Brazil 2014 Butterfly Effect: the 2014 World Cup creates the potential for a malaria outbreak in sub–Saharan Africa

CL Faust[1]*, AP Dobson[1]

[1]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ USA

*correspondence to: CL Faust (cfaust@princeton.edu), 106A Guyot Hall, Princeton, NJ 08544 USA

Abstract

The 2014 World Cup Brazil will create excitement around the globe, but viewership in Africa should be especially high after South Africa 2010 and the growing popularity of football. The time difference and scheduling of matches, however, means that 86% of live matches will be shown during active *Anopheles* feeding times, increasing risk for malaria for millions of Africans. The aim of this paper is to draw attention to this potential outbreak and to suggest efforts to mitigate outbreaks.

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

Tension and excitement is mounting for the 2014 Fédération Internationale de Football Association (FIFA) World Cup, to be held in Rio de Janeiro and eleven other Brazilian cities. Teams from 32 countries and six continents have qualified and will compete for the championship from June 12 to July 13, 2014. Throughout Africa the anticipation is particularly high, as increasing interest and investment in football is supporting Algeria, Cameroon, Côte d'Ivoire, Ghana, and Nigeria in Brazil (Fig. 1C). Although dengue outbreaks have been predicted in Brazil [1-2] this will be more of a relative risk for visitors to Brazil than for locals, as the same number of mosquitoes will be distributed across a larger number of potential hosts. The situation may significantly worse in tropical Africa, where interest over which teams will qualify has distracted many from a significant epidemiological problem that may arise. The 2014 World Cup Brazil will be the first to be hosted in the Americas since 1994 (Fig. 1A) and we believe that this tournament will inadvertently expose millions in sub-Saharan Africa to mosquitoes carrying malaria and potentially lead to major malaria outbreaks.

To evaluate how malaria risk in sub-Saharan Africa has changed with this World Cup as opposed to previous global tournaments, we examined timing of live matches, access to televised matches, and growing interest in soccer.

This is the first time the tournament has been held in a country to the west of Africa since 1994, so live matches will be televised during the evenings and at night which coincide with peak mosquito biting times. World Cup matches used to be scheduled only twice a day, but to expand the number of people that can watch, games are scheduled at 1pm, 4pm, 6pm and 9pm local time, in twelve cities, across two time zones, from June 12 to July 13, 2014 [4]. This change in scheduling increases the total time that non-overlapping matches are shown and increases the window of risk for infection by mosquito bite. Most of the schedule matches fall

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

within active *Anopheles* biting times across most of Africa (Fig. 1B). The peak biting times will vary by species, local environment, and behavioral adaptations, but all dominant African malaria vectors feed during dusk or nighttime hours (reviewed by [4]). For example, *An. gambiae senso stricto (s.s.)* is considered one of the most efficient malaria vectors globally and is reported from most countries in Africa [5]. This species is of concern in bars and other indoor viewing areas across a wide range of environments, especially in West Africa where many teams have advanced to the World Cup. Alternatively, *An. arabiensis* is an exophagic vector that can be anthrophilic, depending on locality, and will be of most concern in savannah environments where people are watching outdoors [6]. The degree to which exposure to *Anopheles* malaria vectors is increased will depend on where matches are watched (indoor vs. outdoor) and the biting habits of local malaria vectors.

Although the World Cup was held in Mexico in 1986 and in the USA in 1994, increased risk due to watching World Cup games was minimal because of limited access to electricity and low proportion of households with televisions (Fig. S1). Over the last twenty years, an increasing number of people have been able to watch the footballs games in sub-Saharan Africa: driven by access to electricity and increased TV ownership [7, 8]. Electricity access in sub-Saharan Africa increased from 23% to 32% of the population from 1990 to 2010 [7]. Although sub-Saharan Africa still has relatively low access to electricity, an average of 63% of urban populations have electricity compared to only 14% of rural populations [7]. Proportion of households with televisions has increased in all sub-Saharan African countries (Fig. S1). People across the region watch football matches in bars, kiosks, theatres, outdoor viewing areas or collectively in private households [9]- so we acknowledge that proportion of households with televisions is not a definitive metric but does point towards increased access. This is supported by the fact that

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

during the 2010 World Cup, there were an estimated 86 million independent viewing events (of at least 29 continuous minutes) in South Africa and Nigeria [10]. The growing football fan base in Africa creates a huge stationary pool of mosquito bait and potential malaria hosts.

The overwhelming majority of malaria-induced morbidity and mortality occurs in Africa [11], and we fear that 2014 Brazil will only worsen these numbers. Not all places will be affected equally and increased risk will depend on rainfall immediately before and during the tournament (Fig. 1C). Moreover, the tournament will last long enough for one complete cycles of malaria transmission to occur- sporozoites of *Plasmodium falciparum* can be found in mosquitoes around 10 days after feeding on an infected host [12] and gametocytes are produced 10-15 days after an infection in humans [13]. If African teams do well and make the later stages of the tournament, then levels of exposure will increase with sustained interest and enthusiasm for African teams.

What could be done to avert potential outbreaks? Certainly it is unlikely that we will be able to discourage people in Africa from watching the World Cup. Nor are people likely to enjoy watching the games from the relative sanctity of their mosquito net covered beds. Instead we recommend that supplies of combination antimalarial drugs and rapid diagnostic tests (where applicable) be increased in anticipation of an outbreak. Additionally, indoor residual spraying (IRS) can be targeted to bars and other viewing areas to reduce resting *Anopheles*. If mass drug administrations are considered [14], these should be applied in late May or early June to maximize effectiveness in relation to the World Cup. Even though none of these approaches is perfect, in combination they may be the only way to avert a potential major malaria epidemic in Africa during the World Cup 2014.

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

Acknowledgements: Authors are grateful to A. van Leeuwen for her feedback. CF is funded by the National Defense Science and Engineering Graduate Fellowship.

References:

[1] Hay SI (2013) Football fever could be a dose of dengue. Nature 503:439.

[2] Lowe R, Barcellos C, Coelho CAS, Bailey TC, Coelho GE, Graham R, Jupp T, Ramalho WM, Carvalho MS, Stephenson DB, and Rodó X. Dengue outlook for the World Cup in Brazil: an early warning model framework driven by real-time seasonal climate forecasts. Lancet Infectious Diseases (http://dx.doi.org/10.1016/S1473-3099(14)70781-9).

[3] FIFA (2013) Match schedule. Available: http://www.fifa.com/mm/document/tournament/competition/01/52/99/91/2014fwc_matchschedule_04112013_st2_en_neutral.pdf. Accessed 20 October 2013

[4] Sinka ME, Bangs MJ, Manguin S, Coetzee M, Mbogo CM, et al. (2010) The dominant Anopheles vectors of human malaria in Africa, Europe and the Middle East: occurrence data, distribution maps and bionomic précis. Parasit Vectors, 3:117. doi: 10.1186/1756–3305–3–117.

[5] Coetzee M, Craig M, le Sueur D (2000) Distribution of African malaria mosquitoes belonging to the *Anopheles gambiae* complex. Parasitol Today, 16:74–77.

[6] Tirados I, Costantini C, Gibson G, Torr SJ (2006) Blood–feeding behaviour of the malarial mosquito *Anopheles arabiensis*: implications for vector control. Med Vet Entomol 20:425–437.

[7] Banerjee SG, Bhatia M, Azuela GE, Jaques I, Sarkar A, et al. (2013) Overview. Vol. 2 of Global Tracking Framework. Sustainable energy for all. Washington: The World Bank

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

Available: http://documents.worldbank.org/curated/en/2013/01/17752511/global-tracking-framework-vol-2-3-overview. Accessed 1 November 2013.

[8] ICF International. (1986–2012). Demographic and Health Surveys. Available: http://www.measuredhs.com/Data/. Accessed 11 October 2013.

[9] Akindes GA (2011) Football bars: urban sub-Saharan Africa's trans-local 'stadiums.' Int. J. History of Sport 28: 2176-2190.

[10] KantarSport (2010). 2010 FIFA World Cup South Africa™: Television Audience Report. Available: http://www.fifa.com/mm/document/affederation/tv/01/47/32/73/2010fifaworldcupsouthafricatvaudiencereport.pdf. Accessed 1 November 2013.

[11] WHO Global Malaria Programme (2012) World Malaria Report 2012. Geneva: World Health Organization.

[12] Beier JC (1998) Malaria parasite development in mosquitoes. Ann Rev Entomol 43: 519-543.

[13] Garnham PCC (1966) Malaria Parasites and Other Haemosporidia. Oxford: Blackwell Scientific. 1114 p.

[14] Greenwood B (2004) The use of anti-malarial drugs to prevent malaria in the population of malaria-endemic areas. Am J Trop Med Hyg 70: 1-7.

[15] Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *Int J Climatol*, 25:1965–1978.

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014

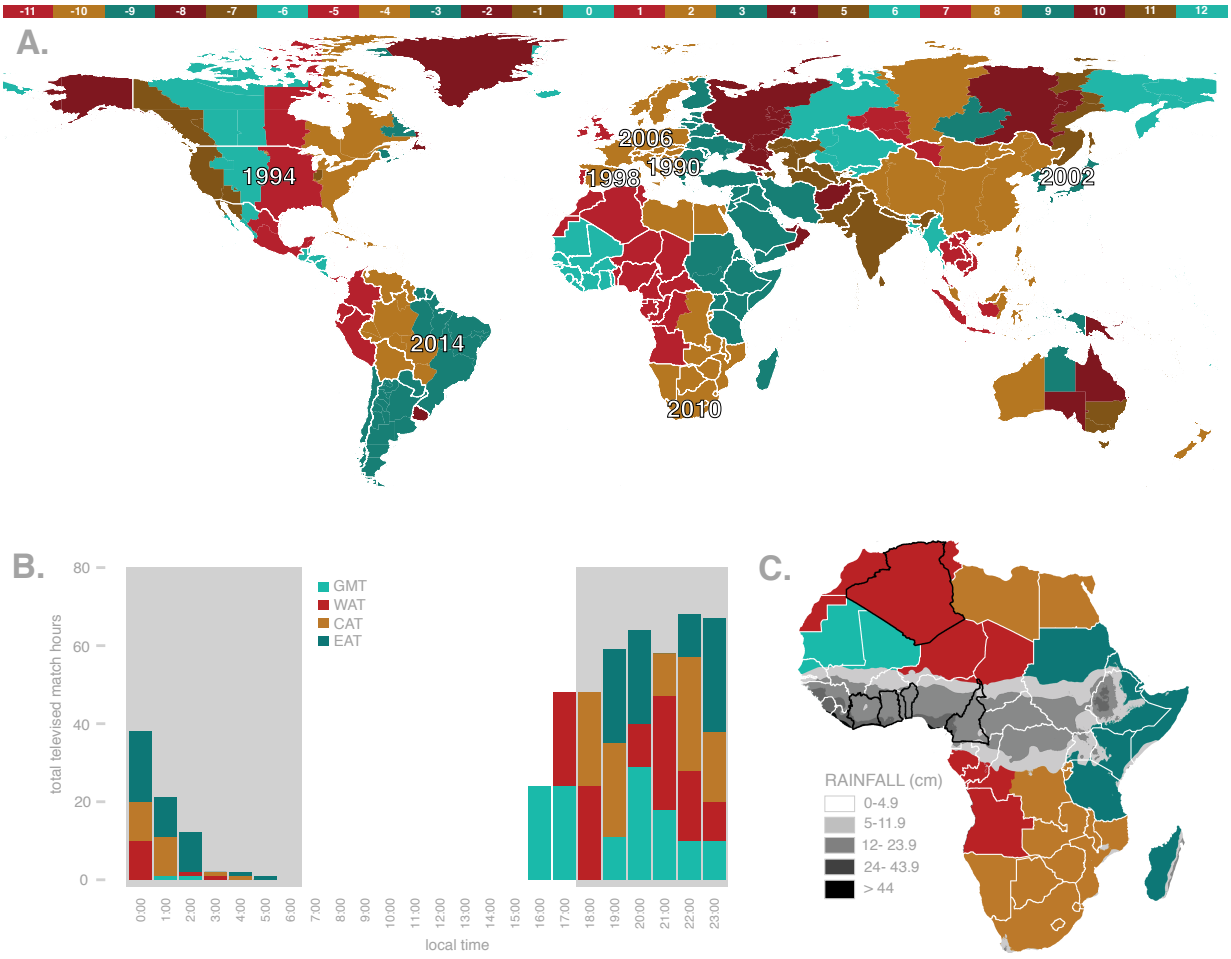

Figure 1. World Cup hosts and local viewing times in Africa. (A) The time zones are shown with daylight savings time for the relevant countries. The last world cup to be held west of Africa was the 1994 World Cup USA– all other World Cups in the last twenty years were shown in similar time zones or early in the morning in Africa. (B) Total hours of matches that will be shown at local time in the four African time zones: Greenwich Mean Time (GMT/UTC 0), West Africa Time (WAT/ UTC +1), Central Africa Time (CAT/ UTC +2), and Eastern Africa Time (EAT/ UTC +3). The gray shading indicates active Anopheles feeding times. (C) The map of Africa shows average cumulative June rainfall from 1980–2011 [15]. Countries outlined in black have qualified teams in the 2014 World Cup.

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.402v1 | CC-BY 4.0 Open Access | received: 3 Jun 2014, published: 3 Jun 2014