosquitoes with a case study to assess the efficacy of insecticide control strategies in temperate areas. Parasites and Vectors. 2015;8(1).
55. Englbrecht C, Gordon S, Venturelli C, et al. Evaluation of BG-Sentinel trap as a management tool to reduce *Aedes albopictus* nuisance in an urban environment in Italy. Journal of the American Mosquito Control Association. 2015;31(1):16-25.
56. Flacio E, Engeler L, Tonolla M, et al. Strategies of a thirteen year surveillance programme on *Aedes albopictus* (Stegomyia albopicta) in southern Switzerland. Parasites and Vectors. 2015;8(1).
57. Marini L, Baseggio A, Drago A, et al. Efficacy of two common methods of application of residual insecticide for controlling the Asian tiger mosquito, *Aedes albopictus* (Skuse), in urban areas. PLoS ONE. 2015;10(8).
58. Scholte EJ, Den Hartog E, Dik M, et al. Introduction and control of three invasive mosquito species in the Netherlands, July-October 2010. Eurosurveillance. 2010;15(45):3.
59. Scholte EJ, Dik M, Ibanez-Justicia A, et al. Findings and control of two invasive exotic mosquito species, *Aedes albopictus* and *Ae. atropalpus* (Diptera: Culicidae) in the Netherlands, 2011. European Mosquito Bulletin. 2012;30:1-14.
60. Manica M, Cobre P, Rosa R, et al. Not in my backyard: effectiveness of outdoor residual spraying from hand-held sprayers against the mosquito *Aedes albopictus* in Rome, Italy. Pest Manag Sci. 2017;73(1):138-45.
61. Ayuntamiento de Huelva. Control de mosquitos [Mosquito control]. Huelva: Ayuntamiento de Huelva, 2015. Available from: http://www.lineaverdehuelva.com/documentacion/destacado/Texto%20web%20mosquitos%202015.pdf.
62. Diputación Provincial de Cádiz. Control integrado de mosquitos en la janda [Integrated mosquito control in the janda] Cadiz: Diputación Provincial de Cádiz, 2014. Available from: http://www.dipucadiz.es/export/sites/default/galeria_de_ficheros/desarrollo_sostenible/docu_servicios_centrales/mosquitos/2014/Guia-Buenas-Practicas.pdf.
63. Generalitat Valenciana. Buenas prácticas para el control de los mosquitos [Good practices for the control of mosquitoes] Valencia: Generalitat Valenciana. Available from: http://www.agroambient.gva.es/documents/20550103/94463338/Control+de+mosquitos/8e2a5044-283e-4d70-987d-be3b2b162797;jsessionid=3A69F9A0C12584A48F52E753FF2AB0CB?version=1.2.
64. EC. Report from the Commission to the European Parliament and the Council on the sustain able use of biocides pursuant to Article 18 of Regulation (EU) No 528/2012 of the European Parliament and of the Council concerning the making available on the market and use of biocidal products. Brussels: European Commission, 2016. Available from: http://ec.europa.eu/health//sites/health/files/biocides/docs/2016_report_sustainableuse_biocides_en.pdf.
65. Caputo B, Manica M, D'Alessandro A, et al. Assessment of the effectiveness of a seasonal-long insecticide-based control strategy against *Aedes albopictus* nuisance in an urban area. PLoS Neglected Tropical Diseases. 2016;10(3).
66. WHO. Insecticide resistance [Internet]. Geneva: WHO Pesticide Evaluation Scheme (WHOPES) Available from: http://www.who.int/whopes/resistance/en/.
67. IVCC. IVCC: vector control, saving lives [Internet]. Liverpool: The innovative vector control consortium Available from: http://www.ivcc.com/.
68. WHO. WHO pesticide evaluation scheme (WHOPES) [Internet]. Geneva: WHO Pesticide Evaluation Scheme (WHOPES) Available from: http://www.who.int/whopes/en/.
69. ECDC. Zika virus disease epidemic: Preparedness planning guide for diseases transmitted by *Aedes aegypti* and *Aedes albopictus.* Stockholm: European Centre for Disease Prevention and Control, 2016
70. Chang FS, Tseng YT, Hsu PS, et al. Re-assess vector indices threshold as an early warning tool for predicting Dengue epidemic in a Dengue non-endemic country. PLoS Negl Trop Dis. 2015;9(9).

71. Carrieri M, Bellini R, Maccaferri S, et al. Tolerance thresholds for *Aedes albopictus* and *Aedes caspius* in Italian urban areas. Journal of the American Mosquito Control Association. 2008;24(3):377-86.
72. The malERA Consultative Group on Vector Control. A research agenda for Malaria eradication: vector control. PLoS Medicine. 2011;8(1):e1000401.
73. CDC. Guideline for evaluating insecticide resistance in vectors using the CDC bottle bioassay. Atlanta (GA): Centers for Disease Control and Prevention, 2015. Available from: https://www.cdc.gov/malaria/resources/pdf/fsp/ir_manual/ir_cdc_bioassay_en.pdf.
74. WHO. Coordinated public health surveillance between points of entry and national health surveillance systems: advising principles. Geneva: World Health Organization, 2014. Available from: http://apps.who.int/iris/bitstream/10665/144805/1/WHO_HSE_GCR_LYO_2014.12_eng.pdf?ua=1&ua=1.
75. Nazareth T, Teodósio R, Porto G, et al. Strengthening the perception-assessment tools for dengue prevention: a cross-sectional survey in a temperate region (Madeira, Portugal). BMC public health. 2014;14:39.
76. Alves GM, Pires B, Seixas G, et al., editors. Methods for larval control of *Aedes aegypti* in the city of Funchal, Madeira Island, Portugal2015; Valencia: 7th EMCA Workshop 2015.
77. Pestana JF. Operação de combate ao mosquito vector de transmissão da dengue no Funchal [Operation of mosquito control vector dengue transmission in Funchal] [Internet]. Funchal: Diario de Notícias. Available from: http://www.dnoticias.pt/hemeroteca/461634-operacao-de-combate-ao-mosquito-vector-de-transmissao-da-dengue-no-funcha-AIDN461634.
78. Benelli G, Jeffries CL, Walker T. Biological control of mosquito vectors: past, present, and future. Insects. 2016;7(4).
79. Fotakis EA, Chaskopoulou A, Grigoraki L, Tsiamantas A, Kounadi S, Georgiou L, et al. Analysis of population structure and insecticide resistance in mosquitoes of the genus *Culex, Anopheles* and *Aedes* from different environments of Greece with a history of mosquito borne disease transmission. Acta Trop. 2017. 174:29-37. doi: 10.1016/j.actatropica.2017.06.005. Available at: http://www.bioone.org/doi/abs/10.2987/11-6177.1
80. Chaskopoulou A, Latham MD, Pereira RM, Connelly R, Bonds JAS, Koehler PG. Efficacy of aerial ULV applications of two novel water-based formulations of unsynergized pyrethroids against Riceland mosquitoes in Greece. J. Am. Mosq. Control Assoc. 2011. 27: 414-422. Available at: http://www.bioone.org/doi/abs/10.2987/11-6177.1

Annexes

Annex 1. Bibliographic database search strategies

Embase.com search strategy

#1	eu:ti,ab OR (europe* NEAR/3 union):ti,ab OR (europe* NEAR/3 community):ti,ab OR austria:ti,ab OR belgium:ti,ab OR bulgaria:ti,ab OR croatia:ti,ab OR cyprus:ti,ab OR (czech NEAR/3 republic):ti,ab OR denmark:ti,ab OR estonia:ti,ab OR finland:ti,ab OR france:ti,ab OR germany:ti,ab OR greece:ti,ab OR hungary:ti,ab OR ireland:ti,ab OR italy:ti,ab OR latvia:ti,ab OR lithuania:ti,ab OR luxembourg:ti,ab OR malta:ti,ab OR netherlands:ti,ab OR poland:ti,ab OR portugal:ti,ab OR romania:ti,ab OR slovakia:ti,ab OR slovenia:ti,ab OR spain:ti,ab OR sweden:ti,ab OR britain:ti,ab OR wales:ti,ab OR scotland:ti,ab OR england:ti,ab OR uk:ti,ab OR gb:ti,ab
#2	'european union':de OR austria:de OR belgium:de OR bulgaria:de OR croatia:de OR cyprus:de OR 'czech republic':de OR denmark:de OR estonia:de OR finland:de OR france:de OR germany:de OR greece:de OR hungary:de OR ireland:de OR italy:de OR latvia:de OR lithuania:de OR luxembourg:de OR malta:de OR netherlands:de OR poland:de OR portugal:de OR romania:de OR slovakia:de OR slovenia:de OR spain:de OR sweden:de OR 'united kingdom'/exp
#3	#1 OR #2
#4	(control NEAR/3 (strateg* OR measure* OR program* OR tool* OR initiative* OR intervention*)):ti,ab
#5	(residual NEXT/3 spray*):ti,ab OR (space NEXT/3 spray*):ti,ab OR (barrier NEXT/3 spray*):ti,ab OR (cold NEXT/3 fog):ti,ab OR (thermal NEXT/3 fog):ti,ab
#6	'resting site*':ti,ab OR 'standing water':ti,ab OR 'breeding site*':ti,ab OR 'source reduction':ti,ab OR 'larval habitat*':ti,ab OR 'water-holding container*':ti,ab OR 'mosquito-producing container*':ti,ab OR 'environmental sanitation':ti,ab
#7	insecticid*:ti,ab OR larvicid*:ti,ab OR adulticid*:ti,ab OR 'pyrethroid*':ti,ab OR 'biological control*':ti,ab OR 'biocontrol*':ti,ab OR 'carnivorous copepods':ti,ab OR 'larvivorous fish':ti,ab OR 'gambusia affinis':ti,ab OR 'bti':ti,ab OR 'bacillus thuringiensis israelensis':ti,ab OR 'larval control*':ti,ab OR 'toxic bait*':ti,ab OR trap*:ti,ab OR lure*:ti,ab OR ovitrap*:ti,ab OR 'mosquito trap*':ti,ab OR 'cdc miniature light trap*':ti,ab OR 'cdc gravid trap*':ti,ab OR 'new jersey light trap*':ti,ab OR 'fan-operated trap*':ti,ab OR 'fay-prince trap*':ti,ab OR 'bg sentinel trap*':ti,ab OR 'cdc-autocidal gravid ovitrap*':ti,ab OR 'cdc-ago':ti,ab OR 'mechanical aspirators':ti,ab OR 'spatial cluster*':ti,ab
#8	insecticide:de OR 'mosquito control':de OR 'pest control'/exp OR pesticide:de OR 'vector control':de
#9	#4 OR #5 OR #6 OR #7 OR #8
#10	'*Aedes aegypti* ':ti,ab OR 'a aegypti':ti,ab OR 'ae aegypti':ti,ab OR 'stegomyia aegypti':ti,ab OR 'Aedes egypti':ti,ab OR 'a egypti':ti,ab OR 'ae egypti':ti,ab OR 'stegomyia egypti':ti,ab OR 'yellow fever mosquito*':ti,ab OR '*Aedes albopictus*':ti,ab OR 'a albopictus':ti,ab OR 'ae albopictus':ti,ab OR 'stegomyia albopicta':ti,ab OR 'tiger mosquito*':ti,ab OR 'forest mosquito*':ti,ab OR vector*:ti,ab OR 'insect vectors':de OR Aedes:de
#11	#9 AND #10
#12	#3 AND #11
#13	#12 AND (2006:py OR 2007:py OR 2008:py OR 2009:py OR 2010:py OR 2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py)

PubMed search strategy

#1	Search ("control strategy"[Title/Abstract] OR "control strategies"[Title/Abstract] OR "control measure"[Title/Abstract] OR "control measures"[Title/Abstract] OR "control program"[Title/Abstract] OR "control programs"[Title/Abstract] OR "control programme"[Title/Abstract] OR "control programmes"[Title/Abstract] OR "control tool"[Title/Abstract] OR "control tools"[Title/Abstract] OR "control initiative"[Title/Abstract] OR "control initiatives"[Title/Abstract] OR "control intervention"[Title/Abstract] OR "control interventions"[Title/Abstract])
#2	Search ("residual spray"[Title/Abstract] OR "residual sprays"[Title/Abstract] OR "residual spraying"[Title/Abstract] OR "space spray"[Title/Abstract] OR "space sprays"[Title/Abstract] OR "space spraying"[Title/Abstract] OR "barrier spray"[Title/Abstract] OR "barrier sprays"[Title/Abstract] OR "barrier spraying"[Title/Abstract] OR "cold fog"[Title/Abstract] OR "cold fogs"[Title/Abstract] OR "cold fogging"[Title/Abstract] OR "thermal fog"[Title/Abstract] OR "thermal fogs"[Title/Abstract] OR "thermal fogging"[Title/Abstract])
#3	Search ("resting site"[Title/Abstract] OR "standing water"[Title/Abstract] OR "breeding site"[Title/Abstract] OR "source reduction"[Title/Abstract] OR "larval habitat"[Title/Abstract] OR "water-holding containers"[Title/Abstract] OR "mosquito-producing containers"[Title/Abstract] OR "environmental sanitation"[Title/Abstract])
#4	Search (insecticid*[Title/Abstract] OR larvicid*[Title/Abstract] OR adulticid*[Title/Abstract] OR pyrethroid*[Title/Abstract] OR "biological control*"[Title/Abstract] OR biocontrol*[Title/Abstract] OR "carnivorous copepods"[Title/Abstract] OR "larvivorous fish"[Title/Abstract] OR "gambusia affinis"[Title/Abstract] OR bti[Title/Abstract] OR "bacillus thuringiensis israelensis"[Title/Abstract] OR "larval control*"[Title/Abstract] OR "toxic bait*"[Title/Abstract] OR trap*[Title/Abstract] OR lure*[Title/Abstract] OR ovitrap*[Title/Abstract] OR "mosquito trap*"[Title/Abstract] OR "cdc miniature light trap*"[Title/Abstract] OR "cdc gravid trap*"[Title/Abstract] OR "new jersey light trap*"[Title/Abstract] OR "fan-operated trap*"[Title/Abstract] OR "fay-prince trap*"[Title/Abstract] OR "bg sentinel trap*"[Title/Abstract] OR "cdc-autocidal gravid ovitrap*"[Title/Abstract] OR "cdc-ago"[Title/Abstract] OR "mechanical aspirators"[Title/Abstract] OR "**spatial cluster***"[Title/Abstract])
#5	Search ((("Insecticides"[MeSH Major Topic]) OR "Mosquito Control"[MeSH Major Topic]) OR "Insect Control"[MeSH Major Topic]) OR "Pesticides"[MeSH Major Topic] OR "Pest Control, biological"[MeSH Major Topic]
#6	Search (#1 OR #2 OR #3 OR #4 OR #5)
#7	Search ((("a aegypti"[Title/Abstract] OR "ae aegypti"[Title/Abstract] OR "**aedes aegypti**"[Title/Abstract] OR "stegomyia aegypti"[Title/Abstract] OR "a**edes egypti**"[Title/Abstract] OR "**a egypti**"[Title/Abstract] OR "**ae egypti**"[Title/Abstract] OR "**stegomyia egypti**"[Title/Abstract] OR "yellow fever mosquito*"[Title/Abstract] OR "aedes albopictus"[Title/Abstract] OR "a albopictus"[Title/Abstract] OR "ae albopictus"[Title/Abstract] OR "stegomyia albopicta"[Title/Abstract] OR "tiger mosquito*"[Title/Abstract] OR "forest mosquito*"[Title/Abstract] OR vector*[Title/Abstract])) OR "insect vectors"[MeSH Major Topic]) OR "Aedes"[MeSH Major Topic]
#8	Search (#6 AND #7)
#9	Search ("european union"[Title/Abstract] OR "european community"[Title/Abstract] OR austria[Title/Abstract] OR belgium[Title/Abstract] OR bulgaria[Title/Abstract] OR croatia[Title/Abstract] OR cyprus[Title/Abstract] OR "czech republic"[Title/Abstract] OR denmark[Title/Abstract] OR estonia[Title/Abstract] OR finland[Title/Abstract] OR france[Title/Abstract] OR germany[Title/Abstract] OR greece[Title/Abstract] OR hungary[Title/Abstract] OR ireland[Title/Abstract] OR italy[Title/Abstract] OR latvia[Title/Abstract] OR lithuania[Title/Abstract] OR luxembourg[Title/Abstract] OR malta[Title/Abstract] OR

	netherlands[Title/Abstract] OR poland[Title/Abstract] OR portugal[Title/Abstract] OR romania[Title/Abstract] OR slovakia[Title/Abstract] OR slovenia[Title/Abstract] OR spain[Title/Abstract] OR sweden[Title/Abstract] OR britain[Title/Abstract] OR wales[Title/Abstract] OR scotland[Title/Abstract] OR england[Title/Abstract] OR uk[Title/Abstract] OR gb[Title/Abstract])
#10	Search ("european union" OR austria OR belgium OR bulgaria OR croatia OR cyprus OR "czech republic" OR denmark OR estonia OR finland OR france OR germany OR greece OR hungary OR ireland OR italy OR latvia OR lithuania OR luxembourg OR malta OR netherlands OR poland OR portugal OR romania OR slovakia OR slovenia OR spain OR sweden OR "great britain"[MeSH Major Topic])
#11	Search (#9 OR #10)
#12	Search (#8 AND #11)
#13	Search (#8 AND #11) Filters: published in the last 10 years
#14	Search (#13 NOT Medline[SB]) Filters: published in the last 10 years Sort by: PublicationDate

Annex 2. List of included documents

1. CNEV. Guide méthodologique: surveillance et contrôle des moustiques aux points d'entrée ouverts au trafic international [Methodological guide: surveillance and mosquito control at points of entry open to international traffic]. Montpellier: 2012.
2. CNEV. La mobilisation sociale contre *Aedes albopictus*: cléments pour la définition d'une stratégie [Social mobilization against *Aedes albopictus*: elements for defining a strategy]. Montpellier: 2016.
3. CNEV. Guide à l'attention des collectivités souhaitant mettre en oeuvre une lutte contre les moustiques urbains vecteurs de Dengue, de Chikungunya et de Zika [Guide to communities wishing to implement a fight against the urban mosquito vectors of Dengue, of Chikungunya and Zika]. Montpellier: Centre National d'Expertise sur les Vecteurs, 2016.
4. Comunidad de Madrid. Control de vectores y plagas manual de buenas prácticas introducción [Vector and pest control good practices manual introduction] Madrid: Comunidad de Madrid.
5. DGS. Circulaire interministerielle no DGS/RI1/DGALN/DGAL/2012/360 du 1er Octobre 2012 relative aux mesures visant à limiter la circulation du virus West Nile en France métropolitaine [Interministerial circular no. DGS / RI1 / DGALN / EB / 2012/360 of 1 October 2012 on measures to limit the circulation of West Nile virus in metropolitan France]. Paris: Ministère des affaires sociales et de la santé: Direction Générale de la Santé, 2012.
6. DGS. Guide relatif aux modalités de mise en œuvre du plan anti-dissémination du Chikungunya et de la Dengue en métropole [Guide to the implementation of the anti-spread of Chikungunya and Dengue plan in metropolitan France]. Paris: 2013.
7. DGS. Mise en place des programmes de surveillance et de contrôle des vecteurs au niveau des points d'entrée: guide méthodologique [Implementation of programs monitoring and control vectors at the level entry points]. Paris: 2014.
8. DGS. Instruction no DGS/RI1/2015/125 du 16 avril 2015 mettant à jour le guide relatif aux modalités de mise en oeuvre du plan anti-dissémination du Chikungunya et de la Dengue en métropole [Directive no DGS / RI1 / 2015/125 of 16 April 2015 updating the guide on the implementation of the anti-spreading plan for Chikungunya and Dengue fever in metropolitan France]. Paris: 2015.
9. DGS. Estratégia: plano nacional de prevenção e controlo de doenças transmitidas por vetores [National plan for the prevention and control of vector-transmitted diseases]. Lisbon: Direção-Geral da Saúde, 2016.
10. EMCA. Guidelines for the control of mosquitoes of public health importance in Europe. Speyer: 2011.
11. Institutul Cantacuzino. Informatii si propuneri privind tinerea sub control a populatiei de tantari din specia invaziva *Aedes albopictus* in Bucuresti [Information and suggestions on keeping under control the population of mosquitoes *Aedes albopictus* in Bucharest invasive species]. Bucharest: Institutul Cantacuzino, 2015.
12. LIFE CONOPS. Σχέδιο Διαχείρισης για το Aedes albopictus στην Ελλάδα [Management plan for the *Aedes albopictus* in Greece] Kifissia: LIFE CONOPS. Available from: http://www.conops.gr/management-plans/aedes-albopictus-2/.
13. LIFE CONOPS. Management plan for the *Aedes albopictus* in Greece and Italy Kifissia: LIFE CONOPS. Available from: http://www.conops.gr/management-plan-for-aedes-albopictus-in-greece/?lang=en.
14. MS. Piano nazionale di sorveglianza e risposta alle arbovirosi trasmesse da zanzare (Aedes sp.) con particolare riferimento a virus Chikungunya, Dengue e virus Zika-2016 [National surveillance plan and response to mosquitoes (*Aedes* sp.) with particular reference to Chikungunya virus, Dengue virus and Zika-2016 virus]. Rome: Ministero della Salute, 2016.
15. MSSI. Plan nacional de preparación y respuesta frente a enfermedades transmitidas por vectores: parte I Dengue, Chikungunya y Zika [National plan for preparedness and response to vector-borne diseases: part I Dengue, Chikungunya and Zika]. Madrid: Ministerio de Sanidad, Servicios Sociales e Igualdad, 2016.
16. Regione del Veneto. Linee operative per la lotta all zanzara: manuale per gli operatori [Anti-mosquito guidelines: manual for operators]. Venice: Regione del Veneto, 2009.
17. RIVM. Preventie en bestrijding van exotische muggen in Nederland [Prevention and control of exotic mosquitoes in Netherlands]. Bilthoven: 2012.

18. Roberto Romi L, Toma FS, Marco Di Luca, Daniela Boccolini MG, ia Ciufolini LN, letti GM. Linee guida per il controllo di Culicidi potenziali vettori di arbovirus in Italia [Guidelines for the control of Culicidae potential vectors of arboviruses in Italy] Rome: 2009.
19. Servizio Sanitario Regionale Emilia-Romagna. Zanzara tigre e altri insetti pericoli pubblici: line guida per gli operatori dell'Emilia-Romagna [Tiger mosquito and other public hazards insects: guidelines for the Emilia-Romagna operators]. Bologna: 2016.
20. Servizio Sanitario Regionale Emilia-Romagna. Piano sorveglianza arbovirosi 2016 [Arbovirus surveillance plan]. Bologna: Servizio Sanitario Regionale Emilia-Romagna, 2016.
21. SRAS. Mosquito *Aedes aegypti*: boas práticas de prevenção na construção civil [Good prevention practices in construction: mosquito *Aedes aegypti*]. Madeira.
22. SRAS. Dengue: boas práticas na construção civil [Dengue: good practices in construction]. Madeira.
23. SRAS. Plano de comunicação para a prevenção e control do *Aedes aegypti* [Communication plan for the prevention and control of *Aedes aegypti*]. Madeira: 2012.
24. SRAS. Plano municipal de combate ao mosquito vetor de transmissão da Dengue [Municipal mosquito control plan Dengue transmission vector]. Madeira: 2012.
25. SRAS. Plano de contingência para o surto de Dengue [Contingency plan for the Dengue outbreak]. Madeira: 2013.
26. van den Berg H, Velayudhan R, Ejov M. Regional framework for surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases 2014-2020. Copenhagen: 2012.
27. WHO. Global strategic framework for integrated vector management. Geneva: World Health Organization, 2004.
28. WHO. Handbook for integrated vector management. Geneva: 2012.
29. Υπουργείο Υγείας. [Mosquito control programme, relative information and protection of the public for the year 2016]. Athens: Υπουργείο Υγείας, 2016.

Reviews, cost-effectiveness, assessments and evaluations of vector control

30. Abramides GC, Roiz D, Guitart R, Quintana S, Guerrero I, Giménez N. Effectiveness of a multiple intervention strategy for the control of the tiger mosquito (*Aedes albopictus*) in Spain. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2011;105(5):281-8.
31. Baldacchino F, Bussola F, Arnoldi D, Marcantonio M, Montarsi F, Capelli G, et al. An integrated pest control strategy against the Asian tiger mosquito in northern Italy: a case study. Pest Manag Sci. 2017;73(1):87-93.
32.Baldacchino F, Caputo B, Chandre F, Drago A, della Torre A, Montarsi F, et al. Control methods against invasive *Aedes* mosquitoes in Europe: a review. Pest Management Science. 2015;71(11):1471-85.
33. Bellini R, Albieri, A, Carrieri, M, Colonna, R, Donati, L, Magnani, M, Pilani, R, Veronesi, R, Chiot, G, Lanza, N. Efficacy and lasting activity of four IGRs formulations against mosquitoes in catch basins of northern Italy European Mosquito Bulletin. 2009;27:33-46.
34 Bellini R, Medici A, Puggioli A, Balestrino F, Carrieri M. Pilot field trials with *Aedes albopictus* irradiated sterile males in Italian urban areas. Journal of Medical Entomology. 2013;50(2):317-25.
35. Caputo B, Ienco A, Cianci D, Pombi M, Petrarca V, Baseggio A, et al. The "auto-dissemination" approach: a novel concept to fight *Aedes albopictus* in urban areas. PLoS Neglected Tropical Diseases. 2012;6(8).
36. Caputo B, Ienco A, Manica M, Petrarca V, Rosà R, Della Torre A. New adhesive traps to monitor urban mosquitoes with a case study to assess the efficacy of insecticide control strategies in temperate areas. Parasites and Vectors. 2015;8(1).
37. Englbrecht C, Gordon S, Venturelli C, Rose A, Geier M. Evaluation of BG-Sentinel trap as a management tool to reduce *Aedes albopictus* nuisance in an urban environment in Italy. Journal of the American Mosquito Control Association. 2015;31(1):16-25.
38. Flacio E, Engeler L, Tonolla M, Lüthy P, Patocchi N. Strategies of a thirteen year surveillance programme on *Aedes albopictus* (Stegomyia albopicta) in southern Switzerland. Parasites and Vectors. 2015;8(1).

39. Manica M, Cobre P, Rosa R, Caputo B. Not in my backyard: effectiveness of outdoor residual spraying from hand-held sprayers against the mosquito *Aedes albopictus* in Rome, Italy. Pest Manag Sci. 2017;73(1):138-45.
40. Marini L, Baseggio A, Drago A, Martini S, Manella P, Romi R, et al. Efficacy of two common methods of application of residual insecticide for controlling the Asian tiger mosquito, *Aedes albopictus* (Skuse), in urban areas. PLoS ONE. 2015;10(8).
41. Medlock JM, Hansford KM, Schaffner F, Versteirt V, Hendrickx G, Zeller H, et al. A review of the invasive mosquitoes in Europe: ecology, public health risks, and control options. Vector-Borne and Zoonotic Diseases. 2012;12(6):435-47.
42. Regione Emiliana Romagna. Controllo della zanzara-tigre: analisi dei costi sostenuti dagli enti locali [Control of mosquito-tiger: analysis of the costs incurred by local authorities]. Bologna: 2012.
43. Rivas Morales S. Economics of vector-borne diseases prevention: the case of the tiger mosquito control and Chikungunya and Dengue prevention plan in the Emilia-Romagna region (Northern Italy) Bologna: University of Bologna; 2016.
44. Scholte EJ, Den Hartog E, Dik M, Schoelitsz B, Brooks M, Schaffner F, et al. Introduction and control of three invasive mosquito species in the Netherlands, July-October 2010. Eurosurveillance. 2010;15(45):3.
45. Scholte EJ, Dik M, Ibanez-Justicia A, Den Hartog E, Schoelitsz B, Brooks M, et al. Findings and control of two invasive exotic mosquito species, *Aedes albopictus* and *Ae. atropalpus* (Diptera: Culicidae) in the Netherlands, 2011. European Mosquito Bulletin. 2012;30:1-14.
46. SRAS. Plano de ação para Dengue. Madeira: 2013.
47. von Hirsch H, Becker, N. Cost-benefit analysis of mosquito control operations based on microbial control agents in the upper Rhine valley (Germany) European Mosquito Bulletin. 2009;27:47-55.

Annex 3. List of the 47 excluded documents retrieved via the call for evidence

Reference	Reason for exclusion
ARS. Psage_dengue_18-09-07.pdf. Guadeloupe: Agence Régionale de Santé Guadeloupe, Saint-Martin, Saint-Barthélémy, 2007.	Beyond geographical scope.
ARS. Annexes_Psage_13-08-07.pdf. Guadeloupe: Agence Régionale de Santé Guadeloupe, Saint-Martin, Saint-Barthélémy, 2007.	Beyond geographical scope.
Bellini R, Bonilauri P, Puggioli A, Lelli D, Galbani P. Chikungunya and dengue risk assessment in Greece. Vector Biol J. 2016;1(2).	Surveillance-focused.
Boubidi SC, Roiz D, Rossignol M, Chandre F, Benoit R, Raselli M, et al. Efficacy of ULV and thermal aerosols of deltamethrin for control of Aedes albopictus in nice, France. Parasit Vectors. 2016;9(1):597.	Duplicate – retrieved via grey literature searching.
Ceianu CS, Falcuta E, Priorteasa LF. Aedes albopictus: specie invaziva cu potential vector, controlabila prin implementarea unui program integrat de management al vectorilor [Aedes albopictus: invasive species with vector potential, controllable through the implementation of a program integrated vector management]. Bucharest: Institutul Cantacuzino, 2016.	Study design not relevant to this review - suggested forms of control based on other guidance. It is not described as or does not constitute a piece of guidance itself.
CNEV. Utilisation des insecticides et gestion de la résistance [Use of insecticides and resistance management]. Montpellier: 2014.	Not fully extracted and included in the review because it only contains information on resistance management, included as a discussion/background paper.
DGS. Actions de lutte et de prévention contre les moustiques autour des établissements hospitaliers [Measures to prevent and control mosquitoes around hospitals]. Paris: Direction Générale de la Santé, 2016.	Not relevant – highly specific setting.
DGS. Saúde e números [Health and numbers] Lisbon: Direção-Geral da Saúde; 2016.	Not relevant – health statistics.
Kormány. 1195/2016. (IV. 13.) Korm. határozat az országos szúnyoggyérítési program központi megvalósításáról és az ehhez szükséges források biztosításáról [1195/2016. (IV 13) on the central implementation of the national mosquito netting program and the provision of the necessary resources]. Budapest: Magyar kormány, 2016.	Study design not relevant to this review - not guidance itself, but is an instruction regarding the formulation and financing of plans. Financing information relates to the use of netting, which is not relevant to invasive species.
LIFE CONOPS. Distribution map of Aedes albopictus (Asian tiger mosquito) in Greece Kifissia: LIFE CONOPS; 2013.	Surveillance-focused.
Magyar Kártevőirtók Országos Szövetsége. A Magya Kártevõirtók Országos Szövetégének információs lapja: az Európai kártevõirtási szolgáltatási szabványról [Information sheet of the National Association of Hungarian Pest Controls: European pest management standard] Kártevőirtás. 2015;2015(1).	Study design not relevant to this review - describes what was done, with no reporting of outcomes.
Magyar Kártevőirtók Országos Szövetsége. A Magya Kártevõirtók Országos Szövetégének információs lapja: trófeák[Information sheet of the National Association of Hungarian Pest Controls: trophies]. Kártevőirtás. 2015;2015(2).	Study design not relevant to this review - describes what was done, with no reporting of outcomes
MOH. Σχέδιο διαχείρισης των διαβιβαστών σε περίπτωση κρούσματος Δάγκειου πυρετού, λοίμωξης από ιό Chikungunya ή Zika [Circular topic: vector management plan in the event of an outbreak Dengue, Chikungunya virus infection or Zika]. Athens: 2016.	Study design not relevant to this review - references the full national guidance, which has been included.
MOH. ΘΕΜΑ: «Σχέδιο διαχείρισης των διαβιβαστών σε περίπτωση κρούσματος Δάγκειου πυρετού, λοίμωξης από ιό Chikungunya ή Zika» [Circular topic: "management plan in the event of an outbreak Dengue, Chikungunya virus infection or Zika"]. Ministry of Health	Study design not relevant to this review - references the full national guidance, which has been included and extracted.
Nazareth T, Teodósio R, Porto G, Gonçalves L, Seixas G, Silva AC, et al. Strengthening the perception-assessment tools for dengue prevention: a cross-sectional survey in a temperate region (Madeira, Portugal). BMC public health. 2014;14:39.	Duplicate – retrieved via grey literature searching.
NVWA. Vondst exotische mug: wat nu? NVWA draaiboek [Find exotic mosquito: what now? NVWA Scenario]. Utrecht: Nederlandse Voedsel-en Warenautoriteit, 2014.	Study design not relevant to this review - not really guidance, scenario based.
Országos Epidemiológiai Központ. A szúnyogok elleni védekezésről [Control of mosquitoes] Budapest: Országos Epidemiológiai Központ; 2001. Available from: http://www.oek.hu/oek.web?nid=175&pid=1.	Outside of date range.
República Portuguesa. Plano nacional de prevenção e controle de Doenças transmitidas por vetores [National plan for the prevention and control of vector-borne diseases]. Diário da República. 2016;1(41):635-6.	Study design not relevant to this review - record of the passing into law of the national vector plan, which is included.

Reference	Reason for exclusion
RIVM. Preventie en bestrijding van exotische muggen in Nederland [Prevention and control of exotic mosquitoes in Netherlands]. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu, 2012.	Duplicate – retrieved via grey literature searching.
RIVM. Beleid bij exotische steekmuggen in Nederland [Policy at exotic mosquitoes in Netherlands implementation and tasks within the GGD]. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu, 2013.	Duplicate – retrieved via grey literature searching.
Roberto Romi L, Toma FS, Marco Di Luca, Daniela Boccolini MG, et al. Linee guida per il controllo di Culicidi potenziali vettori di arbovirus in Italia [Guidelines for the control of Culicidae potential vectors of arboviruses in Italy] Rome: 2009. Available from: http://www.iss.it/binary/publ/cont/09_11web.pdf.	Duplicate – retrieved via grey literature searching.
SRAS. Procedimentos de segurança individual e coletiva face a riscos epidémicos: a Dengue [Individual and collective safety procedures against epidemic risks: Dengue] Madeira: Secretaria Regional da Saúde. Available from: http://iasaude.sras.gov-madeira.pt/DengueEscolas/index.cfm.	Study design not relevant to this review – website does not have any content apart from title.
SRAS. Folheto: medidas de prevenção nas doenças transmitidas por mosquitos - 2005 [Brochure: prevention measures in mosquito-borne diseases - 2005]. Madeira: Secretaria Regional da Saúde, 2005.	Outside of date range.
SRAS. Folheto: medidas de prevenção nas doenças transmitidas por mosquitos - 2005 [Brochure: prevention measures in mosquito-borne diseases - 2005]. Madeira: Secretaria Regional da Saúde, 2005.	Outside of date range.
SRAS. Cartaz: alerta de saúde: medidas de protecção individual [Poster: health warning: individual protection measures]. Madeira: Secretaria Regional da Saúde, 2005.	Outside of date range.
SRAS. Circular normativa nº 6 de 09-11-2012: principais alterações: nova definição de caso; consulta dedicada a Dengue (CDD) no centro de saúde do Bom Jesus; inclusão dos cuidados de saúde privados; inclusão do inquérito epidemiológico para a notificação de casos do setor privado [Regulatory circular nº 6 of 09-11-2012: main changes: new case definition; consultation dedicated to Dengue (CDD) in the health center of Bom Jesus; inclusion of private health care; inclusion of the epidemiological inquiry for private sector case reporting]2012.	Surveillance-focused.
SRAS. Circular normativa nº 5 de 26-10-2012: normas de monitorização do surto e gestão de casos de dengue na RAM [Regulatory circular No. 5 of 26-10-2012: standards for outbreak monitoring and management of dengue cases in RAM]. Madeira: Secretaria Regional da Saúde, 2012.	Surveillance-focused.
SRAS. Folheto: eliminar o mosquito Aedes aegypti e controlar a Dengue depende de todos - 2012 [Brochure: eliminating the Aedes aegypti mosquito and controlling dengue depends on everyone - 2012]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Aedes aegypti Dengue: recomendações a viajantes multilingue regresso à RAM [Aedes aegypti Dengue: recommendations to multi-lingual travelers returning to RAM]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Aedes aegypti Dengue: recomendações a viajantes multilingue entradas na RAM [Aedes aegypti Dengue: recommendations to travelers multilingual entering RAM]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Aedes aegypti Dengue: recomendações a viajantes bilingue Russo/Chinês [Aedes aegypti Dengue: recommendations to Russian / Chinese bilingual travelers]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Aedes aegypti Dengue: recomendações a viajantes bilingue PT/Ing [Aedes aegypti Dengue: recommendations to Portuguese/English bilingual travelers]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Cartaz: eliminar o mosquito Aedes aegypti e controlar a Dengue depende de todos - 2012 [Poster: eliminating the Aedes aegypti mosquito and controlling dengue depends on everyone - 2012]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Cartaz Dengue: sintomas [Dengue poster: symptoms] Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Folheto: não mosquito - dê 10 minutos do seu tempo à prevenção (moradias) [Flyer: do not mosquito - give 10 minutes of your time to prevention (houses)]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Folheto: não mosquito - dê 10 minutos do seu tempo à prevenção condomínios [Brochure: do not mosquito - give 10 minutes of your time to prevention condominiums]. Madeira: Secretaria Regional da Saúde, 2012.	Study design not relevant to this review - information for the public.
SRAS. Jogo: supermeninos no combate à Dengue [Game: supermen in the fight against Dengue]: Secretaria Regional da Saúde; 2013.	Study design not relevant to this review - information for the public.
SRAS. ABCD a tua cartilha de saúde – 2º ciclo [ABCD your health booklet - 2nd cycle]. Madeira: Secretaria Regional da Saúde, 2014.	Study design not relevant to this review - information for the public.
SRAS. Folheto: eliminar o mosquito Aedes aegypti e controlar a Dengue depende de todos nós [Leaflet: eliminating the Aedes aegypti mosquito and controlling dengue depends on us all]. Madeira: Secretaria Regional da Saúde, 2014.	Study design not relevant to this review - information for the public.
SRAS. Folheto: saiba distinguir sintomas de uma Gripe sazonal e da Dengue [Brochure: learn to distinguish symptoms of a seasonal and Dengue Flu]. Madeira: Secretaria Regional da Saúde, 2014.	Study design not relevant to this review - information for the public.

Reference	Reason for exclusion
SRAS. ABCD a tua cartilha de saúde – 1º ciclo [ABCD your health booklet - 1st cycle] Madeira: Secretaria Regional da Saúde; 2015.	Study design not relevant to this review - information for the public.
SRAS. Decreto legislativo regional no 26/2016/M: plano regional de prevenção e controlo de doenças transmitidas por vetores [Regional legislative decree no 26/2016/M regional plan for prevention and control of vector-borne diseases]. Madeira: Secretaria Regional da Saúde, 2016.	Study design not relevant to this review - information for the public.
SRAS. Circular normativa n.º 13/2014: orientações Dengue e Chikungunya [Regulatory circular No 13/2014: Dengue and Chikungunya guidelines]. Madeira: Secretaria Regional da Saúde, 2016.	Surveillance-focused.
SRAS. Cartaz proteja-se do Mosquito Aedes aegypti e evite a sua proliferação [Poster protect yourself from the Aedes aegypti mosquito and prevent its proliferation]. Madeira: Secretaria Regional da Saúde, 2016.	Study design not relevant to this review - information for the public.
SRAS. Cartaz: não mosquito - dê 10 minutos do seu tempo à prevenção (condomínios) [Poster: do not mosquito - give 10 minutes of your time to prevention (condominiums)]. Madeira: Secretaria Regional da Saúde, 2016.	Study design not relevant to this review - information for the public.
SRAS. Zika: o que é? [Zika: what is it?]. Madeira: Secretaria Regional da Saúde, 2016.	Study design not relevant to this review - information for the public.
SRAS. O círus Zika em grávidas [The Zika virus in pregnant women]. Madeira: Secretaria Regional da Saúde, 2016.	Study design not relevant to this review - information for the public.

European Centre for Disease Prevention and Control (ECDC)

Postal address:
Granits väg 8, SE-171 65 Solna, Sweden

Visiting address:
Tomtebodavägen 11A, SE-171 65 Solna, Sweden

Tel. +46 858601000
Fax +46 858601001
www.ecdc.europa.eu

An agency of the European Union
www.europa.eu

Subscribe to our publications
www.ecdc.europa.eu/en/publications

Contact us
publications@ecdc.europa.eu

Follow us on Twitter
@ECDC_EU

Like our Facebook page
www.facebook.com/ECDC.EU

ECDC is committed to ensuring the transparency and independence of its work

In accordance with the Staff Regulations for Officials and Conditions of Employment of Other Servants of the European Union and the ECDC Independence Policy, ECDC staff members shall not, in the performance of their duties, deal with a matter in which, directly or indirectly, they have any personal interest such as to impair their independence. Declarations of interest must be received from any prospective contractor(s) before any contract can be awarded.
www.ecdc.europa.eu/en/aboutus/transparency

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);
- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or
  calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

Publications Office