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Long-term spatio-temporal dynamics of the mosquito *Aedes aegypti* in temperate Argentina.

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Abstract

Buenos Aires city is located near the southern limit of the distribution of *Aedes aegypti* (Diptera: Culicidae). This study aimed to assess long term variations in the abundance of *Ae. aegypti* in Buenos Aires in relation to changes in climatic conditions. *Ae. aegypti* weekly oviposition activity was analyzed and compared through nine warm seasons from 1998 to 2014, with 200 ovitraps placed across the whole extension of the city. The temporal and spatial dynamics of abundances were compared among seasons, and their relation with climatic variables were analyzed. Results showed a trend to higher peak abundances, a higher number of infested sites, and longer duration of the oviposition season through subsequent years, consistent with a long-term colonization process. In contrast, thermal favorability and rainfall pattern did not show a consistent trend of changes. The long term increase in abundance, and the recently documented expansion of *Ae. aegypti* to colder areas of Buenos Aires province suggest that local populations might be adapting to lower temperature conditions. The steadily increasing abundances may have implications on the risk of dengue transmission.

Key words: *Aedes aegypti*, ovitrap, long-term dynamics, oviposition activity, rainfall, temperature.

Introduction

Aedes (=Stegomyia) aegypti (Diptera: Culicidae) is a species original from West Africa, which was introduced into the Americas with the first arrival of Europeans, most likely transported by slave ships in water-holding containers. This species is considered invasive based on its tremendous potential to spread to new environments (Lounibos, 2002). Other traits associated with its invasion success are the desiccation-resistant eggs, installment hatching, and the behavior of females to distribute eggs in several containers, all of which ensure that at least part of the offspring survives and reproduces, and facilitate the establishment in recently colonized areas (Becker et al., 2012).

Although the presence of *Ae. aegypti* has been documented in Buenos Aires in the first half of the 20th century (Del Ponte & Blacksley, 1947), after the continent-wide control program implemented between 1930 and 1960 this species was considered eradicated from Argentina and its neighboring countries in 1965 (Soper, 1967). However, after the cessation of the intensive control measures in the early 1970´s, *Ae. aegypti* reinvaded most of the territory where it was previously present (Eisen & Moore, 2013), probably transported passively as eggs in used tires (Reiter & Sprenger, 1987). In Argentina, *Ae. aegypti* was detected in 1986 in the provinces of Misiones and Formosa (Curto et al.; 2002), in 1991 in the locality of Quilmes in the province of Buenos Aires (Campos, 1993), and in 1995 in Buenos Aires city (Junín et al., 1995). In the following three years, from 1996 to 1998, 810 premises were surveyed in Buenos Aires city, among which 103 (12.7%) were infested, exceeding the minimum thresholds according to the OPS for the transmission of dengue (Schweigmann et al., 2002). Studies with ovitraps during a three-year period from 1998 to 2001 showed that this species was established across the city, although with a certain spatial heterogeneity in its distribution, which has been related to urbanization differences (Carbajo et al., 2006), and to differences in temperature dynamics due to the influence of the river (De Majo et al., 2013).

The seasonal dynamics of *Ae. aegypti* exhibits a recurrent pattern, with increasing oviposition activity during late spring and early summer (November-January), a peak during late summer (February-March), and a decrease during fall (April-May). No immature stages or adults are observed during winter (Vezzani & Carbajo, 2008). Thus the population persists through the unfavorable (cold temperature) season in the egg stage, subject to a relatively low mortality under the environmental and climatic winter conditions in Buenos Aires (Fischer et al., 2011).

The increase in the population abundance during the subsequent spring season starts when the overwintered eggs hatch and larval development initiates as soon as favorable conditions return in spring. The relationship between the seasonal dynamics on temperature has been supported by simulation with mathematical models of population dynamics, in particular for Buenos Aires city (Otero et al., 2008).

The influence of temperature on *Ae. aegypti* abundance is especially important at the cool margins of its geographic range, where climate warming is expected to have a critical impact by making these regions more suitable for the mosquito (Eisen & Moore, 2013). Although Carbajo et al. (2004) found certain variability in total infestation between years for Buenos Aires city, these authors analyzed only a three-year period, and did not assess the relationship between the inter-annual variability observed and meteorological variables such as temperature or rainfall. Given the short time elapsed from the reinvasion of *Ae. aegypti* in Buenos Aires city, both the abundance and distribution of this species might still be increasing. Such increases might be a consequence of processes occurring at three different scales: the colonization of new environments (i.e. neighborhoods) via active flight of egg-laying females or passive dispersal of eggs, the colonization of new containers within a neighborhood, and the colonization of the same container by a higher number of individuals. These increases may have important consequences for human health, since this species is the main vector of dengue in America, and increased abundances will have direct impacts on transmission risk (Gubler, 2004).

Long-term abundance data are needed to understand the current status of the invasion of this species near the limits of its distribution range, and to assess the existence and effect of evident changes in climatic variables. Such long-term data are scarce for tropical regions, but are not available within the temperate region.

The aims of this study were to analyze the long-term dynamics of *Ae. aegypti* in Buenos Aires city over a 16-year study period (1998-2014), to assess the hypothesis of an increase in abundance during the last years, and to relate possible changes in *Ae. aegypti* abundance with the variation of climatic conditions.

Materials and methods

Study area: Buenos Aires city (34° 36 S and 58° 26' W) is located on the western shore of the Río de La Plata river. The city has a temperate humid climate with seasonally varying temperatures. In fall and spring, the mean temperature varies around 17ºC, with cool mornings and nights, whereas in winter the mean temperature is 11.5ºC, with moderately cold days and cold nights. In summer, there is strong solar radiation and mean temperatures of 23.6ºC. The mean maximum and minimum temperatures are recorded in January and July, respectively. Annual cumulative rainfall is 1200 mm on average, and rainfall events are recorded throughout the year (National Meteorological Service, 2014). The city covers an area of 200 km^2, has a population of 2.8 million people, and is surrounded by urban and suburban areas with over nine million people covering 3600 km^2 (Mehrotra et al., 2011).

Field work: *Ae. aegypti* oviposition activity was studied with ovitraps throughout nine warm seasons. The seasons lasted from September to May-June of the following years: 1998-1999, 1999-2000, 2000-2001, 2007-2008, 2009-2010, 2010-2011, 2011-2012, 2012-2013 and 2013-2014. A total of 200 sites, covering the whole extension of Buenos Aires city (approximately 1 site per km^2), were monitored. Ovitraps 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) was placed inside each flask, and attached to the wall in a vertical position by a clip (Fay & Eliason, 1966). Ovitraps were placed on plant beds located on the sidewalks of the roads, at a height less than 1 meter, with the criterion of maximizing surrounding vegetation cover. Ovitraps were reconditioned weekly, container walls washed, and water and paddles replaced in situ. This activity was maintained from the beginning of spring through the end of fall, and ended after two consecutive weeks without detection of eggs. Missing or broken ovitraps 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. Ovitraps containing a paddle with eggs were considered positive, while those without eggs were considered negative in the corresponding week. All the eggs collected were assumed to correspond to *Ae. aegypti* because this is the only container breeding Aedine mosquito species in this region (Rubio et al., 2012).

Data analyses:

Temporal dynamics of oviposition activity: the proportion of ovitraps with eggs (number of ovitraps with eggs / total number of active ovitraps) was calculated for each week, and monthly averages of these proportions were calculated. The weekly proportion of traps with eggs was compared among periods with a nonparametric Friedman ANOVA. Post-hoc comparisons were performed with Wilcoxon´s test for paired samples, adjusting the significance of the test with the Holm-Bonferroni correction for multiple comparisons (Holm, 1979). General indicators were calculated for each season: time of the first detection of eggs, time of the last detection of eggs, duration of oviposition season (number of weeks from the first to the last detection of eggs), and maximum weekly infestation (proportion of ovitraps with eggs in the week with maximum activity).

Site-specific changes in activity: The number of weeks with oviposition activity was calculated for each site and season. From these data, the total number of infested sites (number of sites where activity was detected at least once in the season), and the maximum prevalence at one site (number of weeks with eggs at the site with maximum activity) were calculated. The number of weeks with oviposition activity was compared between consecutive study periods with Wilcoxon´s test for paired samples. The significance of the test was adjusted with the Holm-Bonferroni correction for multiple comparisons (Holm, 1979).

To assess the long-term changes in activity by site, the mean frequency of activity was calculated for the first three seasons (1998-2001), for the intermediate three seasons (2007-2011), and for the three last seasons (2011-2014). Site specific differences in the average activity period were calculated between 1998-2001 and 2007-2011, and between 2007-2011 and 2011-2014. Then, sites were plotted on maps differentiating areas with average changes larger than one week/year (large changes), areas with average changes of one week/year or less (small changes), and areas with no changes.

Relationship of oviposition activity with temperature and rainfall: the thermal favorability for each season was analyzed as the number of consecutive gonotrophic cycles (GC) that could potentially be completed. The fraction of the GC that could be completed each hour was calculated based on temperatures and the Sharpe & DeMichele enzyme kinetics approach, using the equation and parameters from Focks et al., (1993). Hourly temperature data corresponded to the Villa Ortúzar Station, and were provided by the National Meteorological Service of Argentina.

The cumulative GC was calculated for each week from July 1st onwards, and compared among seasons with a nonparametric Friedman ANOVA. Post-hoc comparisons were performed with Wilcoxon´s test for paired samples, adjusting the p of the test with the Holm-Bonferroni correction for multiple comparisons (Holm, 1979). Two different periods were analyzed: a) the whole season from July 1st to June 30th, and b) the beginning of the warm season from July 1st to December 31th, when the main population increase occurs. The relationship of the cumulative number of ovitraps with eggs each period with the corresponding Friedman ANOVA mean rank of GC was assessed with Pearson's correlation analysis.

Weekly cumulative rainfall data were calculated from July 1st to April 30th, and compared with the same method described for GC. The relationship between the cumulative number of positive traps and the following rainfall indicators was assessed with Pearson's correlation analysis: the Friedman ANOVA mean rank of total rainfall, the cumulative rainfall from July to September, the cumulative rainfall from July to December, the cumulative rainfall from July to March, and the number of annual dry events (periods of 15 days or more without rainfall events over 10 mm).

The relationship between monthly oviposition activity and weather variables was analyzed with a General Linear Mixed Model (GLMM) using R software, Version 3.2.3 (R Core Team 2015), accessed through a user friendly interface in Infostat Software (Di Rienzo et al., 2015). Models were fitted using the lme function from the nlme library, and parameters were estimated using the restricted maximum likelihood (REML) method (Pinheiro & Bates, 2004). The dependent variable was the monthly average proportions of traps with eggs, and the variables included in the model were: mean temperature of the previous month (T_{prev}), accumulated rainfall during the previous month (R_{prev}), and the interaction of T_{prev} x R_{prev}. Season was included as a categorical variable to specifically assess the hypothesis of increase after accounting for weather variables. Multiple comparisons among seasons were performed with the DGC test with a p value of 0.05 (Di Rienzo et al., 2002).

Results

Temporal dynamics of oviposition activity: The first detection of eggs was recorded between the fourth week of September and the second week of November, although in most of the seasons analyzed eggs were first detected between the second and the fourth week of October. Inter-annual variations showed no evident pattern between successive seasons (Table 1). The last detection of eggs occurred in mid-May during the first three seasons (1998-2001), and prolonged oviposition activity periods were recorded in the last seasons, at least until the last week of May from 2007 onwards (Table 1).

Table 1: General information of *Aedes aegypti* oviposition activity in nine activity seasons

Season	Time of first detection (week)	Time of last detection (week)	Duration of oviposition season (weeks)	Maximum weekly infestation (proportion)	Total number of infested sites	Maximum prevalence at one site (weeks)
1998-1999	Oct 2nd	May 2nd	31	0.38	149	14
1999-2000	Nov 2nd	May 2nd	26	0.43	140	16
2000-2001	Oct 4th	May 2nd	29	0.39	151	16
2007-2008	Oct 4th	May 5th	32	0.49	169	20
2009-2010	Oct 2nd	June 1st	35	0.59	179	20
2010-2011	Sept 4th	May 5th	36	0.56	176	19
2011-2012	Oct 4th	June 3rd	35	0.61	185	24
2012-2013	Oct 2nd	June 2nd	36	0.59	190	24
2013-2014	Oct 3rd	May 5th	32	0.78	196	22

A seasonal pattern of oviposition activity was maintained throughout seasons, beginning in early spring (October), and then showing a pronounced increase in late spring and early summer (December-January), maximum activity in late summer (February-March), and a progressive decrease in fall (April-May). The increase in late spring occurred earlier and the decrease in fall later during the last three study periods (white symbols in Figure 1) than during the first three (black symbols in Figure 1).

A detailed analysis of the pattern during the first months of oviposition activity shows a relatively small initial peak (lasting one or two weeks), followed by a substantial decrease in activity (at most a few weeks). After this period, a few additional peaks were recorded during the three first seasons (Figure 2a) while in the six remaining seasons a continued increase in abundances was observed (Figures 2b, 2c). The initial peaks were smallest during the first three study periods, intermediate during the intermediate study periods, and highest during the last three periods.

Figure 1: Temporal dynamics of *Aedes aegypti* oviposition activity in nine favorable seasons in Buenos Aires city, Argentina.

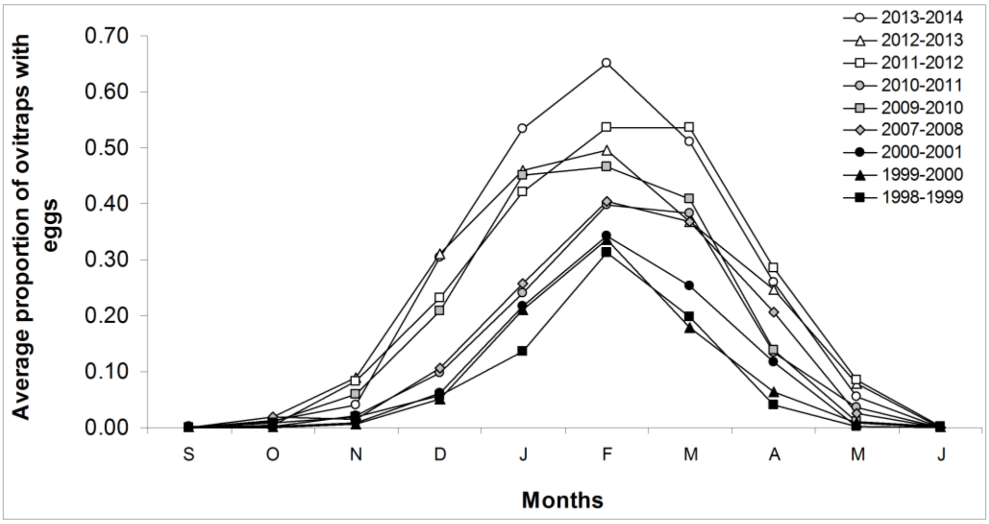
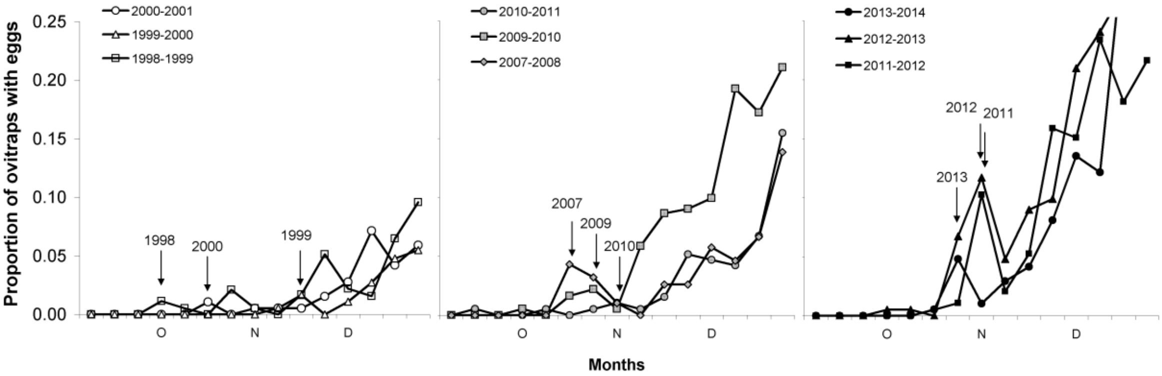
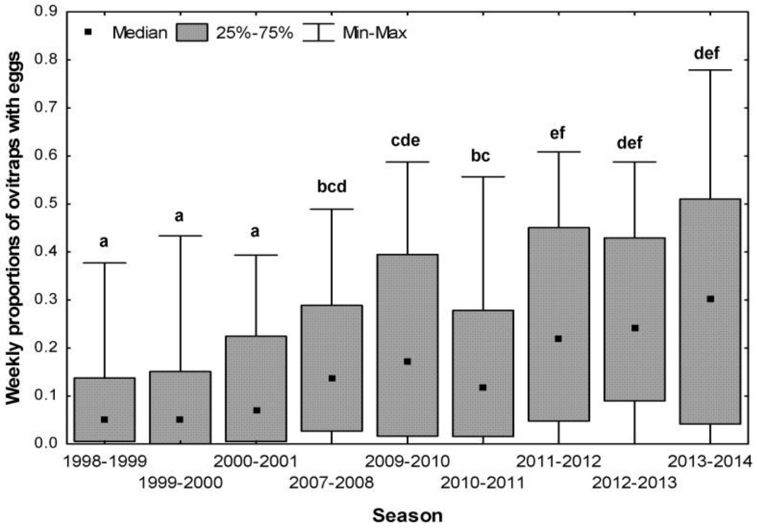


Figure 2: Detail of temporal dynamics of *Aedes aegypti* oviposition activity at the beginning of the favorable season from September to December of: 1998, 1999, 2000 (left); 2007, 2009, 2010 (center); and 2011, 2012, 2013 (right). Arrows indicate the initial peak for each season.



The weekly proportion of ovitraps with eggs showed statistical differences among at least some of the nine periods analyzed (Friedman ANOVA Chi Sqr. = 156.7, N = 35, df = 8, p<0.001), with significant differences between the three early seasons (1998-2001) and the remaining seasons. Although no differences between the subsequent seasons were detected, a general trend towards increased abundances can be observed (Figure 3).

Figure 3: Weekly proportion of ovitraps with *Aedes aegypti* eggs (October-May) for different activity seasons in Buenos Aires, Argentina. The same letters indicate seasons with no significant differences.



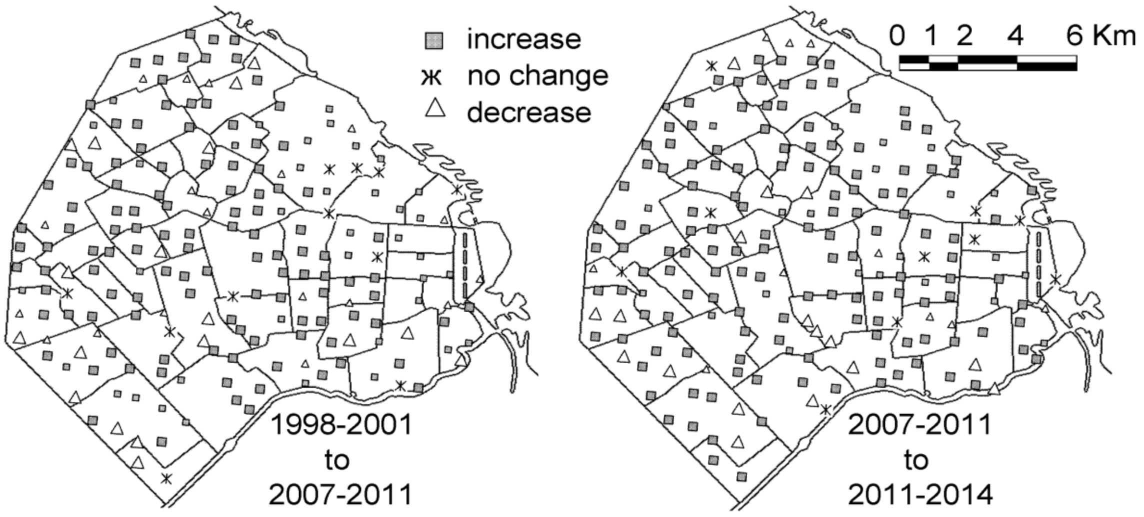
<u>Site-specific changes in activity</u>: An increase in activity from 1998-2001 to 2011-2014 was recorded throughout the city, and both the total number of infested sites and the maximum prevalence at one site exhibited gradual increases with time during the 16-year study period (Table 1). The inter-annual changes within sites showed a significant increase between four inter-annual periods, and a significant decrease only from 2009-2010 to 2010 to 2011 (Table 2). The previously described pattern of lower activity near the river and higher activity in the periphery was maintained, and in general, sites with null, low and medium activity in 1998-2001 increased to low, medium and high activity respectively in 2011-2014. The 2007-2011 period attained intermediate values. Taking the nine study periods together, all the sites analyzed were positive for *Ae. aegypti* at least once. The long term increases in activity occurred throughout the city both from 1998-2001 to 2007-2011 and from 2007-2011 to 2011-2014. Similarly, sites with no changes and sites with reduced activity were interspersed across the city (Figure 4).

Table 2: Inter-annual site-specific changes in oviposition activity

Observed Inter annual changes	Increased activity frequency	Decreased activity frequency
1998-1999 to 1999-2000	78	70
1999-2000 to 2000-2001	93	65
2000-2001 to 2007-2008	**104**	**63**
2007-2008 to 2009-2010	**109**	**54**
2009-2010 to 2010-2011	**56**	**115**
2010-2011 to 2011-2012	**141**	**36**
2011-2012 to 2012-2013	77	94
2012-2013 to 2013-2014	**112**	**68**

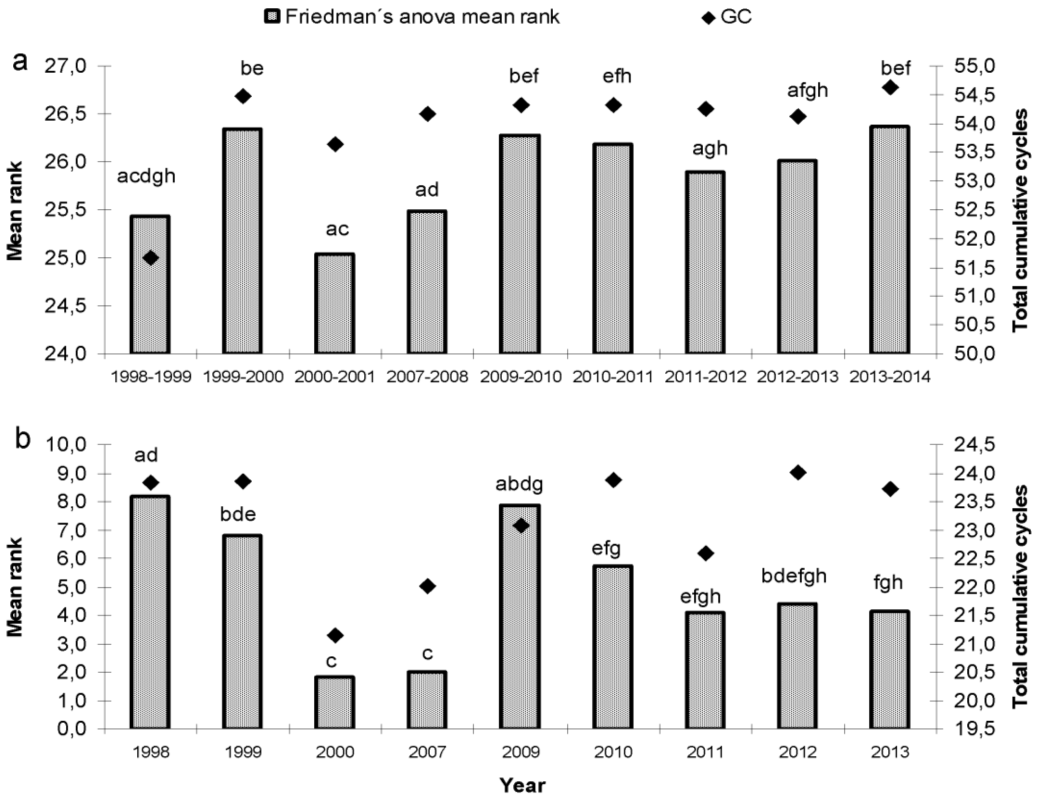
Note: Bold numbers indicate significant differences

Figure 4: Differences in *Aedes aegypti* oviposition activity levels between the three-year averages of 1998-2001 and 2007-2011 (left), and between the three-year averages of 2007-2011 and 2011-2014 (right). Small and large figures indicate small and large changes respectively.



Relationship of oviposition activity with temperature and rainfall: The cumulative GC showed variations among years, and different patterns were recorded for the whole year and the first half of the oviposition season (Figure 5) The statistical analysis showed significant differences of weekly cumulative GC among seasons both for the whole year period (Friedman ANOVA Chi Sqr. = 134.5, N = 52, df = 8, $p<0.001$), and for the fist half of the oviposition season (Friedman ANOVA Chi Sqr. = 149.9, N = 26, df = 8, $p<0.001$). Both for the whole year period and for the first half of the season, post-hoc comparisons of mean ranks identified significant differences among some seasons but no clear trend to increasing thermal favorability in later years (Figures 5a and 5b). The correlation of the cumulative number of ovitraps with eggs each year and the Friedman ANOVA mean rank in the corresponding season was not significant for the whole period (r^2 = 0.20, N = 9, p = 0.22), or for the first half of the season (r^2 = 0.008, N = 9, p = 0.82).

Figure 5: Cumulative potential gonotrophic cycles (GC) and mean ranks from Friedman ANOVA. a) whole year; b) first half of each oviposition season. The same letters indicate seasons with no significant differences.



The total cumulative rainfall showed variations among years, with the lowest value of 895 mm in 2007-2008, the highest value of 1829 mm in 2009-2010, and intermediate values in the remaining seasons. Seasons 2007-2008, 2010-2011 and 2011-2012 exhibited cumulative annual and seasonal rainfall amounts and frequency below the averages, whereas seasons 2000-2001, 2009-2010, 2012-2013 and 2013-2014 exhibited cumulative annual and seasonal rainfall amounts and frequency higher than the average (Table 3).

Table 3: Rainfall statistics and mean ranks from Friedman ANOVA for each of the oviposition seasons studied.

Season	Annual cumulative rainfall	Number of rainfall events >10 mm	Cumulative rainfall Jul-Sept	Cumulative rainfall Oct-Dec	Cumulative rainfall Jan-Mar	Cumulative rainfall Apr-Jun	Annual number of dry events	Mean rank of Friedman´s Anova
1998-1999	1094.8	24	150.3	277.5	**551.7**	115.3	**8**	3.35 (b)
1999-2000	**1397.2**	**31**	**288.7**	125.1	296.7	**686.7**	**9**	4.49 (b)
2000-2001	**1643.4**	**33**	**251.6**	**389.9**	**772.6**	229.3	**8**	**6.02** (d)
2007-2008	895.6	22	186.3	275.8	327.2	106.3	6	3.28 (b)
2009-2010	**1829.8**	**36**	**289.9**	**594.3**	**674**	271.6	6	**8.09** (e)
2010-2011	1030	29	129.9	275.2	335.7	289.2	6	3.51 (b)
2011-2012	928.4	22	134.5	169.5	448.4	176	**7**	2.49 (a)
2012-2013	**1680.3**	**38**	**337.8**	**686.1**	247.9	**408.5**	3	**8.07** (e)
2013-2014	**1524.6**	**31**	**302.3**	186.5	**705.7**	**330.1**	6	**5.70** (c)

Note: similar letters indicate homogeneous groups. Bold numbers indicate values above the average of the nine study periods

Significant differences of cumulative weekly rainfall among years were detected (Friedman ANOVA Chi Sqr. = 200.8, N = 43, df = 8, p<0.001). Post-hoc comparison of mean ranks showed differences among most seasons, except for two homogeneous groups (b and e in Table 3). The cumulative number of ovitraps with eggs each year was not correlated with the Friedman ANOVA mean rank (r^2 = 0.075, N = 9, p = 0.48), with the cumulative rainfall from July to September (r^2 = 0.061, N = 9, p = 0.52), with the cumulative rainfall from July to December (r^2 = 0.059, N = 9, p = 0.53), with the cumulative rainfall from July to March (r^2 = 0.081, N = 9, p = 0.46), or with the annual number of dry events (r^2 = 0.44, N = 9, p = 0.0502).

GLMM analysis showed a significant and positive relationship of monthly oviposition activity with T_{prev} (p<0.001), T_{prev} x R_{prev} (p<0.05), and season (p<0.05). The obtained model did not include R_{prev}, which showed no significant effect. Post hoc comparisons showed that after adjusting for T_{prev} and T_{prev} x R_{prev}, oviposition activity was significantly higher during the last three seasons than during the remaining seasons, whereas no differences were detected within each group of seasons.

Discussion

This is the first study showing long-term activity pattern for *Ae. aegypti* in a temperate region, and our results provide detailed information on the short- and long-term dynamics of this species near the southern limit of its distribution. The previously described seasonal pattern for Buenos Aires city has been maintained along successive years, especially the fact that oviposition activity is limited by temperature during the cold months.

The initial peaks in oviposition activity, which seem to be part of a consistent pattern in the Metropolitan Area of Buenos Aires (Romeo Aznar et al., 2013; Campos & Maciá, 1996), correspond most likely to the first cohort of adults originated from the hatching of overwintered eggs. Despite certain variability, these initial peaks showed increased importance in consecutive seasons. Furthermore, the magnitude of the subsequent increase in activity, which most likely corresponds to a second cohort of adults originated from eggs laid by the first cohort females, was at least partly related to the magnitude of the initial peak.

The delays in the time of last detection, the consistent increase in the weekly number of ovitraps with eggs, the number of sites with eggs and the frequency of detection per site indicate an increase in the abundance of *Ae. aegypti* in Buenos Aires city during the 16-year study period, which might be related to a ongoing colonization process. This increase occurs at the neighborhood scale, where the colonization of new environments is reflected by the detection of *Ae. aegypti* in new sites in consecutive years. These results suggest that there are no absolute barriers for dispersal within Buenos Aires city. At another scale, the colonization of new larval habitats within a neighborhood would be supported by increases in the proportion of water-holding containers that are occupied by immature stages of this species (container index). Although no systematic studies have addressed this issue in Buenos Aires city, independent surveys performed in different years have shown an increase in the container index from 6.4% in 1998 (Schweigmann et al., 2002) to 13% in 2005 (Schweigmann et al., 2009) and 16.4% in 2011 (Ceriani Nakamurakare et al., 2011), suggesting that the use of potential larval habitats has intensified in the last years.

In contrast with mosquito abundances, no consistent inter-annual pattern of change was detected for thermal favorability. Although in Buenos Aires city the temperature is rising at a rate of 0.02ºC/year as a consequence of the urban heat island (Barros & Camilloni, 1994), the temporal scale of the present study might be insufficient to detect this trend. Regarding water availability, the frequency of dry periods was the only variable related to rainfall that showed a marginally significant change through time, with a reduction in the number of dry periods in recent years. The negative relationship of the magnitude of oviposition activity with the number of dry events suggests that the regular and frequent distribution of rainfall events is favorable for *Ae. aegypti* population dynamics.

The result of the GLMM analysis shows the variables associated with high oviposition activity. The relationship with temperature has been previously reported for Buenos Aires city (Otero et al., 2008), and also for other regions along a altitudinal gradient in Mexico (Lozano-Fuentes et al., 2012) or Nepal (Dhimal et al., 2015). The fact that months with higher rainfall amounts during the warm period (as suggested by the significant interaction term) attain higher abundances seems also straightforward because of the increased availability of larval habitats after abundant rainfall. Such findings have been reported for the city of Salto, Uruguay, where a significantly higher number of breeding sites have been observed in a rainy year as compared to a year of drought. Moreover, the most productive larval habitats in that study were those filled by rain water (Basso et al., 2016). However, the manual filling of containers by the human population is a frequent practice that has been reported in other parts of the world (Morrison et al., 2004; Kearney et al., 2009, Basso et al., 2016), and might provide an alternative source of water in the absence of rainfall. Although no statistics on the filling method of water-holding containers are available for Buenos Aires city, filling independent of rainfall has been inferred from simulations of population dynamics with a mathematical model (Romeo Aznar et al., 2013). However, the most interesting result is that oviposition activity significantly relates to season after adjusting for weather variables, which suggests that the observed trend of increasing abundances is independent from weather variables.

In short, our results indicate that environmental and climatic conditions in Buenos Aires city have not changed in the last years, but were favorable enough to allow for steady increases in abundances during the last years. This fact, together with the recently documented expansion towards colder areas in Buenos Aires province (Zanotti et al., 2015), suggest that local populations of this species might be adapting to lower temperature conditions. Such adaptation has been documented within four generations in a population of Taiwan experimentally exposed to low temperatures in the larval stage (Chang et al., 2007).

Vector abundances, together with a complex array of factors that include the arrival of persons with the disease, play a significant role in the transmission dynamics (Eisen & Moore, 2013). The transmission dynamics of dengue has been studied with mathematical models for the particular conditions of Buenos Aires city, considering vector abundance dynamics comparable to that shown in our study for 1998-2001 (Otero & Solari, 2010). In this study, the epidemic risk and the size of the final epidemic outbreak have been estimated under different scenarios, and the results suggest that early outbreaks have a very low probability, but are likely (if they occur) to produce large epidemics because of the long time to evolve before the decrease in the vector populations in the cold season. As a consequence of the faster increase in spring abundances of *Ae. aegypti* during the last years in Buenos Aires, the time window when vector abundances exceed transmission thresholds increases significantly, and conditions become more favorable for early outbreaks with large epidemics. Such conclusions are supported by the increasing importance of local transmission of dengue in Buenos Aires city. The first report of a single case of local transmission in Buenos Aires Metropolitan Area occurred during 2007 (Natiello et al., 2008). For Buenos Aires city a total of 20 cases of local transmission were confirmed two years later in 2009 (0.2 for each imported case), while during the epidemics in 2016 the number of confirmed cases of local transmission increased to 4739 over 9 for each imported case (Health Ministry of Argentina, 2016). According to our findings, the monitoring of *Ae. aegypti* should be continued, but also complemented with studies on the abundance, distribution and dynamics of larval habitats in this region.

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