# LIFE CONOPS: Development & demonstration of management plans against -the climate change enhanced- invasive mosquitoes in S. Europe

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## ABSTRACT

Several invasive mosquito species (IMS) have been inadvertently introduced in Europe, where they find favourable environmental and climatic conditions enhanced by Climate Change, to establish permanent populations. In fact, it is estimated that due to the foreseen Climate Change trends, the IMS problem will be more intense in the immediate future. Consequently, new sanitary and environmental risks are faced, including the reappearance of Mosquito Borne Diseases such as Chikungunya, Dengue, and West Nile which are currently emerging in different Member States, requiring the adoption of specific measures. Within the above mentioned framework, the proposed LIFE CONOPS project aims at the development of integrated management plans for the effective and environmental friendly control of the invasive mosquito species spread and establishment across Europe.

*Keywords: Invasive Mosquito Species, climate change, management plans, vector borne diseases*

## INTRODUCTION

Globalization of trade and travel has facilitated the spread and establishment of non-native species across the Earth causing serious environmental, economic and human health problems. It has been estimated that of the over 12,000 alien species that are found in the European environment, 10-15 % have reproduced and spread, causing environmental, economic and social damage. The negative impacts on the ecology of their new location, as well as serious economic and social consequences, are due to the fact that Invasive Alien Species (IAS) can survive, reproduce and spread. According to the regulation of the European Parliament, invasive alien species are species that are initially transported through human action outside of their natural range across ecological barriers [1].

The problem of invasive mosquito species (IMS) is becoming of primary importance on the EU scenario as evidenced by the increasing number of detection in different EU countries and because of the public health risk related to the vector capacity of some of these mosquitoes. These IMS may become a considerable threat to both human and animal health because of vector diseases [2].

Thus, LIFE CONOPS intends to build and implement both in Greece and Italy the capacity of early detection of possible new IMS, in order to prevent their establishment and distribution in the new areas following the adoption of specific IMS integrated management plans [3, 4].

## IMS AND MOSQUITO BORNE DISEASES

Insects are the dominant group among non-native terrestrial invertebrates in Europe reaching at 86% of the established species. Regarding invasive mosquito species (IMS) a considerable increase has been observed within Europe in the last two decades. The Asian tiger mosquito, *Aedes albopictus,* (Figure 1) is one of the most widely established IMS. Other IMS are *Aedes aegypti*, *Aedes japonicus*, *Aedes atropalpus, Aedes* *triseratus* and *Aedes koreicus* [3]. Their preference to breed in container habitats, such as tires, in domestic areas increased the degree of contact between the mosquitoes and humans.

Except their ability to colonise new territories, IMS are also vectors of several mosquito-borne diseases (MBDs). When an IMS is introduced into a new region it may affect human health by the simultaneous or the independent introduction of a novel pathogen or even to play a critical role in an existing disease transmission cycle by a native pathogen [5].

**Figure 1.** *Aedes albopictus.* This mosquito species is also known as "Asian tiger mosquito" because its striped appearance is similar to that of a tiger (photograph by Stihios Serafeim)

For the epidemiology of MBDs, the vector status is important, since all IMS are vectors or potential vectors for a number of MBDs [6]. For example, the Asian tiger mosquito, which is known as a serious nuisance biting species, is capable of transmitting more than 20 arboviruses. Its medical importance in Europe came to light during the recent chikungunya pandemic but this mosquito species is also responsible for other outbreaks in non-European countries, including dengue and yellow fever viruses [7, 8]. Although, the interactions of invasive species vary in time and depend on local conditions, among aforementioned IMS, *Aedes albopictus* and *Aedes aegypti* are the two vectors which are responsible for the emerging of chikungunya and/or the reappearing of dengue fever in Europe [5, 6, 9]. Particularly, *Aedes albopictus*, except the chikungunya fever outbreak in northern Italy, was also responsible for the autochthonous cases of dengue fever in southern France and Croatia. These autochthonous cases were the first reported cases since the last outbreak of dengue fever in Greece in 1927-1928 [9].

## THE IMPACT OF CLIMATE CHANGE

In recent years, concern has arisen over the potential for an increase in mosquito-borne diseases as a consequence of environmental modifications in ecosystems and global climatic change [10]. Warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising of global average sea level [11].

Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850).The temperature increase is widespread over the globe and is greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000m and that the ocean has been taking up over 80% of the heat being added to the climate system. New analyses of balloonborne and satellite measurements of lower- and mid-tropospheric temperature show warming rates similar to those observed in surface temperature [11].

At continental, regional and ocean basin scales, numerous long-term changes in other aspects of climate have also been observed. Trends from 1900 to 2005 have been observed in precipitation amount in many large regions. Over this period, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia whereas precipitation declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Also, some extreme weather events have changed in frequency [11].

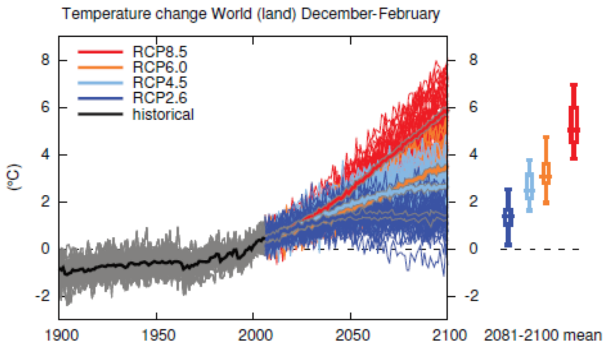


**Figure 2**

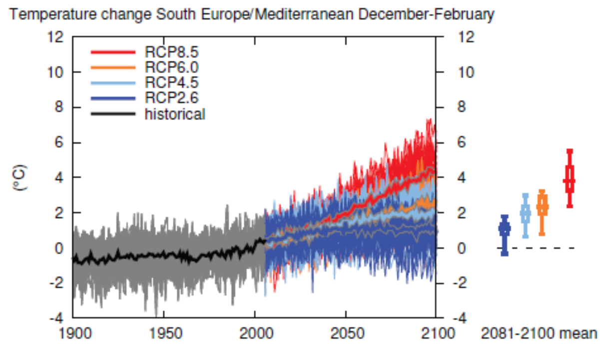


**Figure 3**

**Figures 2-3.** Time series of temperature change relative to 1986–2005 averaged over land grid points over the globe (Figure 2) and in the region South Europe/Mediterranean (30°N to 45°N, 10°W to 40°E) (Figure 3) in December to February. Thin lines denote one ensemble member per model, thick lines the CMIP5 (Coupled Model Intercomparison Project Phase 5) multi-model mean.

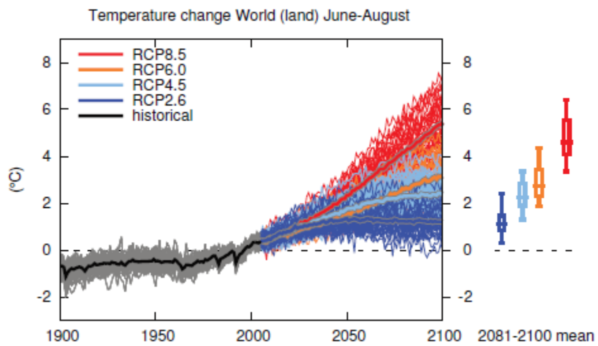


**Figure 4**

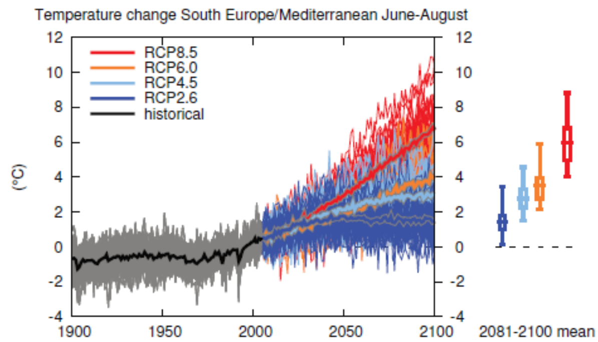


**Figure 5**

**Figures 4-5.** Time series of temperature change relative to 1986–2005 averaged over land grid points over the globe (Figure 4) and in the region South Europe/Mediterranean (30°N to 45°N, 10°W to 40°E) (Figure 5) in June to August. Thin lines denote one ensemble member per model, thick lines the CMIP5 (Coupled Model Intercomparison Project Phase 5) multi-model mean.

From the 5th Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPPC) it becomes clear that the surface temperature on a global scale will most likely continue to rise under all Representative Concentration Pathways (RCPs: four greenhouse gas concentration trajectories adopted by the IPCC for its 5th Assessment Report) for both December to February and June to August periods (Figures 2 and 4). The same is true for the Mediterranean region (Figures 3 and 5). The results for the precipitation show that on a global scale there is a possible increase for both October to March period (Figure 6) and April to September period (Figure 8), however for the Mediterranean region it is likely that there is a slight decrease in mean precipitation for both periods (Figures 7 and 9).

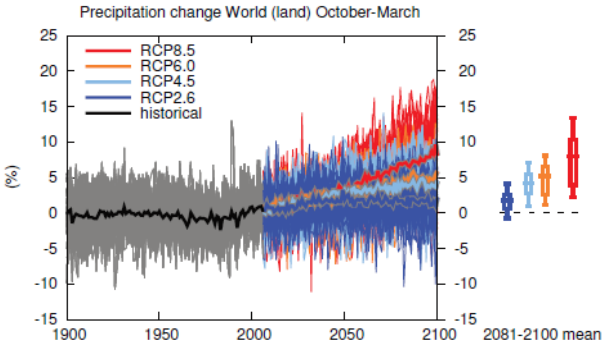


**Figure 6**

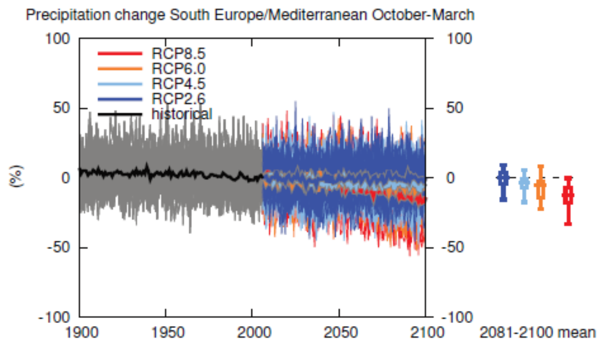


**Figure 7**

**Figures 6-7.** Time series of relative change relative to 1986–2005 in precipitation averaged over land grid points over the globe (Figure 6) and in the region South Europe/Mediterranean (30°N to 45°N, 10°W to 40°E) (Figure 7) in October to March. Thin lines denote one ensemble member per model, thick lines the CMIP5 (Coupled Model Intercomparison Project Phase 5) multi-model mean.

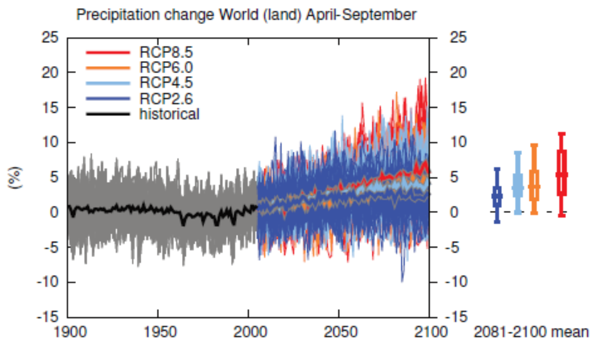


**Figure 8**

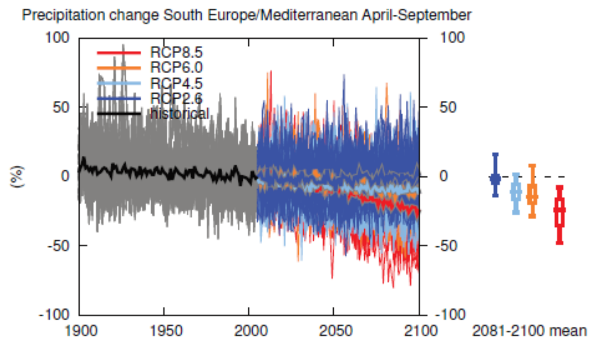


**Figure 9**

**Figure 8-9.** Time series of relative change relative to 1986–2005 in precipitation averaged over land grid points over the globe (Figure 8) and in the region South Europe/Mediterranean (30°N to 45°N, 10°W to 40°E) (Figure 9) in April to September. Thin lines denote one ensemble member per model, thick lines the CMIP5 (Coupled Model Intercomparison Project Phase 5) multi-model mean.

These projected changes have implications for human health around the globe due to changes in vector survival and pathogen development. The predicted changes in climate are likely to extend the distribution of mosquitoes and associated pathogens, in addition to shortening the development time of mosquito larvae and the extrinsic incubation period of pathogens [12].

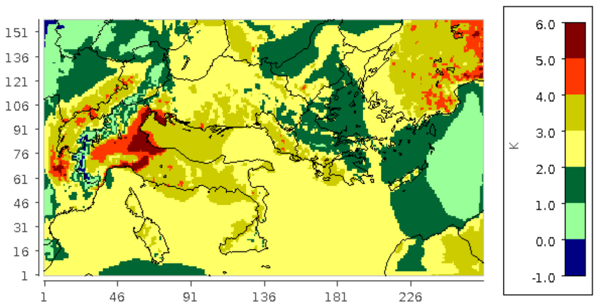


**Figure 10.** Temperature change between January 2009 and January 2059 for the regions of interest

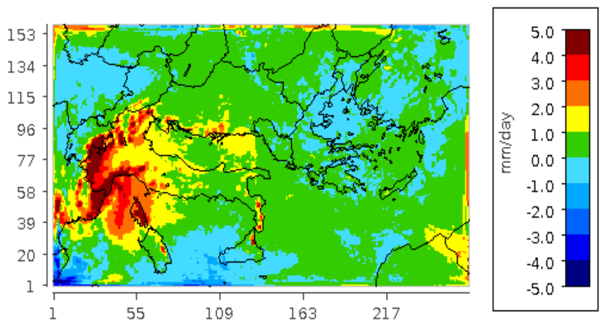


**Figure 11.** Precipitation change between 2009 and 2059 for the regions of interest

The preliminary findings of our project suggest that climate change modifies the meteorological conditions, locally, affecting the establishment and growth of IMS. Specifically, the warmer weather during the coldest month of the year (Figure 10) in combination with the change in the distribution and intensity of rainfalls (Figure 11) benefit the overwintering of IMS and the establishment of permanent populations.

## THE LIFE CONOPS PROJECT

### Phase 1: Preliminary actions

The 1st phase of the project includes the identification of the current situation of the IMS problem. Preliminary data on the distribution and population abundance of IMS will be collected either by an oviposition monitoring system (egg collection) or by human bait method (collection of man-biting adult mosquitoes).

In parallel, climatic and other environmental parameters will be assessed and the results will lead to the identification, listing and geo-reference of areas (in Greece and Italy) with high/medium/low risk of introduction and establishment of IMS [13].

The main environmental/climatic parameters which are related to the suitability of a region for the establishment and seasonal abundance of the IMS based on Caminade et al. [14] and ECDC [3, 13, 15] are:

- Annual precipitation
  The suitability of an area for the establishment of IMS is zero when rainfall is lower than 450 mm and maximum when precipitation is higher than 800 mm
- Coldest month's temperature (critical for eggs' survival during the winter)
  The suitability is zero when temperatures are lower than -1 °C and maximum when temperatures are higher than 3 °C
- Summer temperature
  The suitability is zero when temperatures are lower than 15 °C and higher than 30 °C, and maximum between 20 °C and 25 °C.

Within the areas characterised as of high risk, a finer grid analysis will be performed in order to identify areas or places that are considered ideal for the introduction and establishment of IMS. These areas/ places include:

- Entry gates of passengers and/or products
- Graveyards
- Greenhouses
- Areas of used tires disposal, etc.

The results of this analysis will provide all the necessary information to the project team for the selection of the most representative areas/ places where the pilot monitoring actions will be performed.

Finally, the current situation of the IMS problem will be assessed in terms of socioeconomic impacts with the use of a socioeconomic impact analysis through data collection and stakeholders' engagement through interviews, meetings and workshops.

### Phase 2: Implementation actions

The 2nd phase of the project includes the implementation actions. A novel monitoring device (prototype) will be developed, optimized and pilot implemented at selected high risk areas in Greece and Italy.

The operation of the prototype will be automated and its basic operations will be controlled by an embedded central processing unit (controller) based on pre-defined and scheduled actions. Besides, remote status and health monitoring, operation and re-scheduling of tasks will be supported via the incorporated wireless connectivity and the proper logical interfaces. The provided wireless communications capability among others will allow:

- Remote check of system status
- Receiving alarms, even in the form of texts or emails, when an event occurs
- Setting of the IMS attractant release scheduling
- Checking outside temperature and humidity
- Managing operation faults.

According to the results of the preliminary actions, 5 areas will be selected as Pilot areas for the Pilot monitoring of the prototype device: 3 in Greece and 2 in Italy. In each Pilot area, 2 prototype devices will be installed.

In parallel to the surveillance activities, new, environmentally sound and biodegradable products of natural origin that will be used to control efficiently the mosquito population, diminishing the spread of their corresponding vector diseases, will be developed. The following products will be produced:

- Essential Oils (EOs) from the wastes of orange, lemon and mandarin juicing processes using two methods (hydro-distillation with heating or microwaves). It is estimated to produce 6 EOs from each fruit-waste with 2 different EO production methods x 3 different fruit processing stages, a sum of (3x6=)18 EOs.
- EOs obtained from the leaves, woods and fruits of two Juniperus taxa (J.drupacea and J.phoenicea) using the aforementioned two production methods. Since for each plant the EOs will be obtained from three different vegetative stages, 18 EOs will be produced from each species (2 production methods x 3 parts x 3 vegetative stages), a sum of (2x18=) 36 EOs.

Besides the production phase, detailed assessment of the yield and the chemical composition of each EO will be performed as well as evaluation of their biocide-repellent attributes. Finally, the 2 most suitable EOs (one from each plant-species) will be selected for large scale production and application during the implementation phase of the project.

Additionally, in an effort to investigate the change in the frequency with which IMS find favourable climatic conditions in S.E. Europe and especially Greece and Italy for the establishment of permanent populations in view of a warmer climate, simulation of the current and future climate using the state-of-the-art GISS (Goddard Institute for Space Studies) ModelE global model (GCM) will be performed. Although the outputs of the global climate models (GCM) are very useful, they cannot capture the changes taking place on a regional or local scale since their resolution is relatively coarse. Thus in the framework of the LIFE CONOPS project, in order to increase the spatial resolution of the outputs of the GCM, meteorological fields in a finer grid over the areas of interest will be obtained using dynamical regional downscaling. The purpose of using this methodology is to add-up more detail from local topography, coastline and land uses to obtain high resolution data, with the greatest possible accuracy for the area of interest. This will be performed using the mesoscale meteorological model Weather Research and Forecasting (WRF).

Combining the results from surveillance activities and future climatic projection, integrated management plans of IMS will be designed and pilot implemented in high risk areas. Information and dissemination of the public and the responsible authorities, as well as early detection and elimination methods will reduce the sanitary, environmental and socioeconomic risks caused by IMS.

### Phase 3: Monitoring actions

The pilot implemented management plans will be monitored during the 3$^{rd}$ phase, for the efficiency of their performance in terms of IMS early detection and population control as well as in terms of environmental performance and socioeconomic analysis for the estimation of short-term and long-term benefits.

Aim of the LIFE CONOPS project is to provide European countries with advanced technical equipment as well as decision support tools that have been developed and thoroughly tested in two countries with major IMS problems such as Greece and Italy.

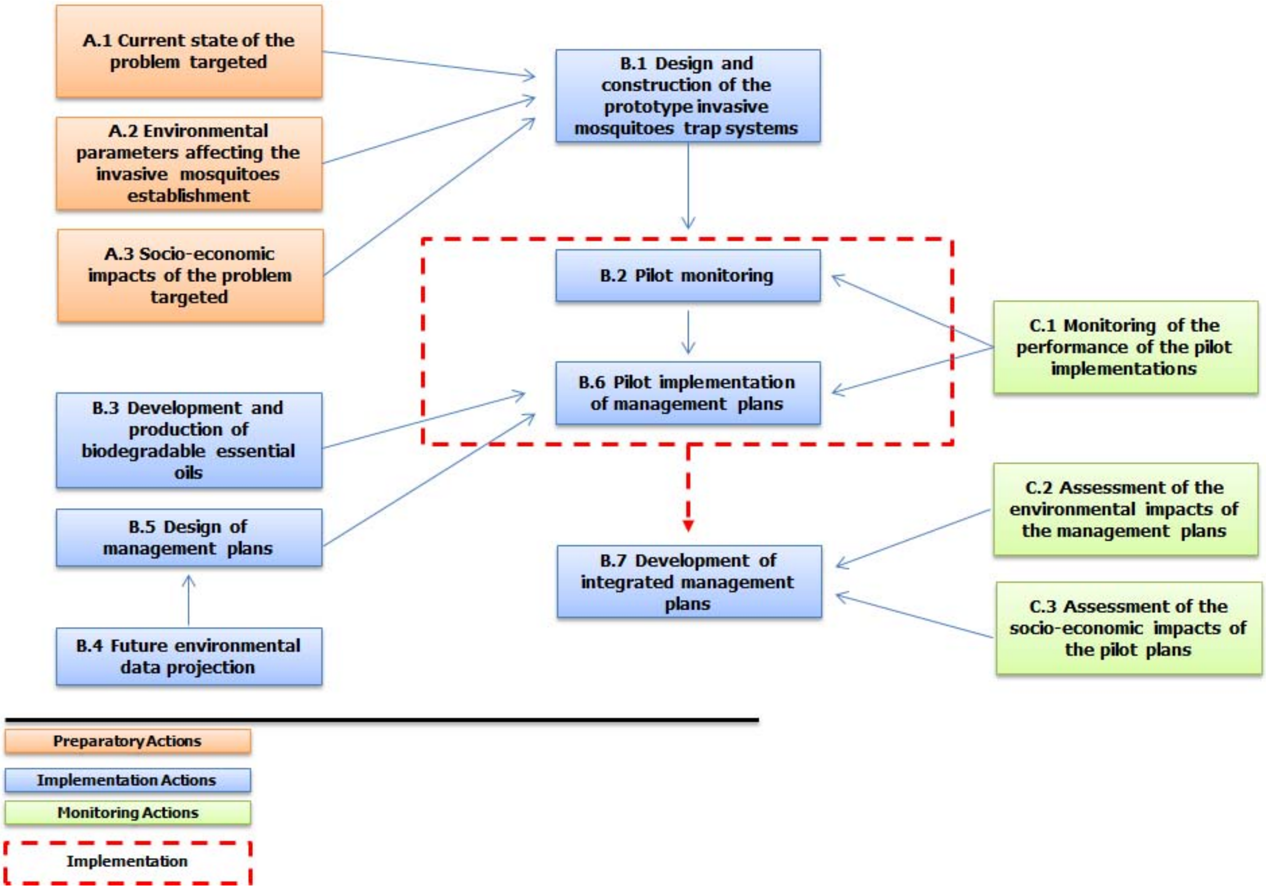


**Figure 12.** Flow chart of LIFE CONOPS' actions

## ACKNOWLEDGMENTS

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## REFERENCES

- [1] Regulation of the European Parliament and of the council on the prevention and management of the introduction and spread of invasive alien species COM(2013) 620 final 2013/0307 (COD)
- [2] LIFE CONOPS Announcement in Bulletin of Insectology 66 (2) 319-320 2013 ISSN 172_8861
- [3] European Centre for Disease Prevention and Control (ECDC) 2012, Technical Report - Guidelines for the surveillance of invasive mosquitoes in Europe
- [4] LIFE CONOPS website www.conops.gr

- [5] Juliano, S. A., & Philip Lounibos, L. (2005). Ecology of invasive mosquitoes: effects on resident species and on human health. Ecology Letters, 8(5), 558-574
- [6] Schaffner, F., Medlock, J. M., & Bortel, W. (2013). Public health significance of invasive mosquitoes in Europe. Clinical Microbiology and Infection.
- [7] Gratz, N. G. (2004). Critical review of the vector status of Aedes albopictus. Medical and veterinary entomology, 18(3), 215-227
- [8] Bonilauri, P., Bellini, R., Calzolari, M., Angelini, R., Venturi, L., Fallacara, F. & Dottori, M. (2008). Chikungunya virus in Aedes albopictus, Italy. Emerging infectious diseases, 14(5), 852
- [9] Medlock J.M., et al. 2012. A Review of the invasive mosquitoes in Europe: Ecology, public health risks, and control options. Vector-Borne and Zoonotic Diseases 12(6): DOI: 10.1089/vbz.2011.0814.
- [10] Tanser FC, et al. 2003. Potential effect of climate change on malaria transmission in Africa. The Lancet, 362: 1792– 1798
- [11] IPCC 2013. The Physical Science Basis, the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change
- [12] McMichael AJ, et al. 2006. Climate change and human health: present and future risks. The Lancet, 367: 859-869
- [13] European Centre for Disease Prevention and Control (ECDC) 2009. Technical Report: Development of Aedes albopictus risk maps.
- [14] Caminade, C., Medlock, J. M., Ducheyne, E., McIntyre, K. M., Leach, S., Baylis, M., & Morse, A. P. (2012). Suitability of European climate for the Asian tiger mosquito Aedes albopictus: recent trends and future scenarios. Journal of The Royal Society Interface, 9(75), 2708-2717.
- [15] European Centre for Disease Prevention and Control (ECDC) 2012. The climatic suitability for dengue transmission in continental Europe, 22 pp.