

# Effects of Thermal Heterogeneity and Egg Mortality on Differences in the Population Dynamics of *Aedes aegypti* (Diptera: Culicidae) Over Short Distances in Temperate Argentina

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**ABSTRACT** In temperate regions, the seasonal dynamics of *Aedes aegypti* (L.) (Diptera: Culicidae) is mainly influenced by temperature, whereas the probability of local extinction depends on the egg mortality during the cold season. The aim of the current study was to assess the importance of temperature and egg mortality in determining the differences in the oviposition dynamics of *Ae. aegypti* between favorable and less favorable areas in Buenos Aires City (Argentina). Year-round temperature dynamics were monitored, and oviposition dynamics were experimentally studied with ovitraps at two sites. Daily egg mortality values were calculated from a previous study performed at the same sites. The relative contribution of the differences in temperature and egg mortality between sites to the oviposition dynamics was assessed by means of a mathematical stochastic population dynamics model for *Ae. aegypti*. The results showed higher temperature and lower daily egg mortality at the site where higher oviposition activity was recorded. A larger influence of temperature than of egg mortality on population abundance during most of the activity season was detected in the results of the simulations. Our results showed a temperature gradient that relates to the distance to the Río de la Plata river and contributes to explaining the spatial heterogeneity in *Ae. aegypti* population abundances previously reported. The hypothesis of local extinctions because of egg mortality during the winter was not supported by the present analysis. The differences between field oviposition dynamics and simulation results suggest that rainfall might also be an important variable under extremely dry conditions.

**KEY WORDS** spatial distribution, oviposition, seasonal dynamics, temperate region, stochastic model

*Aedes aegypti* (L.) is widely distributed in urban areas across tropical and temperate regions of the planet. The epidemiological importance of this mosquito species has increased recently because it is the main vector of dengue virus in the Americas, where the number of cases and range of distribution of this disease increases yearly (Spiegel et al. 2005). In Argentina, the distribution of *Ae. aegypti* covers all the northern and central provinces of the country, including the provinces of La Pampa and Buenos Aires (Vezzani and Carbajo 2008).

Although Buenos Aires City is located near the southern limit of the distribution of *Ae. aegypti*, a high abundance of this species is recorded in this city. Other factors, such as the arrival of people with dengue and the favorability of weather conditions for the

completion of the extrinsic cycle of the virus, increase the risk of disease transmission. These conditions have resulted in several locally transmitted cases during the dengue epidemic occurred throughout northern Argentina in early 2009 (Seijo et al. 2009). Because no effective vaccine for dengue is currently available, the reduction of vector abundance is still the most promising strategy to control the disease (Gubler 2002, Spiegel et al. 2005), and thus, knowledge about the key factors that determine local abundances of the *Ae. aegypti* population becomes increasingly important.

In temperate regions like Buenos Aires City, the population dynamics of *Ae. aegypti* is closely associated with the temperature regime. In this city, atmospheric conditions are favorable for the proliferation of *Ae. aegypti* between September and April (de Garin et al. 2000), and the highest oviposition activity is recorded in March (Vezzani et al. 2004). The population survives the low temperature winter season (June–August) in the egg stage (Sota and Mogi 1992), and the reproductive season begins when the temperature rises above a threshold level and the surviving eggs hatch and initiate larval development (Cam-

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pos and Maciá 1996, Bejarán et al. 2000, Domínguez et al. 2000, Schweigmann et al. 2002).

Oviposition studies covering the 200-km<sup>2</sup> area of Buenos Aires City (one ovitrap per square kilometer) have demonstrated a high spatial heterogeneity in the oviposition dynamics of *Ae. aegypti*, with a pattern that repeats itself in different years (Carbajo et al. 2004). In the neighborhoods located in the western, northern and southern areas of the city (more favorable areas), *Ae. aegypti* activity is recorded from October to May and the population reaches a higher abundance, whereas in areas near the city center and the Río de la Plata river (less favorable areas), the activity season is restricted to February and March, and mosquito abundance is lower. This favorability gradient has been associated with differences in the type of urbanization, and environmental characteristics such as connectivity or vegetation cover (Carbajo et al. 2006).

Subsequent studies with higher spatial resolution performed in areas with similar urban development confirmed the existence of a gradient of mosquito abundance associated with the distance from the Río de la Plata river. These studies allowed rejecting the hypotheses that urbanization, connectivity, vegetation cover (Alem 2012), and the density and characteristics of water-filled containers (Fischer et al. 2008) are determinants of the differences in oviposition activity between areas at this scale.

It is well known that temperature determines the velocity of biological processes such as egg hatching (Bytbeier et al. 2012) and the duration of different developmental stages of *Ae. aegypti* (Rueda et al. 1990, Tun Lin et al. 2000). In fact, Carbajo et al. (2006) suggested that thermal heterogeneity might explain the spatial pattern of *Ae. aegypti* abundance and population dynamics in Buenos Aires City. Although this hypothesis has never been tested, a preliminary study has shown temperatures of up to 2°C lower near the Río de la Plata river than in a more continental location in spring and early summer (Bechara 2009). These differences are coincident with the general pattern recorded in Buenos Aires City, where the areas near the coast have lower temperatures, probably because of the stabilizing effect of the water masses of the Río de la Plata river and the fresh winds from the river during the warm season in the areas close to it (Atlas Ambiental de Buenos Aires 2010).

The effect of temperature on population dynamics should be particularly important for the thermal range typical of spring (around 17°C), when small differences in temperature cause significant variations in development times. For example, the development time of the immature stages is 13 d at 20°C and 40–60 d at 15°C (Rueda et al. 1990, Tun Lin et al. 2000).

However, the delay of 2–4 mo of the first detection of *Ae. aegypti* during the warm season in less favorable areas of Buenos Aires City (Carbajo et al. 2004) suggests the hypothesis of local extinctions during the winter season. The recolonization of the less favorable areas would then depend on adult females from the most favorable areas. Because in the cold season the population remains in the egg stage, the proba-

bility of persistence through the next reproductive season and the size of the initial population depend on the proportion of eggs that survive the unfavorable period. Although the causal factors have not been identified, recent experimental studies in Buenos Aires City have shown a significantly higher winter survival of eggs in the peripheral zone than in the areas close to the Río de la Plata river (Fischer et al. 2011). It should be noted that during this study, average differences in the cold season temperatures were below 0.1°C, and therefore did not explain the differences observed in egg mortality.

The effects of environmental and/or biological factors on population dynamics are extremely difficult to assess through experimental methods and thus a complementary approach to analyze the processes involved in the population dynamics is needed. Mathematical models provide useful tools to test scientific hypotheses through a sensitivity analysis, because they simulate the effects of varying parameters (e.g., rates at which processes occur) on a state variable (e.g., population abundances), and the results can be compared and contrasted with observed data (Lord 2007). A stochastic spatial model for *Ae. aegypti* populations has been recently developed and its results have been contrasted with field data of Buenos Aires City (Otero et al. 2008).

The aim of this work was to assess the relative importance of two possible causal factors in explaining the differences in *Ae. aegypti* oviposition dynamics between two contrasting areas along the favorability gradient in Buenos Aires City. We tested the hypothesis that the population dynamics observed responds to differences in either the thermal behavior, the survival of eggs between zones, or both.

## Materials and Methods

**Study Area.** Buenos Aires City (34° 36' S and 58° 26' W) covers an area of 200 km<sup>2</sup> and has a population of three million people. To the south and west, the city is surrounded by urban and suburban areas with nine million inhabitants (Atlas Ambiental de Buenos Aires 2010), whereas to the north–east it limits with the Río de la Plata river, which at this point attains a width of almost 50 km.

The city is characterized by a temperate climate with a pronounced thermal seasonality. The mean temperature in fall and spring varies around 17°C, with cool mornings and nights, whereas the mean temperature in winter is equal to 11.5°C, with moderately cold days and cold nights. In summer, there is strong solar radiation and high temperatures, with a mean temperature equal to 23.6°C. The mean maximum and minimum temperatures are recorded in January and July, respectively (National Meteorological Service 2012). Annual cumulative rainfall is 1,100 mm on average, and rainfall events are recorded regularly throughout the year (Atlas Ambiental de Buenos Aires 2010).

Two study sites were selected based on a previous study during the high activity season of *Ae. aegypti*

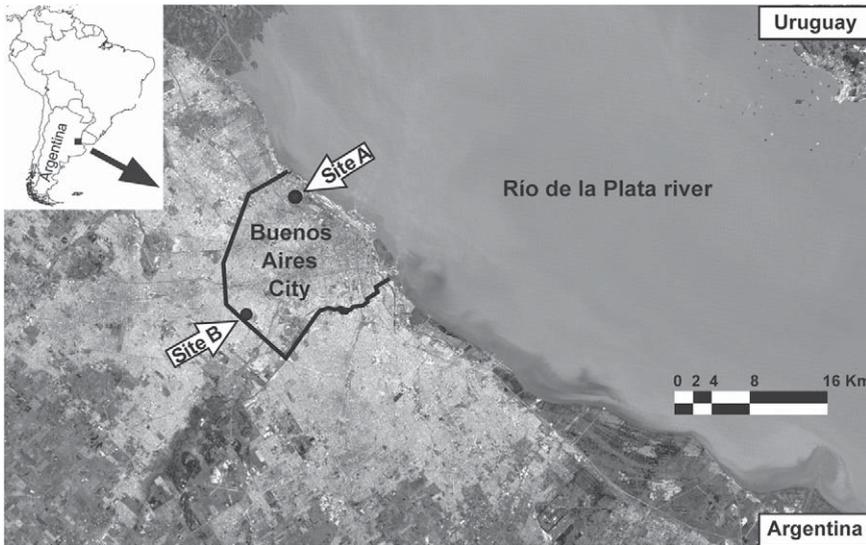


Fig. 1. (a) Location of the study sites in Buenos Aires City (Argentina) in relation to the Río de la Plata river (site A, Belgrano neighborhood; site B, Mataderos neighborhood).

(Fischer et al. 2011): one located in the north eastern border of the city in close proximity to the Río de la Plata river (site A located in Belgrano neighborhood in a less favorable area), and the other in the south western border of Buenos Aires City, 15 km away from downtown and the Río de la Plata river (site B located in Mataderos neighborhood in a more favorable area) (Fig. 1). Both sites have similar characteristics regarding urban development, with wooded roads and residential houses two stories high at most. Neither of the two study areas is crossed by avenues.

**Oviposition and Temperature Dynamics.** *Field Study.* The oviposition dynamics of *Ae. aegypti* was monitored during the warm season of 2008–2009 (from the third week of September 2008 through the fifth week of June 2009).

Twenty-six ovitraps (Fay and Eliason 1966) were placed in each study site, covering a surface area of  $\approx 9$  ha and distributed in an approximately regular grid. The traps were placed on beds with plants located on the sidewalks of the roads, with the criterion of maximizing vegetation cover around the traps. Traps consisted of a glass flask, painted black on the outside, and filled with tap water up to one third of its volume. One oviposition substrate (wooden paddle 9.5 by 1.8 cm, commercially available as a tongue depressor) was placed inside each flask, and attached to the wall in a vertical position by a clip. Traps were reconditioned weekly, container walls washed, and water and paddles replaced in situ. Missing or broken traps were replaced and classified as inactive during the corresponding week (i.e., not considered in the subsequent analyses). The collected paddles were placed in individual polypropylene bags for transportation, and the eggs on each paddle were counted under a stereoscopic microscope. Traps containing a paddle with eggs were considered positive, while those without

eggs on the paddle were considered negative in the corresponding week.

Hourly temperatures at each site were recorded with a HOBO Pendant Temperature Data Logger placed in containers identical to those used in the oviposition study, located in shadowed and vegetated sites. Temperature values obtained were considered representative of the respective study site.

*Data Analyses.* The oviposition dynamics of *Ae. aegypti* was compared between sites by means of two indicators: the weekly proportion of positive traps and the weekly cumulative number of eggs. Statistical comparisons of the two indicators were performed separately for the following time periods: spring (October–November, which is when the oviposition activity begins), early summer (December–January, when the oviposition activity increases), late summer (February–March, when there is maximum activity), and fall (April–May, when the activity decreases and finally ends).

The weekly proportion of positive traps for each site was calculated as the number of traps with eggs divided the number of active traps that week. The weekly cumulative number of eggs was calculated as the sum of the eggs collected in all ovitraps. The comparison of these two indicators between sites was performed for each time period using the Wilcoxon test for paired samples. The constancy of the differences between sites in the weekly proportions of positive traps was tested using the Mantel–Haenszel test (Fleiss et al. 2003).

Hourly temperature data from each location were compared between sites with the Student *t*-test for paired samples. This analysis was performed separately for each month to identify periods with significant differences. Monthly averages of hourly temper-

ature differences between sites (site B minus site A) were calculated and plotted for graphical analysis.

**Effects of temperature and egg mortality on the modeled oviposition.** The effects of temperature and egg mortality on the population dynamics of *Ae. aegypti* were assessed analyzing the outputs of a Stochastic Spatial Dynamical model, whose main input variable of the model is temperature (Otero et al. 2008). Rainfall data are neglected in the model based on the assumption that rainfall events in temperate humid regions are regularly and homogeneously distributed across the year.

The model considers six life stages as subpopulations of the mosquito: eggs, larvae, pupae, adult females during the first gonotrophic cycle, flying females, and adult females in their second or subsequent gonotrophic cycles. The rates in which processes (e.g., adult emergence, oviposition, etc.) occur are parameterized based on the available bibliographic information of the biology of this mosquito species, and detailed in Otero et al. (2008). In particular, within the temperature range of Buenos Aires, the egg mortality coefficient is considered constant (Focks et al. 1993), and the development rates increase exponentially (Otero et al. 2006).

We worked with a square grid of 16 blocks and a density of 75 breeding sites per block, which represents a carrying capacity that is representative of the density of larvae and pupae per hectare recorded in the peak season in Buenos Aires City (Fischer et al. 2008). The quantity and quality of breeding sites per block was considered homogeneous between sites according to our preliminary studies (Fischer et al. 2008). In total, 100 simulations were conducted for each condition, and the output variable analyzed was the number of eggs laid per day throughout a year. In all simulations, we used the original parameters except those of interest to this study: mortality of eggs and mean daily temperature.

We used the mortality values previously obtained in the same study sites (Fischer et al. 2011): 50% (site A) and 8% (site B) in a period of 90 d. Based on these data, the daily mortality of eggs for each site was estimated assuming a constant mortality rate, using an exponential decay equation, values of daily egg mortality obtained were 0.008 for site A and 0.001 for site B.

Three different conditions were simulated for each site:

Condition 1: Using site-specific daily mean temperatures and the between-site average of daily egg mortality.

Condition 2: Using site-specific daily egg mortalities and the between-site average of daily mean temperatures.

Condition 3: Using site-specific daily egg mortalities and site-specific daily mean temperatures.

The monthly average of daily laid eggs was calculated for each series of simulations. The relative importance of the thermal effect and the egg mortality effect was assessed by calculating the differences (site

B minus site A) of the monthly averages of daily laid eggs simulated for conditions 1 and 2, respectively.

**Comparison Between the Simulated Data and the Oviposition Dynamics Observed.** To compare observed and simulated data, field results and simulations were standardized for each site using the following calculations: 1) standardized field egg number (SFEN = sum of cumulative egg number per week divided by the total number of eggs in the season), 2) standardized field positive traps (SFPT = number of positive traps per week divided by the total number of positive traps in the season), 3) standardized simulated egg number (SSEN = cumulative number of eggs simulated each week divided by the cumulative number of eggs simulated for the whole season).

The Pearson correlation coefficients between the indicators obtained in the field (SFEN and SFPT) and the indicator obtained with the simulation (SSEN) were assessed for each site separately. Both types of standardized indicators were compared graphically throughout the activity season of *Ae. aegypti* for each site separately. Weekly cumulative rainfall data were included in the graph for interpretation. Rainfall data were provided by the National Meteorological Service, and corresponded to the Villa Ortúzar station, whose location is intermediate between both study sites.

## Results

**Oviposition and Temperature Dynamics.** The oviposition activity of *Ae. aegypti* lasted 5 wk longer in site B than in site A. The first eggs were detected in site B on the third week of October, 3 wk earlier than in site A. The last eggs in site A were detected on the third week of May, 2 wk earlier than in site B (Fig. 2).

The weekly proportion of positive traps was higher in site B than in site A during most of the reproductive season (Fig. 2). Significant differences were detected during the periods of spring (October–November:  $N = 9$ ,  $Z = 2.20$ ,  $P < 0.05$ ), early summer (December–January:  $N = 8$ ,  $Z = 2.38$ ,  $P < 0.05$ ), late summer (February–March:  $N = 9$ ,  $Z = 2.49$ ,  $P < 0.05$ ), and fall (April–May:  $N = 9$ ,  $Z = 2.52$ ,  $P < 0.05$ ), and according to the Mantel–Haenszel test the weekly differences were consistent along the whole study period ( $\chi^2_1 = 84.9$ ;  $P < 0.001$ ).

The cumulative number of eggs per week attained relatively low values during the warm period in site A, with maximum values at the end of March and early April. In contrast, an increase in this indicator was observed in site B from the second week of February, surpassing in some cases the values observed in site A by one order of magnitude (Fig. 2). The weekly cumulative number of eggs was significantly higher in site B than in site A during the periods of spring ( $N = 9$ ;  $Z = 2.20$ ;  $P < 0.05$ ), late summer ( $N = 9$ ;  $Z = 2.31$ ;  $P < 0.05$ ), and fall ( $N = 9$ ;  $Z = 2.38$ ;  $P < 0.05$ ), while no significant differences were detected between sites in the period of early summer.

Mean temperatures were higher in site B than in site A during most months of the year ( $P < 0.001$ ), except

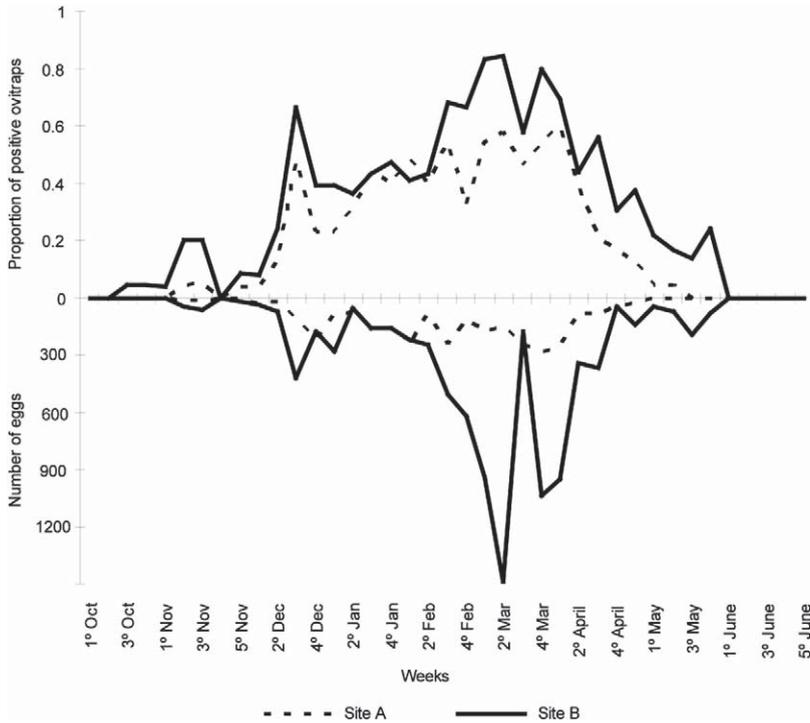


Fig. 2. Oviposition activity in site A and site B: upper half: weekly proportion of positive traps; lower half: weekly cumulative number of eggs.

in August and September (late winter). Particularly in September, the temperature records in site A were significantly higher than in site B ( $P < 0.001$ ). The largest differences (up to 2°C) were recorded during late spring and early summer, from November through January (Fig. 3), in coincidence with the periods of starting and increase of oviposition activity of *Ae. aegypti*.

**Effects of Temperature and Egg Mortality on the Modeled Oviposition.** The effect of temperature (condition 1) and the effect of egg mortality (condition 2)

produced higher simulated abundances of *Ae. aegypti* in site B than in site A during most of the study period. The only exception was observed at the beginning of the oviposition season (September and October) when the differences between sites because of the effect of egg mortality were greater than those because of the effect of temperature (Fig. 4). An interesting result was obtained in September for the simulations considering the temperature differences, because it was the only situation in which there were higher values in site A than in site B.

The comparison of differences between sites in the simulated *Ae. aegypti* oviposition activity showed an

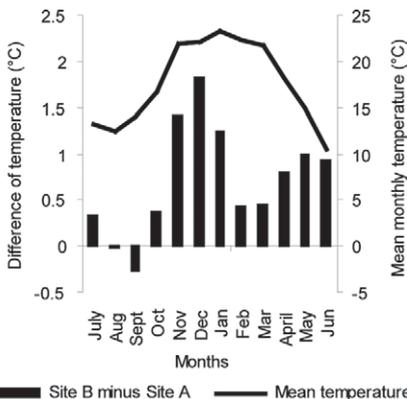


Fig. 3. Mean monthly temperature (line) and average monthly temperature differences between site B and site A (bars).

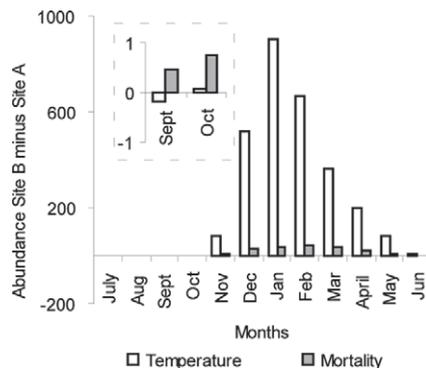


Fig. 4. Differences in abundance (site B minus site A) of monthly average of simulated oviposition activity. Detail for September and October in the upper left.

**Table 1.** Correlation coefficients between the simulation-based indicator (SSEN) and the field indicators based on positive traps (SFPT) and on no. of eggs (SFEN) for both study sites

	Site A	Site B
SSEN-SFPT	$r = 0.96; P < 0.001; N = 52$	$r = 0.88; P < 0.001; N = 52$
SSEN-SFEN	$r = 0.89; P < 0.001; N = 52$	$r = 0.64; P < 0.001; N = 52$

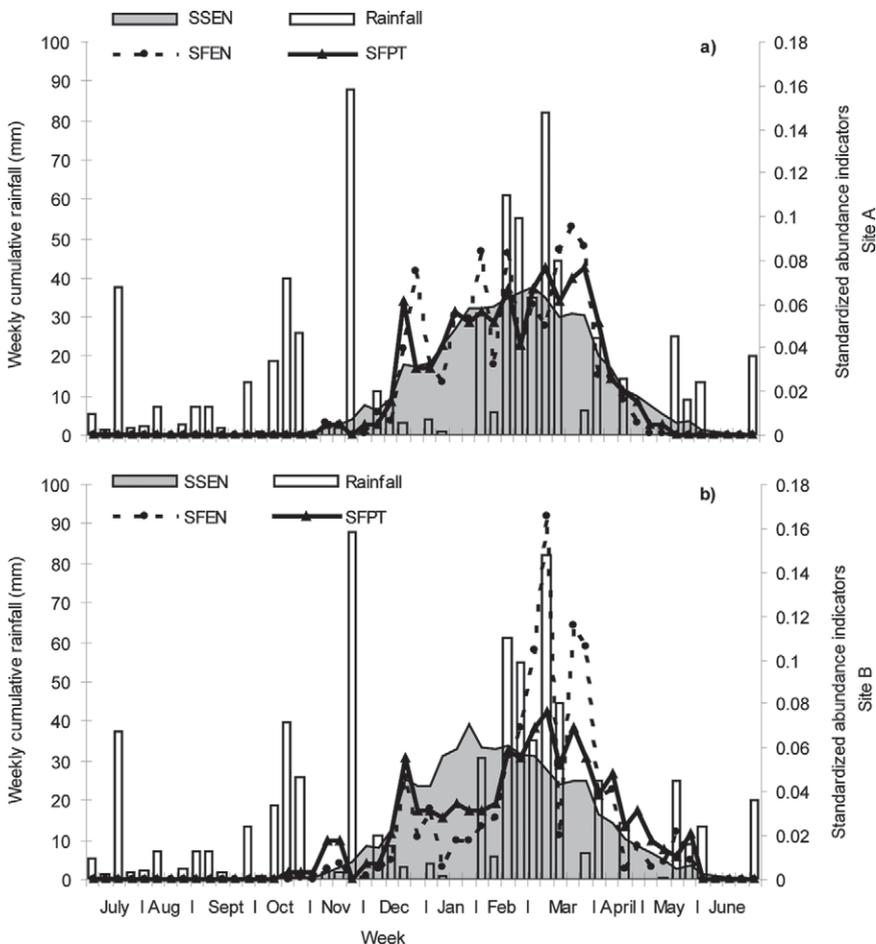
SSEN, standardized simulated egg no.; SFPT, standardized field positive traps; SFEN, standardized field egg no.

effect of temperatures approximately 10 times larger than the effect of egg mortality during most of the study period. The differences of the simulated abundance in both sites showed a seasonal pattern with maximum values in January.

**Comparison Between Simulated Data and Observed Oviposition Dynamics.** Significant positive correlations were observed between the indicator based on simulated data (SSEN) and the field indicators, and a better correlation was observed between the field indicators based on positive traps (SFPT) and the

coefficient obtained by simulation for both study sites (Table 1). The differences in these correlation coefficients are supported by the visual analysis of the temporal dynamics of the three indicators. The field-based indicators showed larger fluctuations between consecutive weeks than the simulation-based indicator both at site A (Fig. 5a) and at site B (Fig. 5b). These fluctuations were less pronounced in the abundance indicator based on positive traps (SFPT) than in the indicator based on the number of eggs (SFEN).

However, higher correlation coefficients were observed between simulation-based and field-based indicators at site A than at site B (Table 1). The indicator based on simulated data (SSEN) at site A showed a pattern fairly similar to that of the indicators based on field data (Fig. 5a). In contrast, the simulated and observed oviposition dynamics showed larger differences at site B (Fig. 5b). The differences were especially important during the first half of the summer (from the last week of December through the second week of February), when relative abundances were



**Fig. 5.** Comparison of weekly values of standardized abundance indicators of field data (based on egg number: SFEN; and on positive traps: SFPT), and simulation data (based on egg number: SSEN) for (a) site A; and (b) site B. Bars correspond to weekly cumulative rainfall in Buenos Aires City.

lower in the field than those predicted by the model. These differences were temporally coincident with a period of low frequency and intensity of precipitation. Furthermore, a considerable increase in field-based indicators was observed at site B from mid-February onwards, which was preceded by a rainy period that started approximately 2 wk before in early February (Fig. 5b).

### Discussion

The use of ovitraps has been suggested to be an unreliable method to compare *Ae. aegypti* abundance between sites and/or dengue transmission risk based on the argument that high densities of water-filled containers in the surroundings of the traps might have a diluting effect (Focks 2003). Although we did not perform studies to assess the availability of water-filled containers in the study areas analyzed, a preliminary assessment of potential breeding sites carried out in Buenos Aires City during 1998–2000 showed that the density and type of water-filled containers is relatively homogeneous across the city (Fischer et al. 2008). Furthermore, previous studies on a city-wide, coarse scale concluded that the spatial pattern of the oviposition dynamics of *Ae. aegypti* detected with ovitraps reflects abundance differences in Buenos Aires City (Carbajo et al. 2006).

This is the first study with high spatial resolution that describes the oviposition dynamics in different neighborhoods of Buenos Aires City. The differences in oviposition activity of *Ae. aegypti* between the study sites are geographically coincident with the gradient previously described (Schweigmann et al. 2002, Carbajo et al. 2004). The results of our study are particularly relevant because the study period was temporally coincident with the dengue outbreak occurred in Argentina during January through March of 2009. Although this might be considered circumstantial evidence, the cases of local dengue transmission documented in the Metropolitan Area of Buenos Aires were clustered toward the south–western edge of the city, which includes Mataderos neighborhood where site B was located. In contrast, near the Río de la Plata river in the north–eastern side of the city, where site A was located, no local transmission was detected, although imported cases were recorded (Seijo et al. 2009). These results suggest that the differences in the oviposition activity between both study sites reflect not only true differences in abundances among them, but also that these differences were sufficiently important to determine the possibility of local transmission of dengue.

This study provides new insights into the population dynamics of this mosquito species in Buenos Aires City. Our results indicate that *Ae. aegypti* maintains oviposition activity throughout the warm season in both more favorable and less favorable areas, contradicting previous studies where it had been detected only during a short time period in less favorable areas (Carbajo et al. 2004). The lower detection of *Ae. aegypti* in previous studies with lower spatial resolution

(one ovitrap per square kilometer) could be explained by a decreased probability of detection caused by the relatively smaller capture effort in these studies. Nevertheless, the hypothesis of an increase in the abundances of this species, and hence in the oviposition activity in recent years should not be ruled out and should be assessed in future studies considering an appropriate scale.

Although we used only one HOBO datalogger per site, we are confident that our data reflect the differences in temperature among sites appropriately, because the temperature records from two meteorological stations (one located near the river [Aeroparque station] and the second located in the geographical [but not urbanistic] center of the city [Villa Ortuzar station]) show the same trends in temperature as those measured in our study. Furthermore, preliminary simulations based on the temperature data from these meteorological stations (De Majo 2011) have shown differences in mosquito abundances similar to those obtained in the current study.

The results of the simulations indicate that both temperature and egg mortality contribute to the differences in population abundances between sites and that both effects contribute in the same direction during most of the year, although the effect of temperature is generally more important than egg mortality. The results of the simulations showed a more significant effect of temperature on population abundances, which exceeded 10-fold the effect of egg mortality.

The relatively small effect of egg mortality on the population could be explained by the fairly low mortality of *Ae. aegypti* eggs estimated for both more favorable and less favorable areas of Buenos Aires City (Fischer et al. 2011) as compared with other sites located in tropical regions (Trpis 1972, Russell et al. 2001). These relatively low mortalities, together with the delay of only 3 wk in the first detection of activity between both study sites, support the rejection of the hypothesis of local extinctions during the winter season, suggesting that there are other factors causing the heterogeneity in population abundance across Buenos Aires City. Furthermore, in the places where at least some eggs survive the cold season, it is expected that differences in mortality are quickly compensated at the beginning of the reproductive season by density-dependent mechanisms (Juliano 1998, 2007; Arrivillaga and Barrera 2003; Braks et al. 2004; Schneider et al. 2004), which are incorporated in the model in the form of density-dependent mortality in the larval stage (Otero et al. 2008).

The proportion of positive traps has been suggested to be a good predictor of egg number per trap (Mogi et al. 1990). Nevertheless, in the current study, the number of eggs showed wide fluctuations between consecutive weeks, not reflected in changes in the proportion of traps with eggs. Taking into account that the peaks in egg numbers were mainly because of high numbers of eggs aggregated in few traps, it seems unlikely that they reflect true fluctuation levels in population abundance. Moreover, the variability in

egg number observed in the field was probably caused, at least in part, by chance, which could explain the lower correlation between this indicator (as compared with the proportion of traps with eggs) and the simulated abundances.

The lower oviposition activity in the field as compared with model predictions in January and part of February in site B was temporally coincident with a period of extraordinary drought occurred between December 2008 and January 2009. This might have exerted a limiting effect on the availability of water in the containers which are typical breeding sites for this species, and therefore, on the abundances of adults. The rainfalls recorded in early February probably triggered a significant increase in the availability and productivity of breeding sites, leading to an explosive increase in the emergence of new adults a few days later. This sequence could justify the increase in oviposition activity observed from the third week of February onwards.

The differences between observed and simulated data at site B could be explained by the fact that the model considers continuous hatching with a rate that depends on temperature data only and does not take into account the rainfall as a possible trigger of immature development. The absence of evidence of the drought effect on the population dynamics of *Ae. aegypti* in site A suggests that, in this site, water availability would not have been limiting. This could be explained by the natural delay in the population increase because of lower temperatures in this area, which suppressed or minimized the effects of competence among individuals for space or food in the breeding sites, which are included in the model as density-dependent larval mortality (Otero et al. 2008).

In summary, the results of this study contribute to a better understanding of the factors that determine the spatio-temporal dynamics of *Ae. aegypti* in temperate regions. We conclude that, among the factors evaluated, temperature is the most important factor to determine the heterogeneity in *Ae. aegypti* abundance in Buenos Aires City, discarding the hypothesis of local extinctions because of winter mortality of eggs. The results also suggest that under certain circumstances, the population abundances may be also limited by the reduced availability of breeding sites during a drought period, although this should be confirmed in future studies.

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