EUROPEAN CENTRE FOR
DISEASE PREVENTION
AND CONTROL

MEETING REPORT

Consultation on vector-related risk for chikungunya virus transmission in Europe
Paris, 22 October 2007

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1. BACKGROUND

The founding regulation[1] establishing the European Centre for Disease Prevention and Control (ECDC) gives ECDC a mandate to strengthen the capacity of the EU to both prevent and control infectious diseases. After the chikungunya outbreak affecting several countries in the Indian Ocean 2005–2006, ECDC called a first consultation of experts in March 2006 in order to assess the risk of virus transmission in Europe. It was concluded that although the magnitude of the risk could not be precisely determined, there was a risk for chikungunya virus (CHIKV) transmission in Europe.

In the summer of 2007, an outbreak of chikungunya fever occurred in Italy. Considering that this was the first time that local transmission of chikungunya virus occurred on the European mainland, ECDC called a consultation of entomological experts to assess the vector-related risk for CHIKV transmission in Europe.

2. OBJECTIVES OF THE CONSULTATION

The objectives of the consultation were (1) to estimate the risk of extension of *Aedes albopictus* distribution in Europe, (2) to define vector-related determinants for transmission of CHIKV, and (3) to make recommendations for refining vector-related risk mapping.

3. EXPERT PRESENTATIONS AND DISCUSSIONS

An overview of the latest knowledge on vector competence and vector capacity of *Aedes albopictus* was presented. This was followed by presentations discussing the mapping of *Aedes albopictus* establishment in Europe and the environmental determinants for the establishment and spread of *Aedes albopictus*.

3.1. Vector competence of *Aedes albopictus* for chikungunya virus

Vector competence refers to the ability of the vector (in this case *Aedes albopictus)* to acquire, maintain and transmit microbial agents (e.g. CHIKV, dengue). In addition to vector competence, there are several external factors that must come into play for efficient vector-borne disease transmission to take place. These external factors fall under the broader category of 'vectorial capacity' (see section 3.2).

Vector competence can be tested in infection and transmission experiments, with the goal of 1) demonstrating infection in the mosquito following experimental feeding on a viraemic host

[1] Regulation (EC) No 851/2004 of the European Parliament and of the Council.

or virus suspension, and 2) transmitting the virus through either feeding on a vertebrate host or by demonstrating the virus in expressed salivary fluid of the mosquito.

- Susceptibility of *Aedes albopictus* to CHIKV was recently studied for different mosquito populations from southern France, La Réunion and Mayotte: the salivary gland infection rates were recorded at 77%, 96% and 88%[2], respectively. It needs to be noted that the 'infection rate' is not necessarily the same as the 'transmission rate'. The infection rate is based on the presence of the virus in the salivary glands of the mosquito. In contrast to the term 'transmission rate', the term 'infection rate' does not consider possible additional barriers which may prevent or limit the mosquito from transmitting the virus.
- Vertical transmission of CHIKV in *Aedes albopictus*—which means passing viruses from the female vector via her eggs to the next generation—has not been demonstrated before[3]. But new experimental data indicate that vertical transmission of CHIKV in *Aedes albopictus* may occur.
- However, it is unknown whether vectors infected with CHIKV through vertical transmission are able to transmit the virus to humans, as no study on assessing transmission effectiveness could be implemented.
- Although vertical transmission of CHIKV in the vector has been shown in experiments, the survival rate of infected diapausal eggs during the winter and thus the possible contribution to a second wave in spring, following hatching, is not known. Since the outbreak in Italy occurred during midsummer, it is likely that most of the eggs laid by CHIKV-infected females were not genetically programmed for winter diapause, but hatched in autumn. Only a small fraction of the mosquitoes from those eggs could have been CHIKV positive. But mosquitoes infected later in the season (September) could have laid diapaused-programmed eggs possibly infected with CHIKV. Therefore, it is not impossible that CHIKV could survive the winter through this winter diapause mechanism.
- Vector competence varies within different mosquito strains, which might influence data about vector competence on *Aedes albopictus* in Europe. Genetically comparable strains have a similar vector competence.

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[2] Vazeille M, Jeannin C, Martin E, Schaffner F, Failloux AB. Chikungunya: A risk for Mediterranean countries? Acta Trop. 2008 Feb;105(2):200-2.

[3] ECDC. Consultation on Chikungunya risk assessment for Europe: Stockholm, 30 March 2006. Meeting report. Stockholm (Sweden): ECDC; 2007 [cited 2007 Dec 13].
Available from: http://ecdc.europa.eu/documents/pdf/Final_chik_meeting_report.pdf.

3.2. Vector capacity of *Aedes albopictus* for chikungunya virus

In vector-borne infections, such as CHIKV, the vectorial capacity is a concept analogous to the contact rate in directly-transmitted diseases. It is a function of (a) the vector's density in relation to its vertebrate host, (b) the frequency with which the vector takes blood meals on the host (human biting rate), (c) the duration of the virus replication in the vector (duration of virus extrinsic development), and (d) the vector's daily survival rate (expressed in a value between 0 and 1), which reflects the likelihood that a mosquito survives from one day to the next.

- The species' biting preference is mixed anthropophilic (humans), zoophilic (other mammals) and ornithophilic (birds); most common hosts (apart from humans) include domestic animals and birds. However, it is currently not known whether there is virus amplification in these species. It is equally unclear what impact a transmission to humans would have.
- Biting habits of *Aedes albopictus*:
  - La Réunion: mostly daytime and mainly exophilic (outdoors).
  - Italy: also mostly exophilic and daytime biting, although night-time biting and indoor biting have been observed. This is most likely linked to the high density of the vector, which increases anomalous behaviour. There are no data available on the existence of indoor developmental cycles, but even if indoor development exists, it may be considered rare.
  - New data have shown that the extrinsic incubation time (the time from the feeding on a viraemic host until the virus can be transmitted within the vector's saliva to the next host) at 26°C is 3–4 days, which is shorter than the previously assumed duration.
  - Life expectancy (longevity) of *Aedes albopictus* depends on the temperature and can be ≥ 1 month if temperatures of 25°C to 30°C persist for several weeks.
  - Minimal threshold temperature to allow CHIKV replication in *Aedes albopictus* is unknown. CHIKV is a rather resistant virus, and it is assumed that replication continues at even lower temperatures, but also at a lower rate.

3.3. Mapping *Aedes albopictus* establishment in Europe

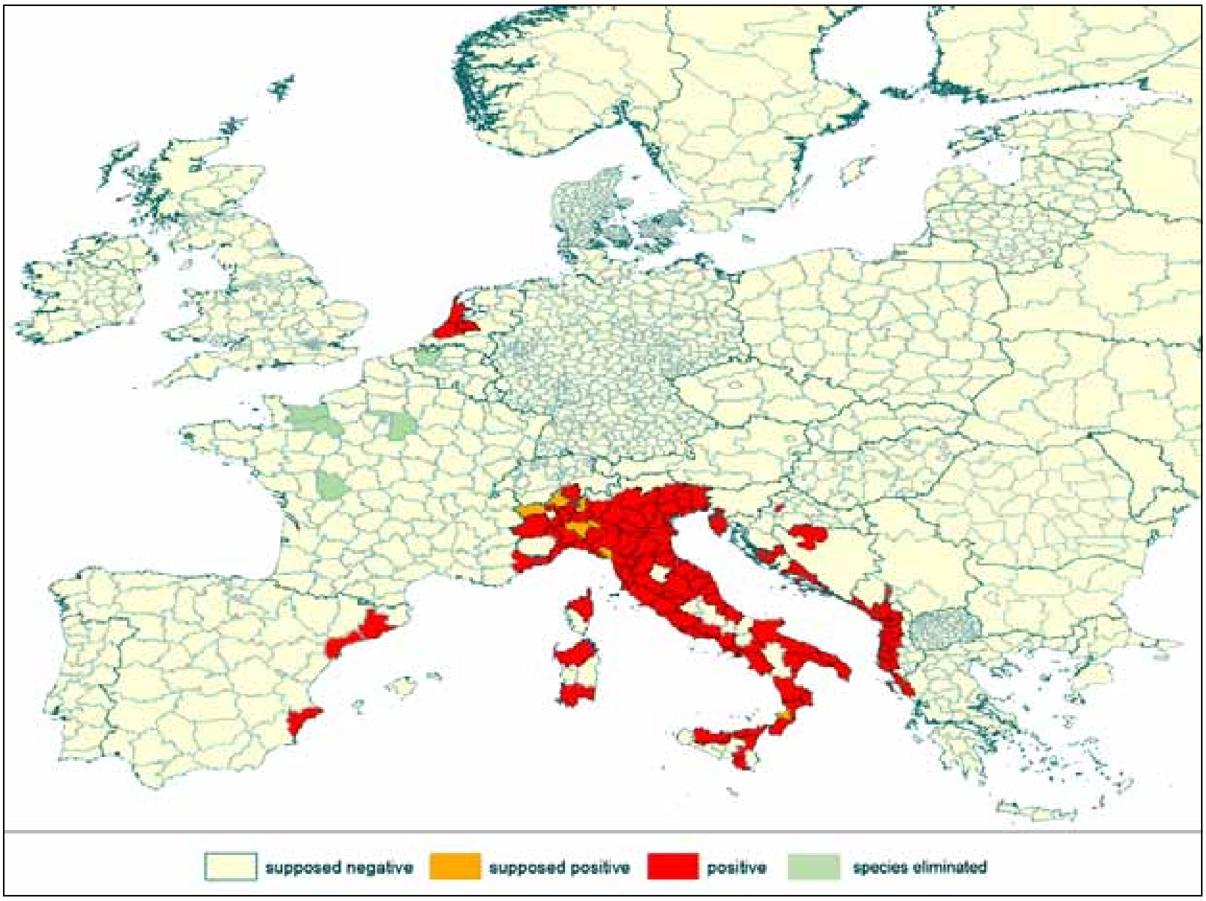

***Figure 1: Presence of* Aedes albopictus *in Europe*[4]**

The currently available map 'Presence of *Aedes albopictus* in Europe' (figure 1) was used as a basis for the discussion of mapping *Aedes albopictus* establishment in Europe. The January 2007 map shows a province-level overview of *Aedes albopictus* establishment, based mainly on surveillance data from specific locations. Vector surveillance in the Member States is predominantly conducted in areas of high risk for *Aedes albopictus* establishment. However, the availability and the quality of the data describing the known presence of *Aedes albopictus* in any particular country in Europe vary. The current map (figure 1) does not, for example, indicate the areas where no surveillance exists.

- The vector *Aedes albopictus* has been introduced in several European countries since 1975. As of 2007, the vector had been observed in Albania, Bosnia and Herzegovina, Croatia, France (Côte d'Azur and Corsica), Greece, Italy, Montenegro, Serbia, Slovenia,

[4] Source: Scholte EJ, Schaffner F. Waiting for the tiger: establishment and spread of the Aedes albopictus mosquito in Europe. In: Takken W, Knols BGJ, editors. Emerging pests and vector-borne disease in Europe. Wageningen: Wageningen Academic Publishers; 2007. p. 241-260.

Spain, Switzerland, and the Netherlands, where *Aedes albopictus* has only been found in greenhouses of companies importing lucky bamboo (*Dracaena sanderiana*). Sporadically, adult mosquitoes have been found in the immediate surroundings of these greenhouses.

- Compared to previous years, the vector has been spreading fast in the Balkan countries, Greece (three foci) and Spain (three spreading foci). In France, five foci were eliminated but since 2005 two areas in Corsica and on the Côte d'Azur have been reporting spreading foci. In Belgium, although identified as having been introduced in 2000, the vector could not establish itself and is now considered eliminated.
- Different surveillance methods are used in Europe including ovitraps, carbon dioxide-baited counterflow traps, CDC (US Centers for Disease Control and Prevention) traps and larval surveys. No European standard is currently available for vector surveillance methods, a fact that may influence data comparability between countries. Furthermore, the density of mosquito eggs in ovitraps does not necessarily reflect precisely the density of the mosquito population in the field, as other ecological factors may play a role. Mosquito eggs in ovitraps only give an indication of the presence or absence of the vector in a certain area.

3.4. Vector-related determinants for *Aedes albopictus* establishment and spread

Main determinants for the establishment of *Aedes albopictus* include cold-month mean temperature, quantity and frequency of precipitation (particularly during summer) and photoperiod. Two maps formed the basis of discussion at the meeting on vector-related determinants for establishment and spread of *Aedes albopictus*. The map 'Areas for possible establishment of *Aedes albopictus* in Europe based on 5 climate scenarios' (figure 2) depicts a combination of the two main environmental factors (mean cold-month temperature and annual rainfall) considered to limit the establishment of *Aedes albopictus* in northerly latitudes.

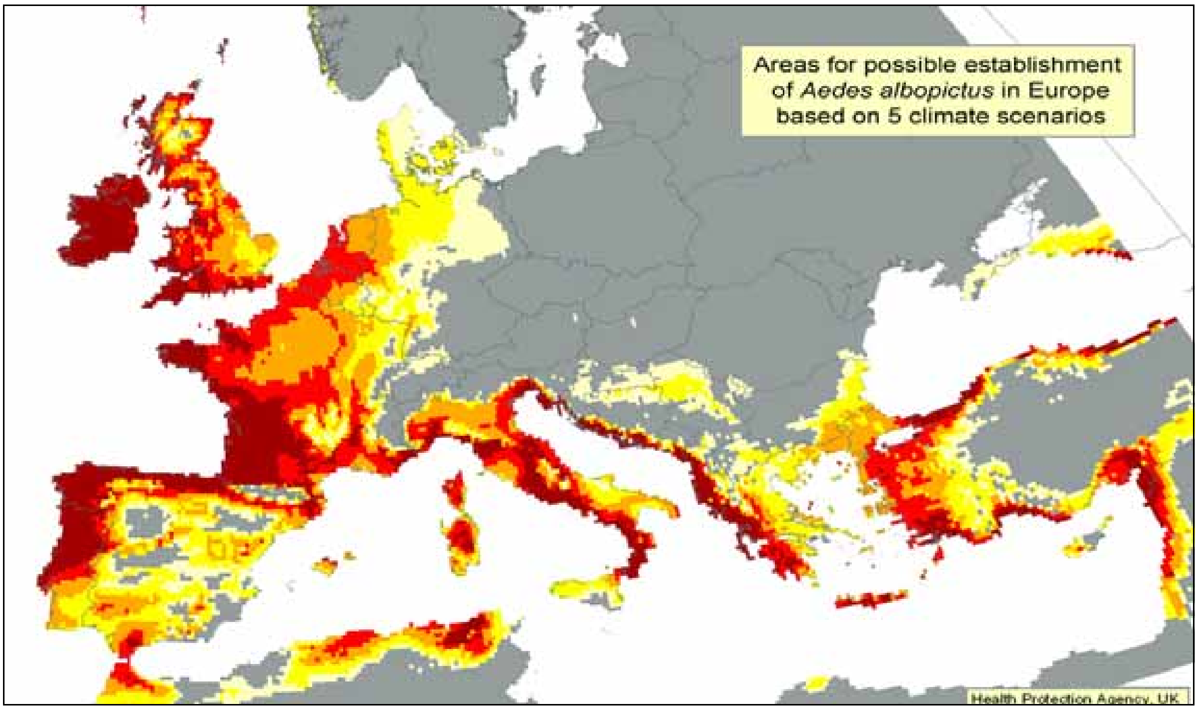

***Figure 2: Areas for possible establishment of* Aedes albopictus *in Europe based on five climate scenarios*[5]**

Scenario 1 (light yellow) = 450 mm annual rainfall, -1°C January isotherm; scenario 2 (yellow) = 500 mm rainfall, 0°C; scenario 3 (orange) = 600 mm, 1°C; scenario 4 (red) = 700 mm, 2°C; scenario 5 (brown) = 800 mm rainfall, 3°C

An additional map 'Possible seasonal activity of *Aedes albopictus* in Europe: weeks between spring hatching and autumn egg diapause' (figure 3) presented the possible number of weeks between egg hatching and the production of diapausing eggs in autumn, which depends on critical climatic conditions and photoperiod. This map assumes that the two establishment criteria for winter isotherm and annual rainfall are 0°C and 500 mm.

[5] Unpublished maps by Medlock JM, Schaffner F, based on:
Medlock JM, Avenell D, Barrass I, Leach S. Analysis of the potential for survival and seasonal activity of Aedes albopictus (Diptera: Culicidae) in the United Kingdom. J Vect Ecol. 2006;31(2):292-304.

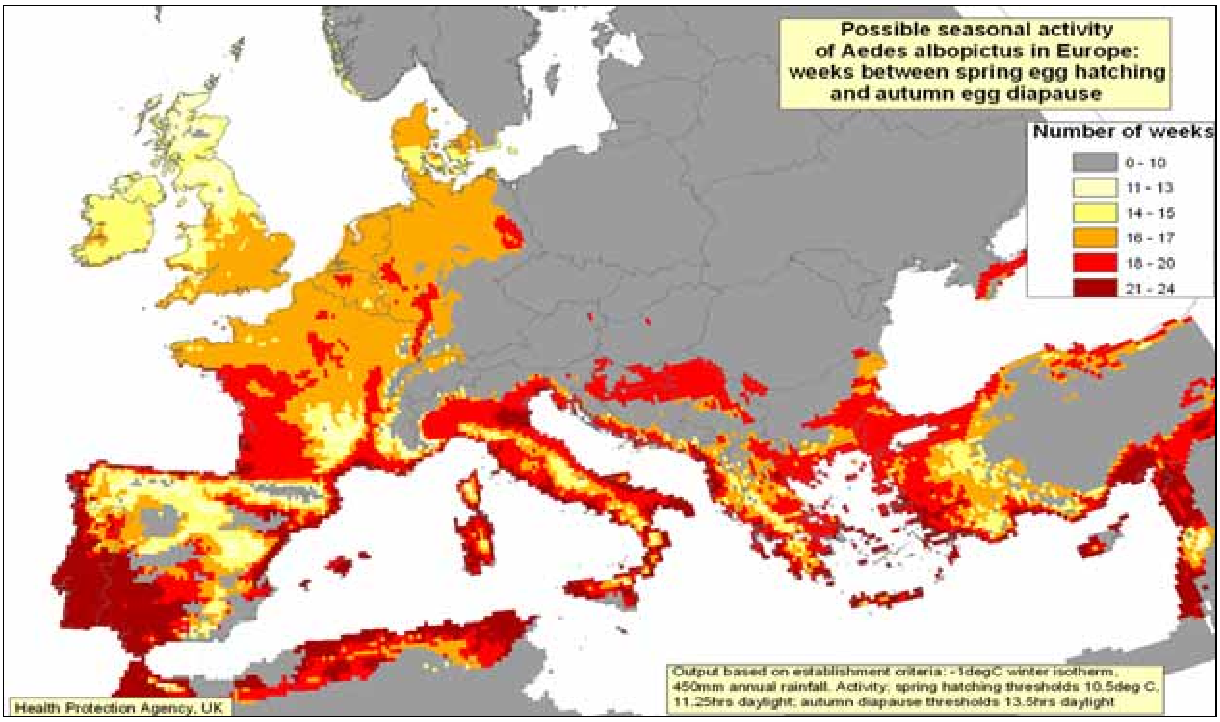

***Figure 3: Possible seasonal activity of* Aedes albopictus *in Europe: weeks between spring hatching and autumn egg diapause*[6]**

Further discussion focused on environmental, seasonal and other relevant vector-related determinants, such as population density, which, as of yet, is not included in current European-wide risk mapping activities as these focus on macro-scale environmental factors.

The use of population data as a surrogate for abundance is a highly complex matter: high-population centres (e.g. tower blocks) do not necessarily correspond to increased breeding sites or an increased number of blood hosts. In order to determine mosquito abundance it is also necessary to consider other blood hosts (e.g. birds and animals). Local scale risk mapping (e.g. by city) was also suggested, but this would require higher spatial and temporal resolution climate data.

Once *Aedes albopictus* is introduced to a specific area, the establishment of the vector seems to depend on four main environmental factors:

1) Minimal winter temperature at which eggs will survive the winter. For mapping the likelihood of establishing the vector in Europe, a 0°C isotherm is considered a conservative threshold, with the lowest threshold reported at -3°C.

[6] Unpublished maps by Medlock JM, Schaffner F, based on:
Medlock JM, Avenell D, Barrass I, Leach S. Analysis of the potential for survival and seasonal activity of Aedes albopictus (Diptera: Culicidae) in the United Kingdom. J Vect Ecol. 2006;31(2):292-304.

2) Sufficient amounts of water to fill appropriate aquatic breeding sites of *Aedes albopictus*. An average annual rainfall of at least 500mm is required.
3) Summer rainfall. A sufficient amount of summer rainfall is necessary in order to maintain vector breeding places during the warm season.
4) Summer temperatures. The speed of development from the immature stage (larvae, pupae) to adult mosquito is optimal when temperatures are between 25°C and 30°C. During summers with mean temperatures of over 25°C, the biological cycle from egg hatching to adult may be completed in 6–7 days. The speed of egg production after the female mosquito's blood meal (gonotrophic cycle) also increases with higher summer temperatures and hence summer temperatures are associated with increased abundance and a higher likelihood of the establishment of the mosquito.

Photoperiod influences the length of activity of *Aedes albopictus*. Therefore, seasonal factors need to be considered in order to improve the risk mapping of *Aedes albopictus* establishment. The map 'Possible seasonal activity of *Aedes albopictus* in Europe: weeks between spring egg hatching and autumn egg diapause' (figure 3) was developed based on data primarily from Italy, but also from Japan, China and North America, applying a model already used for the UK map. Further enhancements would benefit from additional and accurate seasonal activity data from all European foci, preferably with local climate data details. It was suggested that a database could be developed to include field data—collected from unpublished sources—on the subject of seasonal activity of *Aedes albopictus* in several European countries. Utilizing these data, it would become possible to include seasonal activity predictors from across Europe in the enhanced risk maps.

- Human population density is considered to be a contributory factor in the establishment of *Aedes albopictus* because 1) the vector needs a host for its lifecycle, and humans, although not the only hosts, are the preferred blood meal, and because 2) humans also contribute to the number of potential breeding sites. It is unknown which population-size threshold in a given area leads to the establishment of *Aedes albopictus* as this depends on a variety of factors, e.g. the size of a building: high population density in inner city tower blocks does not necessarily mean high abundance. This has an impact on the decisions that need to be made when incorporating human population size in risk maps which cover the establishment and spreading of the vector.
- The presence of *Aedes albopictus* breeding sites is a risk factor for the establishment of the mosquito. In La Réunion, the most common natural breeding sites include bamboo stumps and rock holes. The most common artificial breeding sites include basins, barrels, used tires, buckets and flowerpots. However, suitable breeding sites might differ between European countries.
- *Aedes albopictus* tends to be more frequently present in (sub)urban areas (La Réunion, Italy). Consequently, (sub)urban characteristics are considered to be important in vector-related risk mapping. Quantification of (sub)urban characteristics should be considered a task for the local authorities.

- Competition between different mosquito species influences the likelihood of *Aedes albopictus* establishment. *Aedes albopictus* has been found to displace *Aedes aegypti* in northern America[7].
- A more dynamic model may need to include international cargo and vehicle transportation data (e.g. location and importation data), although such data are difficult to obtain.

4. NEXT STEPS

Based on the discussions outlined above, the group of experts proposed the following next steps.

4.1. Refining vector-related risk mapping to guide vector monitoring activity

It was suggested that a series of maps should be produced to:

- identify the risk of extension of *Aedes albopictus* across Europe;
- guide vector surveillance efforts while monitoring for the introduction and establishment of the vector in different areas.

Mapping the current presence of *Aedes albopictus* in Europe

Production of an updated map showing the current distribution of *Aedes albopictus* in Europe based on vector surveillance data was recommended, as the currently available map, figure 1, is dated January 2007.

Such an updated map should distinguish between areas that have active vector surveillance systems and report positive or negative results, and areas without vector surveillance systems or areas without available data.

While the immediate priority for such mapping should be on *Aedes albopictus*, all experts agreed that activities should be extended to other potential vector species of CHIKV as well; in Madeira, the presence of *Aedes aegypti* is of more concern for the importation and establishment in continental Europe, due to frequent flights between Madeira and the European mainland. It was advised that when maps depict administrative boundaries, they should be accompanied by a textual explanation that differentiates foci from widespread establishment.

[7] Gratz NG. Critical review of the vector status of Aedes albopictus. Med Vet Entomol. 2004;18 (3):215-27.

Mapping the risk of *Aedes albopictus* establishment, if introduced

The panel of experts agreed that the four main climatic factors relevant for mapping the risk of establishment and abundance of *Aedes albopictus* if introduced to an area are: winter temperatures, annual rainfall, summer rainfall and summer temperatures.

Thus, a map based on climatic scenarios was proposed in order to show the establishment risk of the vector. For the best possible result, all four factors need to be studied separately, followed by the identification of the best possible combination of all factors. The map presented in figure 4 uses the following variables: January isotherm, annual rainfall, mean summer temperature (Jun–Aug) and cumulative summer rainfall (Jun–Aug). However, a dynamic model is required, considering the weight of each of the determinants. Better resolution data on a regional or a country scale would significantly improve these maps.

This map could be further enhanced by incorporating the number of weeks of activity, although June–August variables are more important than long periods of activity at slowly increasing spring temperatures.

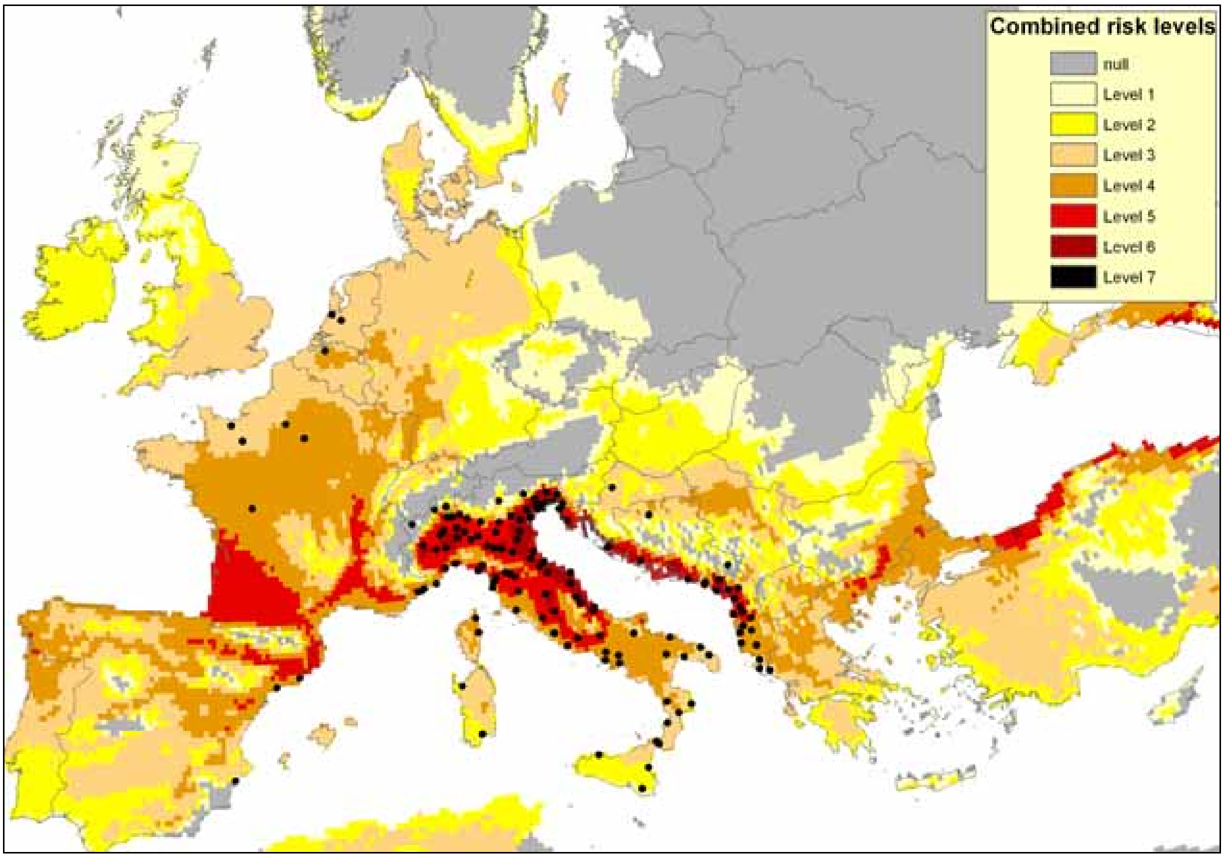

***Figure 4: Combined risk levels for* Aedes albopictus *establishment and abundance*[8]**

[8] Medlock JM. Microbial Risk Assessment: Presentation before ECDC group on Aedes albopictus (Paris, 2007 Oct 22).

Mapping the likely local geographical areas for introduction of *Aedes albopictus*

A third map to be developed should illustrate the possible introduction routes of the mosquito and consequent areas that could be considered at high risk for the introduction of *Aedes albopictus*. This map should be prepared on a national or regional level.

- Active dispersion (mosquito flight): contiguity with an area with *Aedes albopictus*
- Passive dispersion:
  - Importation of goods: used-tire companies or companies importing lucky bamboo are considered risk sites
  - Transport systems allowing connections to infested areas: highways, ferries, through public or private transportation

Mapping local characteristics influencing the implementation of vector monitoring activities

In order to provide guidance for vector monitoring activities at the national and local levels, it is important to map the likelihood for introduction of *Aedes albopictus* based on local-level data (figure 3) and combine this with mapping the risk for establishment (figure 2) of any already-introduced *Aedes albopictus* mosquitoes.

Local characteristics and consequent microclimates should also be considered in their influence on the abundance of *Aedes albopictus*. These characteristics include vegetation, human population density and housing.

4.2. Determinants useful for guiding human case surveillance activities

The experts also agreed on the relevance of a number of vector-related elements which are essential for the surveillance of human cases:

- The risk of creating a sustainable virus transmission chain once the virus is introduced. This depends on climatic data such as seasonal characteristics (temperatures in spring and autumn, etc.), as well as the abundance of the mosquitoes and the duration of the gonotrophic cycle. It was suggested that a database at the European level should be put together, with information on the seasonality of the vector at both the country and the regional levels.
- The risk for importation of the virus through viraemic patients. For this reason, mapping the human population movement from CHIKV-affected areas towards Europe is recommended, including:
  - tourism;
  - military movements; and
  - overseas European territories.

4.3. Vector monitoring methods

Considering the fact that different methods are used for vector surveillance activities, the comparability of the available data was questioned. While all experts agreed that ovitraps are best at detecting the presence or new establishment of *Aedes albopictus,* Member States employ several different methods. Research on defining the most appropriate traps and methods would be useful.

With regard to the monitoring of the vector density (indicating the risk of virus transmission), there is currently no standard procedure in Europe. The relation between the incidence of chikungunya and the mosquito density is not known and needs to be investigated while taking into account the difference between tropical and temperate climates. Experience from assessing the risk for dengue outbreaks could be a useful reference to start with.

In addition, the genetic diversity of *Aedes albopictus* needs to be considered. The main populations present in Europe should be identified, as well as their vector competence and capacity.

5. CONCLUSIONS

While this expert meeting focused on *Aedes albopictus* as a vector for the chikungunya virus—following the first documented autochthonous transmission of the virus in continental Europe—many of the conclusions are also valid for *Aedes aegypti* and for dengue virus.

Aedes albopictus and *Aedes aegypti* are vectors for both chikungunya and dengue fever. Further research is needed into the vector capacity and vector competence for dengue virus of both vectors, but all experts agreed that the possibility of autochthonous transmission of dengue virus in continental Europe should be taken seriously.

ANNEX 1: PARTICIPANT LIST

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Johan Giesecke	ECDC-Scientific Advice Unit, Sweden
Masja Straetemans	ECDC-Scientific Advice Unit, Sweden

ANNEX 2: AGENDA

09:30 – 09:45	Opening remarks: Johan Giesecke
09:45 – 10:00	European risk assessment: Denis Coulombier
10:00 – 11:00	Vectorial capacity and competence for transmitting chikungunya virus: experiences from the 2005–2006 outbreak in the Indian Ocean: Didier Fontenille
11:00 – 11:15	Break
11:15 – 12.00	Establishment, bionomics and behaviours of the tiger mosquito in Italy: Roberto Romi
12:00 – 13:00	Current documented distribution of *Aedes albopictus* in Europe: Francis Schaffner
13:00 – 14:00	Lunch
14:00 – 15:15	Vector-related determinants for enabling chikungunya virus transmission in Europe: Jolyon Medlock
15:15 – 15:30	Break
15:30 – 16:15	Risk for Europe and recommended measures: ECDC
16:15 – 16:30	Conclusions of the meeting and next steps: ECDC