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Seasonality and timing of peak abundance of *Aedes albopictus* in Europe: Implications to public and animal health

Mina Petrić,[1] Els Ducheyne,[1] Céline M. Gossner,[2] Cedric Marsboom,[1] Gaëlle Nicolas,[1] Roger Venail,[1] Guy Hendrickx,[1] Francis Schaffner[3]

[1]Avia-GIS, Zoersel, Belgium; [2]European Centre for Disease Prevention and Control, Solna, Sweden; [3]Francis Schaffner Consultancy, Riehen, Switzerland

Abstract

Aedes albopictus is a known vector of dengue and chikungunya. Understanding the population dynamics characteristics of vector species is of pivotal importance to optimise surveillance and control activities, to estimate risk for pathogen-transmission, and thus to enhance support of public health decisions. In this paper we used a seasonal activity model to simulate the start (spring hatching) and end (autumn diapause) of the vector season. In parallel, the peak abundance of the species was assessed using both VectorNet field survey data complemented with field studies obtained from literature across the Mediterranean Basin.

Our results suggest that spring hatching of eggs in the current distribution area can start at the beginning of March in southern Europe and in April in western Europe. In northern Europe, where the species is not (yet) present, spring hatching would occur from late April to late May. *Aedes albopictus* can remain active up to 41 weeks in southern Europe whilst the climatic conditions in northern Europe are limiting its potential activity to a maximum of 23 weeks. The peak of egg density is found during summer months from end of July until end of September. During these two months the climatic conditions for species development are optimal, which implies a higher risk for arbovirus transmission by *Ae. albopictus* and occurrence of epidemics.

Correspondence: Guy Hendrickx, Avia-GIS, Risschotlei 33, 2980 Zoersel, Belgium.
E-mail: ghendrickx@avia-gis.com

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See online Appendix for additional materials.

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Introduction

The Asian tiger mosquito *Aedes (Stegomyia) albopictus* (Skuse, 1894) (Diptera: Culicidae) is recognised as an alien invasive arthropod species of major importance (Medlock *et al*., 2015).

Globally, *Ae. albopictus* is considered as a potential vector for a range of pathogens driving vector-borne diseases of public and/or animal health importance (*e.g.* chikungunya, dengue, Japanese encephalitis, Zika, Rift Valley fever and West Nile viruses, as well as *Dirofilaria* filarial nematodes) (Schaffner *et al*., 2013; McKenzie *et al*., 2019). In mainland Europe, the species is considered to be the main vector of dengue and chikungunya viruses. Sporadic events of dengue and chikungunya virus transmissions, but also Zika (Giron *et al*., 2019), have been described since 2007 in Croatia, France, Italy and Spain (ECDC, 2017; ECDC, 2019b; ECDC, 2020a).

Over the last decade, through the VectorNet project, the European Centre for Disease Prevention and Control and the European Food Safety Authority have been collecting presence/absence and abundance data using standardised protocols, either actively through field surveys (ECDC & EFSA, 2018a) or passively *via* literature reviews of scientific reports and peer-reviewed journal articles. One of the outputs is the production of biannual maps of confirmed presence/absence of invasive and native mosquito species, which are published on ECDC website (ECDC, 2020b).

Temperate strains of *Ae. albopictus* have developed reproductive diapausing as a convenient form of phenotypic plasticity, allowing the overwintering of pharate larvae in temperate regions and supporting its invasion of more northern latitudes (Hawley, 1988; Lacour, 2016).

Whilst the presence of *Ae. albopictus* is well documented and closely followed in Europe, the seasonality (start and duration of the season of activity) and abundance of the species is less studied. Understanding these characteristics of population dynamics is of critical importance in order to improve vector monitoring and control operations, to contribute to the assessment of the risk of transmission of pathogens and, thus, to strengthen support for public health decisions. The change in abundance of a species over the year is referred as seasonality, one or more abundance peaks and decline in population size may occur over a single year. These repetitive fluctuations in time are driven by external factors such as seasonal variations in temperature and photoperiodicity.

Local scale field studies (Medlock *et al*., 2006; Roiz *et al*., 2010) provided important insights on the impact of climatic variables and supported the development of local-scale mathematical models (Baldacchino *et al*., 2017). However, a broader-scale analysis of *Ae. albopictus* seasonality is lacking. A first step was made by ECDC (2009) in which a series of continental maps indicating the start of season as determined by egg hatching was presented. Abundance modelling at a continental scale was later carried out by Caminade *et al*. (2012), Erguler *et al*. (2016) and Metelmann *et al*. (2019).

ECDC & EFSA (2018b) highlighted the difficulties of abundance monitoring and their implication to public and/or animal health. Season and seasonality can vary from year to year and be influenced by a variety of environmental and anthropological factors such as climate, vegetation and host availability. The most relevant abiotic variables appear to be temperature, photoperiodicity, and precipitation, for which threshold values have been estimated in a number of surveys in Asia (Nawrocki & Hawley, 1987; Kobayashi *et al*., 2002), the Americas (Nawrocki & Hawley, 1987; Swanson *et al*., 2000) and Europe (Knudsen *et al*., 1996; Toma *et al*., 2003).

The temperature threshold for establishment of *Ae. albopictus* populations is considered to be an annual mean temperature of 11°C (Kobayashi *et al*., 2002). The optimal temperatures at which the population can proliferate are between 15 and 35°C; below these temperatures reduced mobility and longevity are observed (Hylton, 1969; Brady *et al*., 2013). Mean January temperatures and total annual precipitation have been found to limit the winter survival of diapausing eggs in the northern hemisphere, with egg mortality increasing significantly if temperatures are below 0°C (Nawrocki & Hawley, 1987; Kobayashi *et al*., 2002) and precipitation is below 500 mm (Kobayashi *et al*., 2002). In temperate areas, the timing of the production of diapausing eggs in autumn and their subsequent hatching in spring are mainly determined by temperature and photoperiod (Focks *et al*., 1994; Hawley, 1988).

Medlock *et al*. (2006) assumed spring hatching to start when i) spring temperature exceeds 10.5°C; and ii) photoperiod exceeds 11.25 h. Female activity is observed to stop in autumn (diapausing) when temperature goes below 9.5°C and photoperiod below 13.5 h. Assuming an increase in temperature in the short to medium term, climate change is expected to support the development of non-diapausing populations of *Ae. albopictus* in the Mediterranean Basin (Collantes *et al*., 2014). Continuous egg-laying has already been observed in southern Spain and Italy (Collantes *et al*., 2014; Bonacci *et al*., 2015). Lacour (2016) suggests that this adaptive selection is likely directed by the advantage to expand its period of activity but may be also linked to the suppression of a cost of diapause (Scheiner, 1993). All these factors make the exact prediction of the start and end of the activity season of the species over a larger area complex as local small-scale environmental and climate factors could strongly influence its seasonality and peak of abundance.

This main goal of this paper is to present updated seasonality maps of *Ae. albopictus* in Europe: i) the timing and length of the annual peak in abundance; ii) the expected start of spring hatching; iii) and the expected number of active weeks leading to autumn diapause. The aim is to provide information on the main seasonal characteristics for *Ae. albopictus* in order to inform European public health and animal health authorities about the risk of arbovirus transmission and support authorities in their vector control activities.

Materials and methods

Seasonality

The spring and autumn thresholds for weekly photoperiod and temperature governing the seasonality of *Ae. albopictus* were searched in literature, as well as annual precipitation and temperature influencing the climatic suitability for vector overwintering and establishment. The review was carried out using PubMed and Embase. The screening was focused on peer-reviewed research and review papers describing *Ae. albopictus* seasonality and establishment thresholds. The search string for updating the climatic thresholds was run on the 21st of January 2021. Non-primary studies were excluded and only papers in English were included.

Following this, the spatially explicit seasonality model from Medlock *et al*. (2006) was adapted using the threshold values inferred from literature. The mean of the extracted values was retained as the optimal value for the climatic threshold and standard error was calculated to report the uncertainty. Normality was first assessed using the Shapiro-Wilk test (Ghasemi & Zahediasl, 2012), for parameters that did not assume a normal distribution bootstrapping was utilised to calculate the uncertainty. The model was validated on data from the VectorNet database.

First, a suitability mask was generated excluding areas that did not meet the necessary climatic and environmental constraints. The first criterion is based on precipitation, the second on the mean January temperature. The minimal annual precipitation and mean January temperature were derived from the ERA5 Land database (CCCS, 2019). An area was classified as suitable if the rainfall was higher than 422 mm and the mean January isotherm higher than –3.0°C.

Second, within the suitable areas, spring hatching and autumn diapause were determined on a weekly basis. The ERA5 Land (CCCS, 2019), hourly, 2-meter air temperature was used to generate 7-day mean temperatures. The photoperiod was calculated using the meteor R-package (Hijmans, 2019) for every latitude for the last day of the 7-day composite.

The start of spring hatching was then defined as soon as the mean weekly temperature exceeded 10.6°C and the photoperiod exceeded 11.2 hours. Similarly, the start of autumn diapause was defined as soon as the mean weekly temperature was lower than 10.4°C and the photoperiod lower than 13.3 h. The spring hatching and autumn diapause maps were then used to calculate the expected annual activity window.

The model uses a simple conditional statement to capture the week in which the thresholds for spring hatching and autumn diapause are met. The annual activity is calculated as the difference between these two dates. The calculations are run on a 0.1°×0.1° grid. The model was first validated against the current distribution (presence/absence) of *Ae. albopictus* in Europe for 2019 (ECDC, 2019a). This was done using the area under the ROC curve (AUC) score and the True Skill Statistic (TSS). The AUC score ranges in value from 0 to 1, and defines the probability that a randomly chosen positive example will be ranked higher than a randomly chosen negative example. An AUC score >0.5 indicated that the model is performing better than random, while a score of 1 indicates perfect prediction. The TSS statistic ranges from -1 to 1, where 1 indicates perfect agreements and values less than 0 indicate a performance no better than random. Both the AUC score and the TSS statistic have been shown to be independent of prevalence (Allouche *et al*., 2006). In a second step, the dates generated by the seasonal activity model were compared against longitudinal VectorNet field data collected from 5 locations in Greece in 2017. Validation was not performed for the year 2020 because ERA5 temperature data is updated monthly with a delay of approximately 3 months relative to the current date (CCCS, 2019), and would thus prevent a full record for 2020.

Abundance

Over the last decade several population models have been created for *Ae. albopictus* for the USA (Erickson *et al*., 2010) and for Europe (Poletti *et al*., 2011; Caminade *et al*., 2012; Tran *et al*., 2013; Erguler *et al*., 2016; Baldacchino *et al*., 2017; Metelmann *et al*., 2019; Wint *et al*., 2020), with some having explicit references to environmental conditions (Erguler *et al*., 2016). All models focused on local abundance levels with the exception of Erguler *et al*. (2016) which tried to extrapolate the method developed to Europe, but the output represents an index of mosquito habitat suitability instead of abundance.

Given the lack of data that might be used in a pan-European model, field studies reported in literature were examined to obtain local seasonality and abundance profiles to complement data collected under VectorNet. The time series representing the egg density *versus* the week were analysed for the reported literature using the metagear v0.4 package (Lajeunesse, 2016). The significant peaks were identified using the pracma v2.1.4 package (Borchers, 2019).

Results

Climatic thresholds

In total 59 full text papers were screened, of which 31 were retained. The results indicated that thresholds both for overwintering as well as spring hatching and autumn diapausing as defined by Medlock *et al*. (2006) should be adjusted. In total 133 values were extracted for: mean January temperature (14); total annual precipitation (13); mean weekly temperature (6) and photoperiod (5) conducive to spring hatching; and mean weekly temperature (4) and photoperiod (91) conducive to autumn diapause. The updated threshold estimates are presented in Table 1. Please see the supplementary material (S1) for a more detailed overview of the literature review.

In Asia, overwintering of diapausing eggs occurs where mean January temperatures are lower than –2°C (Kobayashi *et al*., 2002) or even –3°C and –4°C (Nawrocki & Hawley, 1987; Wu *et al*., 2011). In Europe Waldock *et al* (2013) suggested to use a –4°C isotherm, while in the USA a threshold of –5°C was suggested (Khan *et al*., 2020). Tippelt *et al*. (2020) specify that the vector is capable of overwintering at temperatures <2°C in Europe.

Even though the cut-off for total annual precipitation of 500 mm was previously reported for Europe (Knudsen *et al*., 1996; Medlock *et al*., 2006), Proestos *et al*. (2015) suggested that a lower threshold should be used for *Ae. albopictus,* since it has been consistently confirmed to be established in areas with <500 mm annual precipitation (Eritja *et al*., 2005; Waldock *et al*., 2013).

No studies reported spring hatching at temperatures <10°C. Spring hatching was reported to occur with weekly temperatures between 10°C to 15°C and photoperiods between 11 h and 12 h (Medlock *et al*., 2006; Romi *et al*., 2006; Takumi *et al*., 2009; Gatt *et al*., 2010; Mogi & Tuno, 2014; Flacio *et al*., 2016). Autumn conditions triggering diapause were reported to occur when weekly temperatures go below 12.5°C to as low as 9°C, and photoperiods from 14 h to 11.2 h (Focks *et al*., 1994; Toma

Table 1. Climatic thresholds governing the overwintering, establishment, spring hatching and autumn diapause of *Aedes albopictus.*

	Climatic parameter	Value	Literature
1	Mean January temperature limiting overwintering	–3.0±0.46 [°C]	(Nawrocki & Hawley, 1987; Kobayashi *et al*., 2002; Medlock *et al*., 2006; Wu *et al*., 2011; Neteler *et al*., 2013; Waldock *et al*., 2013; Ogden *et al*., 2014; Proestos *et al*., 2015; Kuhlisch *et al*., 2018; Petri *et al*., 2018; Khan *et al*., 2020; Tippelt *et al*., 2020)
2	Total annual precipitation limiting establishment	422±32 [mm]	(Knudsen *et al*., 1996; Eritja *et al*., 2005; Medlock *et al*., 2006; Takumi *et al*., 2009; Roiz *et al*., 2011; Neteler *et al*., 2013; Waldock *et al*., 2013; Ogden *et al*., 2014; Proestos *et al*., 2015; Cunze *et al*., 2016; Kuhlisch *et al*., 2018; Sherpa *et al*., 2019; Khan *et al*., 2020)
3	Critical temperature for spring hatching	10.6±0.36 [°C]	(Medlock *et al*., 2006; Romi *et al*., 2006; Takumi *et al*., 2009; Gatt *et al*., 2010; Mogi & Tuno, 2014; Flacio *et al*., 2016; Komagata *et al*., 2017)
4	Critical photoperiod for spring hatching	11.2±0.24 [h]	(Medlock *et al*., 2006; Romi *et al*., 2006; Takumi *et al*., 2009; Gatt *et al*., 2010; Flacio *et al*., 2016)
5	Critical temperature for autumn diapause	10.4±0.65 [°C]	(Medlock *et al*., 2006; Takumi *et al*., 2009; Mogi & Tuno, 2014; Pasquali *et al*., 2020)
6	Critical photoperiod for autumn diapause	13.3±0.06 [h]	(Focks *et al*., 1994; Toma *et al*., 2003; Medlock *et al*., 2006; Lacour *et al*., 2015; Tsunoda *et al*., 2015; Armbruster, 2016; Erguler *et al*., 2016; Xia *et al*., 2018; Pasquali *et al*., 2020)

et al., 2003; Medlock *et al*., 2006; Takumi *et al*., 2009; Lacour *et al*., 2015; Tsunoda *et al*., 2015; Armbruster, 2016; Erguler *et al*., 2016; Xia *et al*., 2018; Pasquali *et al*., 2020).

Seasonality

The start of the spring hatching of eggs for 2019 (Figure 1) shows a very clear gradient from south to north. Around the Mediterranean Basin, spring hatching is expected to occur as early as week 8, corresponding to late February. More northwards, in most of Western Europe, hatching is expected to occur six to eight weeks later, from early to mid-April.

In areas where the species is currently not observed (Figure 2), such as in Scandinavia and Scotland for example, spring hatching could potentially occur in week 16-25 if *Ae. albopictus* was to establish itself there.

Some areas in *e.g*. Spain and Italy do not have any spring hatching week predicted, because of insufficient rainfall. However, this can be compensated by human-generated water, which is not included in the model. Looking at the potential weeks of activity (Figure 3), we see that the longest period of activity can be found in the Mediterranean Basin going from 39 to 43 weeks.

This means that in this region, the season can potentially start from end of February and run until mid-November, yielding four to six generations within a single vector season (Kobayashi *et al*., 2002). At higher altitude and where the species is not yet present, the number of potential weeks of activity could potentially reach 23 weeks.

The performance of the model in reproducing the observed distribution of *Ae. albopictus* in Europe for 2019 (Figure 2) was validated with an AUC score of 0.89 (P<0.0001) and TSS statistic of 0.68, indicating good performance. The observed end-of-activity in Greece in 2017 was in week 44, showing fairly good correspondence with the simulated onset of diapause (week 43).

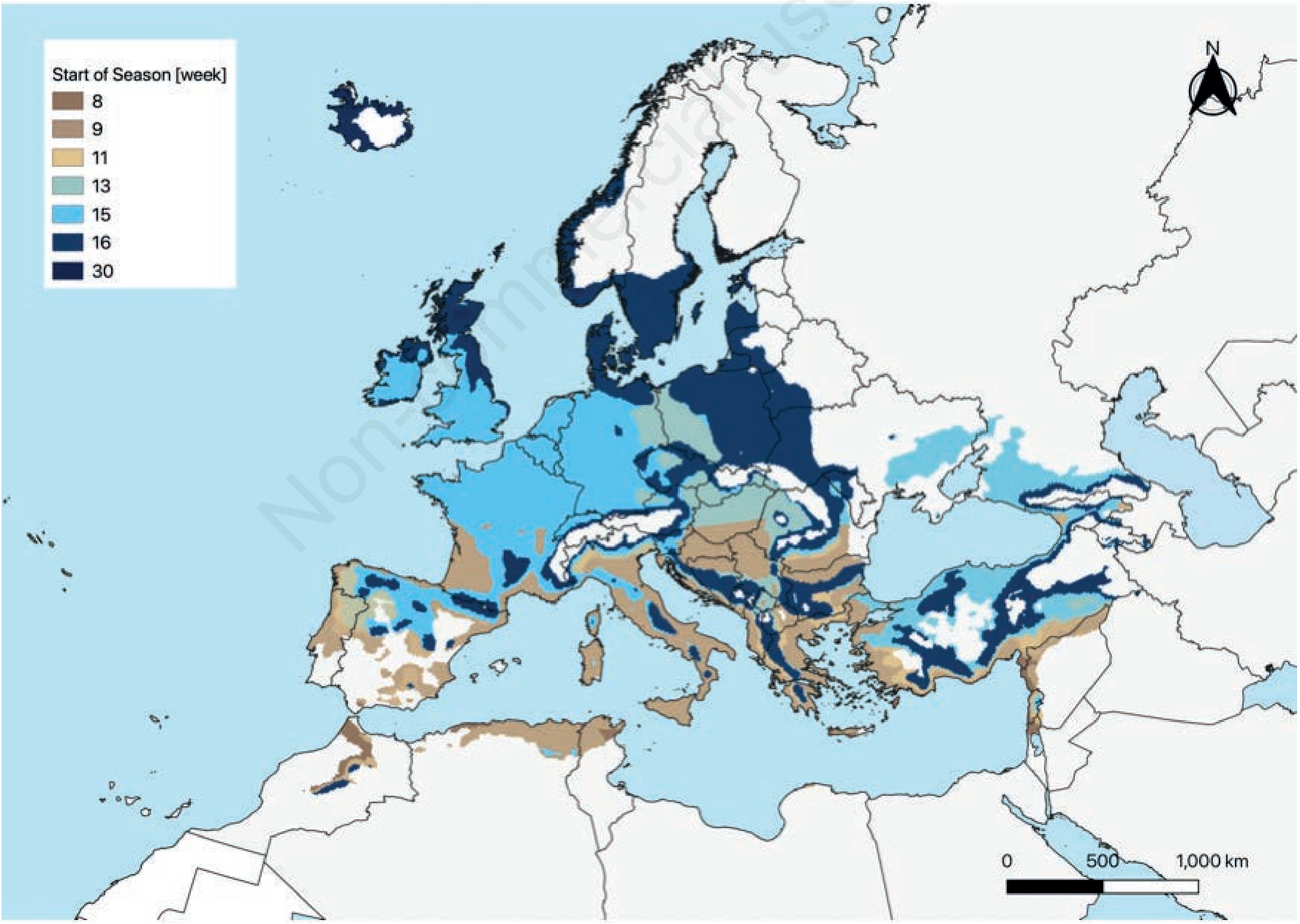


Figure 1. Potential mean week of start of spring hatching of *Aedes albopictus* for the VectorNet area for 2019, with first adults appearing ca. 2-4 weeks later. Colours show the range of activity start, from early (dark brown) to late (dark blue) start. White areas are the masks from temperature and precipitation. Country boundaries are downloaded from Natural Earth. Free vector and raster map data @naturalearthdata.com.

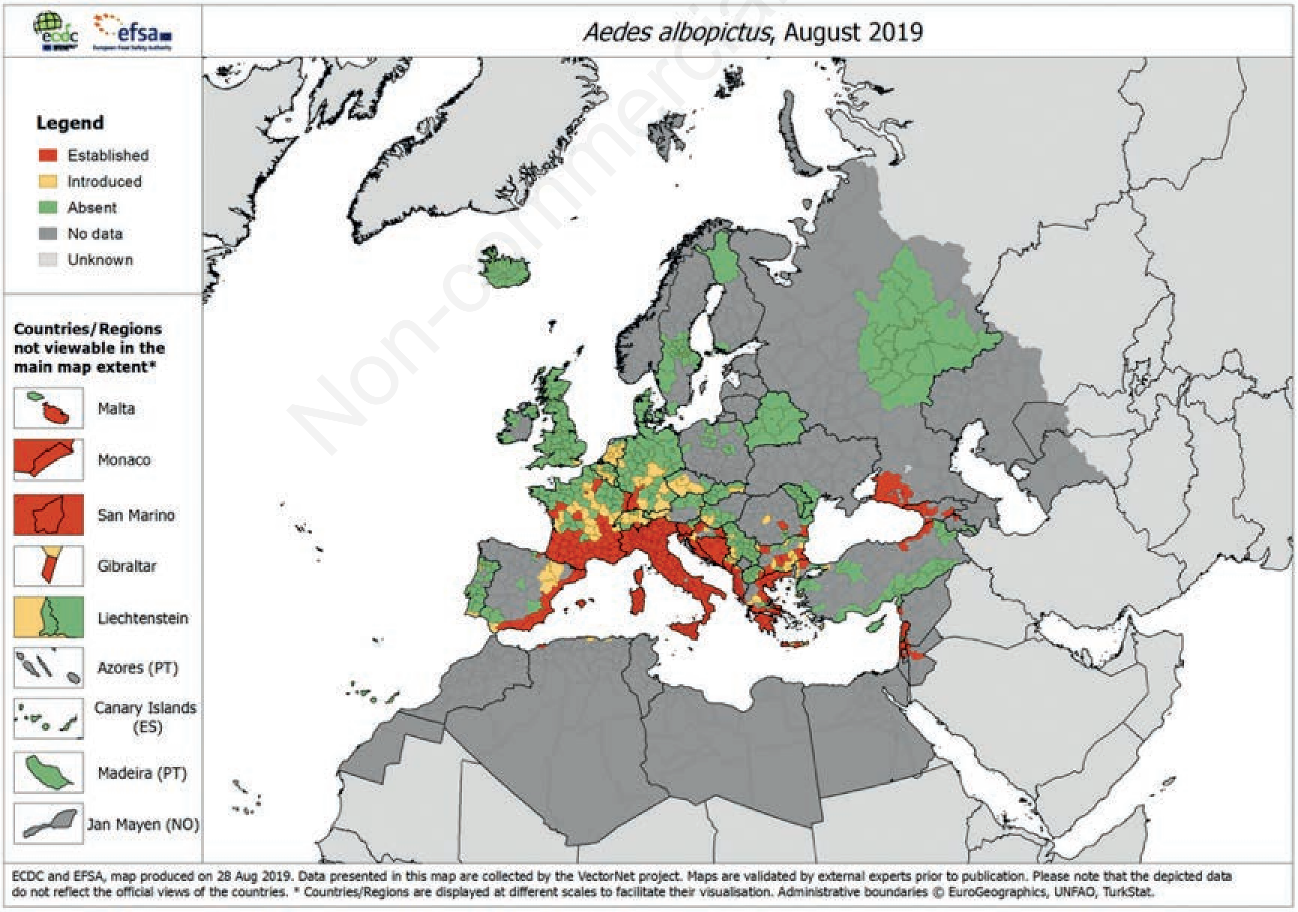
Peak of abundance

Observed egg peak timing, with week number if this was reported, and the size of the peak are shown in Table 2. In general, the peak of abundance is reached over summer, but the actual timing when the peak is reached varies spatially and temporally according to the prevailing eco-climatic variables. In southern Europe, the abundance curve of the species increases rapidly from end of June and will decrease by November in a unimodal situation. The seasonal dynamic patterns analysed by Manica *et al*. (2016) and resulting from field survey outputs of VectorNet in Italy showed, however, a bimodal pattern (with a peak of abundance in August and another one in October) which is consistent with field observations in the city of Rome. The first peak was temperature-driven whilst an unusual amount of rainfall in September seems to be a major driver of the second peak in mid-October. When temperatures and photoperiod became sub-optimal for the species, a rapid decrease of the abundance was found despite frequent rainfall. A bimodal seasonal dynamic pattern with host-seeking mosquito abundance would prolong the potential transmission season in suburban areas.

Discussion

The main aims of this study were to present updated maps capturing the seasonality of *Ae. albopictus* in Europe. The results indicate that the total number of weeks between spring hatching and autumn diapause is expected to be over 34 weeks around the Mediterranean Basin, from 12 to 28 weeks in the UK, and would be 12 to 23 weeks in northern Europe if the mosquito was to be established there.

The biggest difference with the continent-wide analysis performed by ECDC (2009) is the inclusion of areas which were previously deemed as unsuitable for establishment such as Germany, Switzerland, Austria and parts of Eastern and Northern Europe. In their study for the UK, Medlock *et al*. (2006) calculated the maximum number of weeks of activity to be 24 weeks, corresponding to the southern country border, and no activity for the area along the border with Scotland. This important difference might be due to a combination of the update of the thresholds, inter-annual temperature differences and increase of temperature compared to the 1971-2000 period (Kendon *et al*., 2020), affecting the start and end of the season. Medlock *et al*. (2006) did not provide an output for their model at the more



ECDC and EFSA, map produced on 28 Aug 2019. Data presented in this map are collected by the VectorNet project. Maps are validated by external experts prior to publication. Please note that the depicted data do not reflect the official views of the countries. * Countries/Regions are displayed at different scales to facilitate their visualisation. Administrative boundaries © EuroGeographics, UNFAO, TurkStat.

Figure 2. Current known distribution of *Aedes albopictus* in Europe by 2019 (ECDC, 2019a). Source: ECDC.

Table 2. **Timing and size of expected *Aedes albopictus* egg abundance peak by country.**

Country	Egg peak timing (week number)	Size of peak	Reference
Croatia	End of July/Early August (w 30-31) Early September (w 34-35)	Major Major	(Žitko & Merdić, 2014)
Greece	September (w 35-40) November (w 48)	Major Minor	(Giatropoulos *et al*., 2012)
Italy			
Central (Lazio)	End of August (w 35) October/November (w 44)	Major Minor	(Manica *et al*., 2016; Toma *et al*., 2003)
South (Calabria)	Mid-July August Mid-September	Major Minor Major	(Bonacci *et al*., 2015)
South (Sicily)	End-July/Early August Late August Mid-September	Minor Major Major	VectorNet database
France (south)	Late June-early July (w 27) End of August (w 33)	Major Major	(Lacour *et al*., 2015; Tran *et al*., 2013)
Switzerland (south)	Mid-August (w 34-35)	Major	(Flacio *et al*., 2016; Suter *et al*., 2016)
Spain			
North East (Catalonia)	July-early September (w 29-37)	Major	(Collantes *et al*., 2015)
South East (Murcia)	Late August-October (w 35-43)	Major	(Collantes *et al*., 2015)
Balearic Island of Majorca	Early September-October (w 37-43)	Major	(Collantes *et al*., 2015)

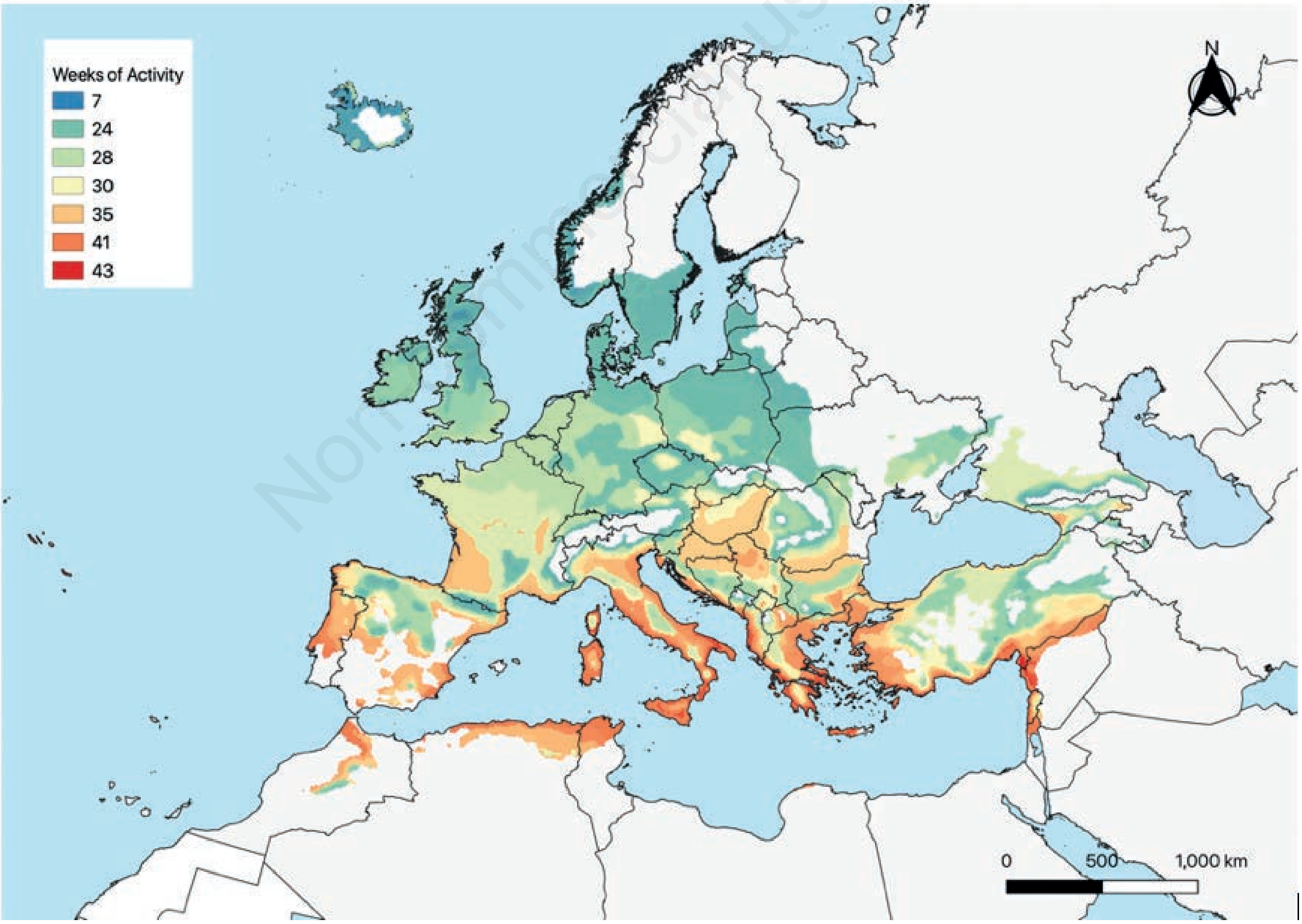


Figure 3. Mean number of weeks during which *Aedes albopictus* can remain active in the VectorNet area for 2019, obtained after subtracting the modelled end of activity with the modelled start of activity. Colours show the range of activity period, from long (red) to short period (blue). White areas are the masks from temperature and precipitation. Country boundaries are downloaded from Natural Earth. Free vector and raster map data @naturalearthdata.com

northern latitudes because of the constraint imposed by the mean January isotherm limit.

The spring hatching map can be considered as the first indicator of starting of the vector season. However, this is still different from the emergence of the first adults. The development from larvae L1 to adult during an optimal season with temperatures between 25-30°C is about 8-10 days (Gomes *et al*., 1995). A laboratory study with *Ae. albopictus* from La Réunion, France, showed that at these temperatures the mean generation time (the average period between two generations in a population) is about 24-30 days, whilst at a constant temperature of 15°C, the mean generation time is about 43 days and the development of larvae (L1) until adults is about 35 days (Delatte *et al*., 2009). At 20°C, the development from L1 larvae until adults is estimated to last 14 days (Delatte *et al*., 2009).

As the species breeds in small containers (Stefopoulou *et al*., 2018), the water temperature can quickly reach high values, even if the air temperature is lower (Kumar *et al*., 2018). During spring, the temperature conditions often allow a complete development from egg to adult in 2-3 weeks; however, clear field information on the mean duration of a generation time is still missing.

Knowing the timing and size of peak abundance of a vector species, and the factors influencing it, will help decision-makers to guide surveillance and control activities in cost-efficient and effective way. In recent years studies have been performed on seasonal dynamic models at a local scale especially in France (Tran *et al*., 2013) and Italy (Poletti *et al*., 2011; Erguler *et al*., 2016; Manica *et al*., 2016).

The seasonal abundance patterns predicted by these local-scale dynamic models as well as those collected from the reported field studies are also supported by the work done by Liu-Helmersson *et al*. (2016) on climate change and dengue virus transmission in Europe. The authors identified seasonal windows of transmission based on the potential vectorial capacity the species has or would have in Europe. Their results show that in several south-European countries, climatic conditions under current climate change scenarios would favour *Ae. albopictus* populations, increase their vectorial capacity and allow local dengue virus transmission. The potential for sustained transmission in southern European cities was confirmed by the study of Guzzetta *et al*. (2016b) for Zika virus.

We observe a good correspondence between the identified abundance peaks and the occurrence of vector-borne disease in the EU (ECDC, 2019c; ECDC, 2020a). The occurrences of dengue and chikungunya in France, with the highest number of autochthonous cases, were reported from July to September (Succo *et al*., 2016, 2018; Franke *et al*., 2019). This corresponds well to the two identified peaks in weeks 27 and week 33. In Italy, two significant chikungunya outbreaks were reported in 2007 (July-September) and 2017 (August-November) (Angelini *et al*., 2007; Rezza *et al*., 2007; Venturi *et al*., 2017; Lindh *et al*., 2019), coinciding with the major peaks in vector abundance identified between July and November.

Whilst the seasonality of *Ae. albopictus* can be determined on a European scale, predicting the peak abundance of *Ae. albopictus* at the same scale is challenging. Populations are highly variable across areas and are depending on eco-climatic factors such as local temperature patterns (influencing their life cycle) and the amount and quality of the breeding and resting sites. In turn, the availability of these breeding and resting sites will depend on a high number of factors such as precipitation and proximity to water bodies (Dieng *et al*., 2012), vegetation and land cover (Vanwambeke *et al*., 2007; Ferraguti *et al*., 2016; Steiger *et al*., 2016), artificial watering and the presence of artificial containers (Guzzetta *et al*., 2016a).

One of the major issues for an European scale peak abundance models is that micro-environmental conditions in potential habitats are currently not measured in a standardised way and that there is no direct link from the field matching laboratory conditions. The microclima R-package developed by Maclean *et al*. (2018) provides a possible solution to bridge part of this gap by providing fine-scale estimates of near-ground temperature, however, its scalability to different eco-climatic settings still needs to be validated (Maclean *et al*., 2018). It is also essential to further study the link between the observed egg/larval stages numbers and female numbers throughout the season such as the study conducted by Manica *et al*. (2017). Finally, detailed and pivotal data on key life-history traits, such as survival and development, are only available from laboratory experiments but parameters derived solely from such datasets cannot be extrapolated to larger areas (Erguler *et al*., 2020). Research networks such as VectorBite (Shocket *et al*., 2019) try to collate these life traits, but currently these databases are still in the setup phase and cannot be used as such.

Conclusions

The presence of *Ae. albopictus* in several regions of Europe poses many challenges for the public health authorities and to lesser extent to animal health authorities. At the fringe of its current, yet still expanding, distribution the vector population needs to be controlled as soon as it is detected in a new area to reduce the likelihood of establishment. To achieve this, knowing when vector surveillance should be performed is essential. In contrast, in areas permanently colonised by *Ae. albopictus,* it is crucial to identify potential spatial and temporal hot spots of abundance in order to prioritise mosquito control interventions.

Within VectorNet, data from literature and field surveys are collected to define vector presence/absence. This provided input for the bi-annual update of the *Ae. albopictus* distribution maps published online by ECDC. Additionally, abundance data were collected across Europe and within different eco-climatic zones using standardised protocols to feed spatial models and produce updated abundance maps. Risk assessments, which include these abundance data, should focus on the local scale rather than at continental scale because the abundance curve is determined by the local prevailing eco-climatic conditions.

While this paper focused on the egg seasonality and abundance, it is necessary to further promote fundamental and applied research on vectorial capacity and genetic profile of a population and to study the link between the observed egg/larval stages numbers and female numbers to further strengthen initial experiments.

A better knowledge of *Ae. albopictus* seasonality and abundance can then support public health authorities in their surveillance of arboviruses and their outbreak response activities.

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