1   Running head: Excel tool for Zika vector surveillance

2

3   A location-specific spreadsheet for estimating

4   Zika risk and timing for Zika vector surveillance,

5   using U.S. military facilities as an example

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11

12   ABSTRACT

13   Local Zika virus transmission in the United States involving one or both of the known

14   vector species, *Aedes aegypti* and *Ae. albopictus,* is of major concern. To assist efforts

15   to anticipate the risks of transmission, we developed an Excel spreadsheet tool that

16   uses vector and virus temperature thresholds, remotely sensed maximum temperature,

17   and habitat suitability from models to answer the questions: "is Zika transmission likely

18   here?" and "when should we conduct vector surveillance?". An example spreadsheet,

19   updated regularly and freely available, uses near real-time and forecast temperature

20   data to generate guidance, based on a novel four level Zika risk code, for 733 U.S.

21   military facilities in the 50 states, the District of Columbia, and the territories of Guam

22   and Puerto Rico.

23   KEY WORDS: Zika, *Aedes aegypti*, *Aedes albopictus*, Risk, Excel

INTRODUCTION

In 2016, Zika virus disease and congenital infections became nationally notifiable conditions in the United States (Council of State and Territorial Epidemiologists, 2016). A total of 2,382 confirmed and probable cases of ZIKAV disease with illness onset were reported to ArboNET, the U.S. national arboviral surveillance system managed by CDC and state health departments, during January 1 – July 31, 2016 (Walker et al. 2016). In July 2016 the first locally acquired cases of Zika virus (ZIKAV) from mosquitoes were confirmed for the U.S. state of Florida (Likos, 2016). *Aedes* mosquitoes transmit ZIKAV, chikungunya virus (CHIKV), dengue virus (DENV), and yellow fever virus (YFV), among others, so co-infections are possible. Although *Ae. albopictus* is thought to be a competent vector of ZIKAV (Grard et al. 2014), *Ae. aegypti* has been implicated as the primary transmitter of the virus in human populations in the ongoing outbreak in the Americas (Guerbois et al. 2016, Ferreira-de-Brito et al. 2016). This is likely the result of *Ae. aegypti* preferring to feed more frequently on humans (Scott et al. 1993, 2000), and being highly peridomestic compared to *Ae. albopictus*, which can inhabit more rural environments (Braks et al. 2003; Tsuda et al. 2006).

In this study, we concentrated on U.S. Department of Defense (DoD) facilities but the approach could be used for any area of interest. Some military facilities have long standing mosquito surveillance programs (Foley et al. 2011a), and Zika virus surveillance is being enhanced in the U.S. military as a result of the recent threat, for example, through funding from the Global Emerging Infections Surveillance and Response (GEIS), section of the Armed Forces Health Surveillance Branch in the Defense Health Agency's Public Health Division (Pellerin, 2016). According to a March 2016 U.S. DoD memo, 190 DoD installations are located in areas where mosquitoes capable of carrying ZIKAV occur, and increased vector monitoring will be conducted in installations in 27 states, the District of Columbia, Guam and Puerto Rico (Kime, 2016). Four regional commands exist under the U.S. Army Medical Command, and all of these have Entomological Sciences Divisions that conduct mosquito surveillance. Additionally, the U.S. Air Force School of Aerospace Medicine, the U.S. Navy and Marine Corps Public Health Center and regional Navy Environmental and Preventative Medicine

54 Units, and the Navy Entomology Center of Excellence, assist those undertaking vector

55 surveillance or arbovirus testing.

56   For a military entomologist tasked with establishing and maintaining an *Aedes*

57 spp. / ZIKAV surveillance program in temperate areas that experience high mosquito

58 seasonality, two important questions arise: 1) is ZIKAV transmission possible here?;

59 and 2) when should we conduct vector surveillance?. In the following we describe an

60 Excel-based tool that is designed to assist entomologists and other health personnel

61 address these two questions.

62   Habitat suitability models displaying potential distribution have been published for

63 both *Ae. aegypti* and *Ae. albopictus* (Attaway et al. 2016, Brady et al. 2014, Campbell et

64 al. 2015, Khormi & Kumar 2014, Medley 2010), as well as for ZIKAV (Carlson et al.

65 2016, Messina et al. 2016, Perkins et al. 2016, Samy et al. 2016). While these models

66 often display average yearly suitability they do not necessarily provide information that

67 could be used for decisions about the timing of surveillance activities, and are global in

68 extent rather than focused on particular areas where a surveillance program might be

69 established. Questions about timing of mosquito monitoring and allocation of resources

70 requires a consideration of what conditions limit adult mosquito activity and ZIKAV

71 dissemination in the field.

72   Relative humidity, rainfall, drought, and wind velocity affect survival and behavior

73 of mosquitoes, and therefore transmission (Kramer & Ebel, 2003). However,

74 temperature is the most important ecological determinant of development rate in *Ae.*

75 *aegypti* (Couret & Benedict 2014), and one of the principal determinants of *Aedes*

76 survival (Brady et al. 2013). Temperature also directly affects the replication rate of

77 arboviruses, thus affecting the extrinsic incubation period (Gubler et al. 2007). What

78 then, do we know about how temperature limits *Aedes* and arboviruses like ZIKAV?

79   In Saudi Arabia, Khormi et al. (2011) found that the minimum temperature range

80 of 18-25 °C is suitable for *Ae. aegypti* survival, and the survival rate increases up to 38

81 °C. Conner (1924) and Wayne & Graham (1968) found that *Ae. aegypti* is most active at

82 temperatures between 15 °C and 30 °C, while other field and laboratory observations

83 found survival rates from about 18 °C to ≤ 38 °C, based on daily or monthly minimum

84 and maximum temperatures (Macfie, 1920; Bliss & Gill, 1933; Christopher, 1960). In a

85   study of *Ae. aegypti* distribution using the program CLIMEX, Khormi & Kumar (2014) set

86   the limiting low temperature at 18 °C, the lower optimal temperature at 25 °C, the upper

87   optimal temperature at 32 °C and the limiting high temperature at 38 °C. Brady et al.

88   (2014) limited their predictions of temperature suitability to areas with a maximum

89   monthly temperature exceeding 13°C for *Ae. albopictus* and 14°C for *Ae. aegypti*.

90   These threshold temperatures were based on previous studies of the observed

91   temperatures below which biting and movement behaviors are impaired [Christophers,

92   1960; Estrada-Franco & Craig, 1995; Carrington et al. 2013a,b).

93   Studies suggest that an increase between 14-18 °C and 35-40 °C can lead to

94   higher transmission of dengue (Wallis, 2005). Xiao et al. (2014) found that oral

95   infections of DENV2 did not produce antigens in the salivary glands of *Ae. albopictus*

96   kept at 18°C for up to 25 days but did produce antigens at 21°C during this period. It is

97   not known if *Ae. albopictus* held longer at the lower temperature would have

98   disseminated infections, but Dohm et al. (2002) found that *Culex pipiens* required 25

99   days at 18°C to disseminate infections of West Nile Virus. For comparison, WNV is

100 capable of replication from 14-45°C (Cornel et al. 1993, Kinney et al. 2006). Tilston et

101 al. (2009) analyzed monthly average temperature of cities that experience chikungunya

102 outbreaks and found that start and finish occurred when average monthly temperatures

103 were 20°C or higher. At the upper temperature limit, Kostyuchenko et al. (2016) found

104 that ZIKAV is more thermally stable than DENV, and is also structurally stable even

105 when incubated at 40°C, mimicking the body temperature of extremely feverish patients

106 after virus infection (but see Goo et al. 2016).

107 Remotely sensed temperature data is freely available from multiple sources as

108 both near-real time recordings and forecast predictions. Combining remotely sensed

109 temperature data with predicted distributions of the vectors and virus could provide

110 insight into when areas of interest are suitable for transmission and should be actively

111 monitored. Our aim was to produce a knowledge product and surveillance decision tool

112 that makes use of publicly available information about potential distribution and thermal

113 requirements of the vectors and virus at U.S. military facilities.

114

MATERIALS AND METHODS

Areas of interest

The location and boundary of U.S. military facilities was obtained from the US Census Bureau's TIGER/Line 2015 shapefile product (http://www.census.gov/geo/maps-data/data/tiger.html). This shapefile lists facilities in the continental United States (CONUS), Alaska, Hawaii, Puerto Rico and Guam. As some facility names comprised multi-part polygons, these were reduced from 804 to 733, to match the number of unique facility names, using the Dissolve tool in ArcMap 10.4 (ESRI, Redmond, CA – used throughout). The centroid of each facility was selected to produce a shapefile of points using the Feature to Point tool (inside polygon option checked) of ArcMap. The georeference of each point was obtained by the Add XY Coordinates tool and joined to the points shapefile. Extraction of all facility centroid raster values was first obtained by the Extract values to points tool then for polygons using the Zonal statistics as Table tool, and the results merged. This approach was needed because smaller polygons would not produce results using the Zonal statistics as Table tool, which necessitated using the raster data associated with the points for these facilities.

Temperature data

To monitor temperature in near real-time, daily time averaged maps of air temperature at the surface (Daytime/Ascending) were downloaded from the Giovanni 4.19 (Released Date: 2016-04-12. Data provided by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC)) data portal at 1° spatial resolution. Daily gridded temperature analyses were also collected from the NOAA, U.S. National Weather Service Climate Prediction Center (CPC). Forecast temperature data was also provided by the CPC and the NOAA National Digital Forecast Database (NDFD) at 5 km spatial resolution. For predictions based on monthly averages, monthly gridded climate data with a spatial resolution of 1 km were downloaded from the WorldClim (Version 1.4) Global Climate Data center.

Habitat suitability models

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144   We chose the models of *Ae. aegypti* and *Ae. albopictus* by Kraemer et al. (2015),

145   as these are recent and are based on an extensively documented set of presence

146   observations for each vector. For this study, we used the habitat suitability model for

147   ZIKAV transmission by Messina et al. (2016). The 0.5 model suitability score was

148   arbitrarily used as the cut-off for presence/absence.

149   **Thresholds**

150   Temperatures suitable for activity of *Ae. aegypti* and *Ae. albopictus* combined

151   was estimated as 13 – 38°C, and for ZIKAV this was 18 – 42°C. We acted

152   conservatively by using temperatures at the extremes of the reported suitable

153   temperature range, and maximum rather than mean air temperatures.

154   **Human population data**

155   In order to more fully understand the potential impact of ZIKAV risk to military

156   and non-military personnel and their families in and around each facility, we explored

157   risk in terms of human population data, with the following considerations. The flight

158   range of *Ae. aegypti* and *Ae. albopictus* is in the order of hundreds of meters only

159   (Honório et al. 2003, Harrington et al. 2005) and each facility would differ in the average

160   distance that human carriers of ZIKAV would routinely travel to and from each facility.

161   Additionally, some facilities are remote, while others are adjacent to or enclosed within

162   urban and suburban areas. Despite these complications, we created a buffer of 5 km

163   around all facility polygons to capture the human population density according to

164   LandScan 2011 (Oak Ridge National Laboratory). This was accomplished using the

165   LandScan raster and the Buffer and sum output in the Zonal Statistics as Table tools in

166   ArcMap. A buffer of 5 km is a conservative estimate and is meant to give a uniform

167   measure for each facility of the potential host density effected in an outbreak or vector

168   control situation.

169   **Excel-based Zika risk tool**

170   A goal of this project was to display disparate data sources visually and in a

171   simple and intuitive way in order to more effectively communicate the level of risk at

172 each military facility. The risk estimation and alert system needed to be in a format that

173 was readily understandable and that can be easily accessed by military users, who

174 often have IT security restrictions or bandwidth caps. We chose MS-Excel® (Microsoft

175 Corp, Seattle, WA), as a universal platform for performing calculations and reporting

176 results. This software had the added advantage that the scatterplot function can be

177 used to map each military facility (Foley, 2011b), with icons displaying various

178 categories of risk, and using a geocorrected map background (Esri, DeLorme, USGS,

179 NPS. World Terrain Base - Sources: Esri, USGS, NOAA) for each U.S. State. Other

180 notable features that were used in the Excel risk estimation tool were the formula

181 functions, conditional formatting to represent categories of numbers as different types of

182 symbols, dependent dropdown lists and hyperlinks to allow users to navigate more

183 quickly to the results of individual facilities, and textualized results that users can read

184 as statements describing the situation and as guidance for vector surveillance.

185 **Calculations within the Excel Risk Estimation Tool**

186   Given the maximum temperature is available for a site (i.e. "Temp."), the

187 following lists an example sequence of tasks and their calculations, with explanations

188 and the Excel formula (in square brackets), culminating in a risk rating:

189   1. Column A. "Was temperature suitable during period for the vector?", i.e. if the

190   maximum was 13 to 38°C, it is 1 otherwise 0 [=IF((Temp.>=13)-

191   (Temp.>38),1,0)],

192   2. Column B. "Was temperature suitable during period for virus replication in

193   mosquito?", i.e. if the maximum was 18 to 42°C, it is 1 otherwise 0 [

194   =IF((Temp.>=18)-(Temp.>42),1,0)]

195   3. Column C. What is the sum of the thermal suitability values for vector (Column A)

196   and virus (Column B)? (i.e. possible choices are: 0, 1 or 2)

197   4. Column D. If temperature for the vectors (Column A) was within the required

198   range, what is the model suitability for vector?, i.e. this was the maximum

199   modeled suitability (0 – 1.00) for either *Ae. aegypti* or *Ae. albopictus*

5. Column E. Score vector model suitability as 3 if >=0.5, otherwise 2 [=IF(Column D<0.5,2,IF(Column D>=0.5,3))]. The 0.5 model suitability score was arbitrarily used as the cut-off for presence/absence.

6. Column F. If temperature for the virus (Column B) was within the required range, what is the model suitability for the virus? (0 – 1.00)

7. Column G. Score virus model suitability as 7 if >=0.5, otherwise 5 [=IF(Column F<0.5,5,IF(Column F>=0.5,7))]. The 0.5 model suitability score was arbitrarily used as the cut-off for presence/absence.

8. Column H. What is the "Combined Score" for the interaction of temperature suitability of vector and virus, vector model suitability, and virus model suitability score (i.e. = C*E*G)? The use of 0, 1 and prime numbers for the component scores produces a unique semi-prime number for the product, i.e. 0, 10 (=1*2*5), 14 (=1*2*7), 15 (=1*3*5), 21 (=1*3*7), 20 (=2*2*5), 28 (=2*2*7), 30 (=2*3*5), or 42 (=2*3*7). A zero indicated that the temperature at the site was unsuitable for both vector and pathogen, so suitability scores were irrelevant, and combination scores were all scored zero.

9. The nine possible Combined Scores were divided into 6 categories based on whether preconditions do not exist for transmission, are unsuitable for transmission, are somewhat suitable for transmission, or are suitable for transmission (Figure 1).

10. Column I. An Overall Zika Risk Code was established based on the Combined Score (Figure 1), and rates conditions as low (Blue: Code 1) to high risk (Red: Code 4). The nine possible Combined Scores are initially divided according to whether temperature conditions are not suitable (Code 1), or suitable, for the vectors and virus (Codes 2 - 4). Codes 2 - 4 are then characterized according to increasing habitat suitability, with Code 4 being where models predict suitable habitat for vectors and virus.

11. Action statements were constructed based on the temperature and habitat model suitability scores (Figure 2). For example, if conditions are too cold for the development of the vectors, and models predict that the location is unsuitable for the vectors then the Action statement would be: "Too cold or hot for vectors -

231   surveillance unnecessary. When temp. suitable, model suggests vectors unlikely

232   or low numbers.". Alternatively, if conditions are warm enough for the

233   development of the vectors, and models predict that the location is highly suitable

234   for the vectors then the Action statement would be: "Temp. suitable for vectors -

235   surveillance may be needed. When temp. suitable, model suggests vectors likely

236   - may need control, education, and policies minimizing exposure."

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238   **Figure 1**. An overall Zika Risk Code based on the combined score, which rates

239   conditions from low risk (Blue: Code 1) to high risk (Red: Code 4).

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| Zika risk code	Detailed explanation	Preconditions for transmission	Combination score
1	Temperature not OK for Vector and Virus	Preconditions do not exist for Transmission	0
1	Temperature OK for Vector or Virus but not both. Model says habitat not very suitable for Vector	Preconditions do not exist for Transmission	10,14
1	Temperature OK for Vector or Virus but not both. Model says habitat suitable for Vector	Preconditions do not exist for Transmission	15,21
2	Temperature OK for Vector and Virus. Model says habitat not very suitable for Vector and Virus	Preconditions unsuitable for Transmission	20
3	Temperature OK for Vector and Virus. Model says habitat suitable for Vector or Virus but not both.	Preconditions somewhat suitable for Transmission	28,30
4	Temperature OK for Vector and Virus. Model says habitat suitable for Vector and Virus.	Preconditions suitable for Transmission	42

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248   **Figure 2**. Action statements constructed on the basis of the temperature and habitat

249   model suitability scores

| Variable	Outcome	Action Statement
Temperature threshold for Zika vectors	Temperature below threshold (< 13° C)	Too cold for vectors - surveillance unnecessary.
	Temperature above threshold (=> 13° C)	Warm enough for vectors - surveillance may be needed.
Vector Suitability	Low vector suitability (< 50%)	When warm enough, model suggests vectors unlikely or low numbers.
	High vector suitability (=> 50%)	When warm enough, model suggests vectors likely - may need control, education, and policies minimizing exposure.
Temperature threshold for Zika virus	Temperature below threshold (< 18° C)	Too cold for Zika - surveillance unnecessary.
	Temperature above threshold (=> 18° C)	Warm enough for Zika - surveillance may be needed.
Zika Suitability	Low Zika suitability (< 50%)	When warm enough, model suggests Zika unlikely.
	High Zika suitability (=> 50%)	When warm enough, model suggests Zika likely - may need control, education, and policies minimizing exposure.
	No data	No Model result for vector suitability.

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RESULTS

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253   The Excel files provided comprise 12 monthly files based on average monthly

254   maximum temperatures (suitable for longer term planning), and near real-time and

255   forecast file, updated weekly. These files are freely available via the VectorMap website

256   (http://vectormap.si.edu/Project_ESWG_ExcelZika.htm). The tool provides risk maps of

257   facilities as a continental overview (Figure 3), and on a U.S. State basis (Figure 4).

258   Results for individual facilities are navigable via dropdown menus and hyperlinks

259   (Figure 5). State-wide summary data of risk profile and humans potentially impacted is

260   given in Figure 6. The temporal changes in average risk based on the 12 monthly files is

261   given in Figure 7 in terms of the number of facilities affected (of 733) and the number of

262   people within 5 km of these facilities. April to October was the period of greatest risk

263   with suitable conditions for Zika transmission (i.e. code 4) potentially affecting a

264   maximum of 114 facilities in 12 states and territories, and 4,546,505 people within the

265   vicinity of these facilities, of a total of 32,811,618 within the vicinity of all 733 facilities.

266   The maximum number of facilities recording code 4 in any one month (e.g. August)

267   were: Florida (36), Hawaii (16), Louisiana (12), Texas (11), and Virginia (11). Of these,

268   the number of people within 5 km of these facilities were: Texas (1,215,230), Florida

269   (1,125,032), Louisiana (462,586), Virginia (409,066), and Hawaii (247,918).

270 These data may assist public health planning, and can be seen as an indicator of

271 potential disease burden, or of people potentially benefiting from a well-informed vector

272 surveillance and control program conducted within military facilities. Results are

273 provided in a variety of symbologies and as textualized statements of how the factors

274 examined may impact ZIKAV transmissions, and recommended actions for

275 entomologists conducting routine vector surveillance. The action statement textualizes

276 the data and is designed to assist a preparedness posture particularly around vector

277 surveillance and control. Changes in the action statement over the year, for example as

278 a result of rising temperature, can be used as a guide to affect changes in vector

279 surveillance and control activities at particular facilities.

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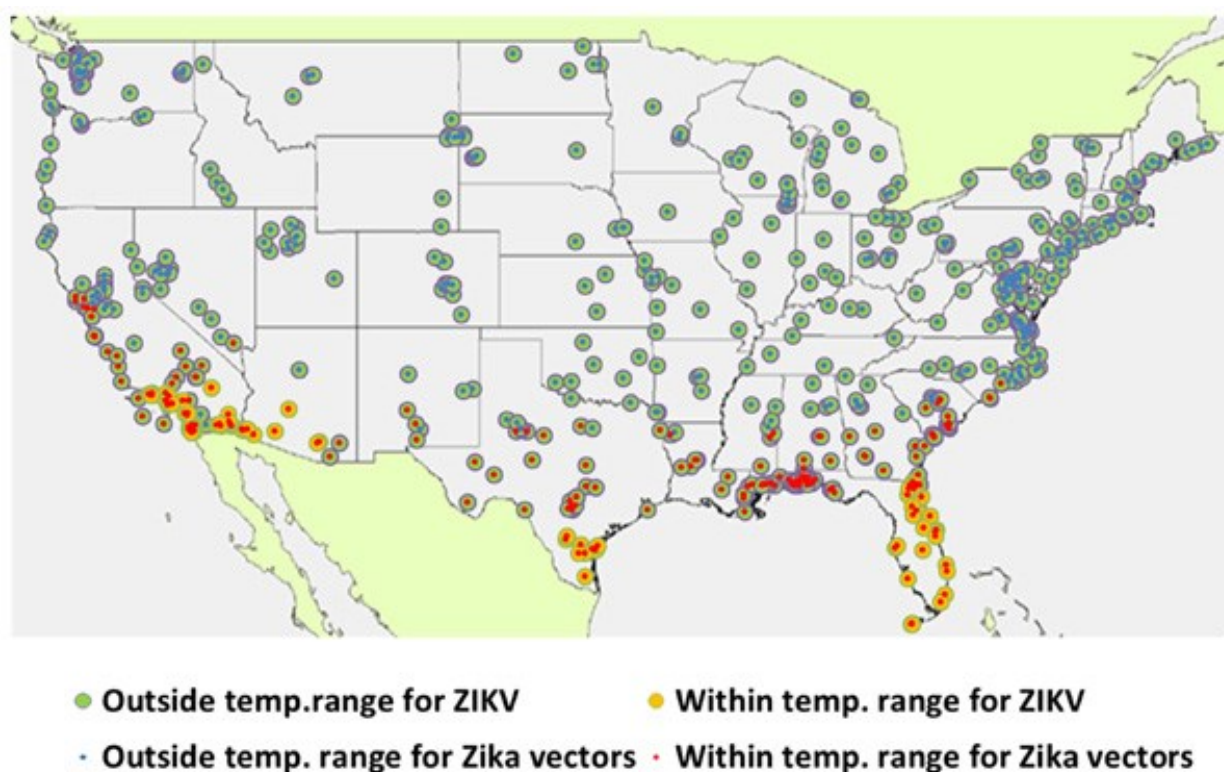
283 **Figure 3.** Average maximum temperature conditions for January for vectors and ZIKAV

284 at military facilities within the lower 48 states of the U.S.

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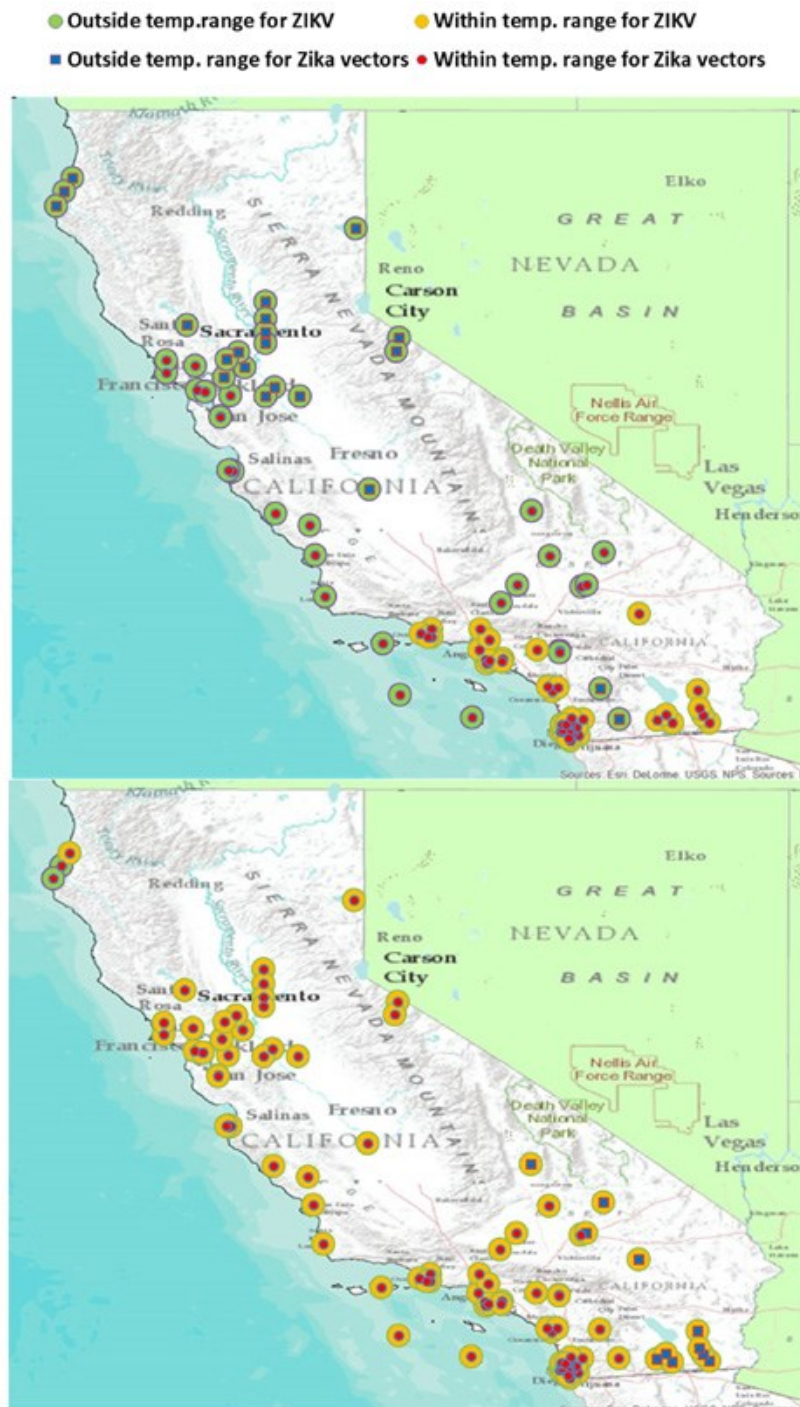
Figure 4. Thermal conditions for January (above) and August (below) for vectors and ZIKAV at military facilities in California. Note, unsuitable conditions in August in the south are due to temperatures being too high for the vectors.

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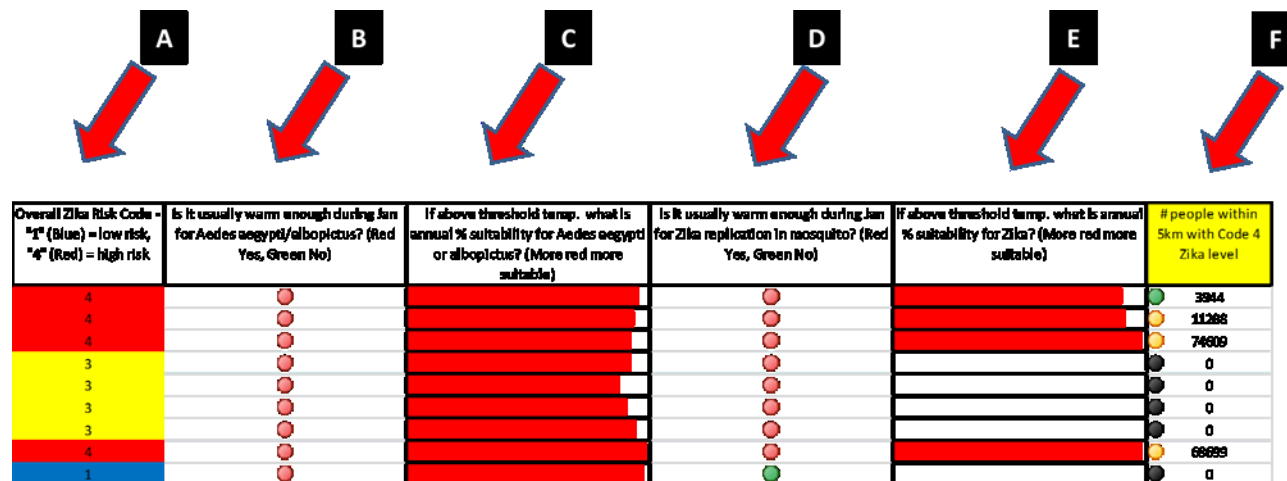
293 **Figure 5.** An overall Zika virus risk code for near real-time and forecast periods (A) is

294 assigned based on a combination of: temperature suitability for adult activity of the

295 vectors (*Ae. aegypti* and *Ae. albopictus*) (B), modeled habitat suitability of the vectors

296 (C), temperature suitability for Zika virus replication within the vectors (D), and modeled

297 habitat suitability of Zika virus transmission (E). If suitable conditions exist (Zika Risk

298 Code 4), the number of people within 5 km is shown (F) as one indication of the number

299 of potential hosts in the vicinity, or the number of humans potentially benefiting from

300 facility-wide vector surveillance and control programs.

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Summary of Vector hazard during January for U.S. Military facilities by State for Zika virus

State	# Military facilities[1]	Zika Risk Code[2-5] (average)	# facilities where preconditions suitable for transmission (Zika Risk Code 4)[5]	# facilities with above threshold temperature for the vectors[6]	# facilities with above threshold temperature for the pathogen[7]	Total population within 5 km of facilities[8]	Total population within 5 km with suitable conditions for transmission
Alaska	20	1	0	0	0	357,044	0
Alabama	14	1	0	10	0	553,648	0
Arkansas	4	1	0	0	0	187,622	0
Arizona	11	2.19	0	10	0	556,120	0
California	100	1.71	0	79	0	6,655,724	0
Colorado	9	1	0	0	0	386,446	0
Connecticut	10	1	0	0	0	212,038	0
District of Columbia	8	1	0	0	0	842,772	0
Delaware	2	1	0	0	0	52,946	0
Florida	48	2.44	17	48	1	1,373,859	653,556
Georgia	16	1	0	9	0	1,021,113	0
Hawaii	36	3.2	16	36	1	980,370	247,918
Iowa	2	1	0	0	0	266,567	0

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303 **Figure 6.** Summary risk data for each U.S. State to assist with public health and
304 resource allocation planning.

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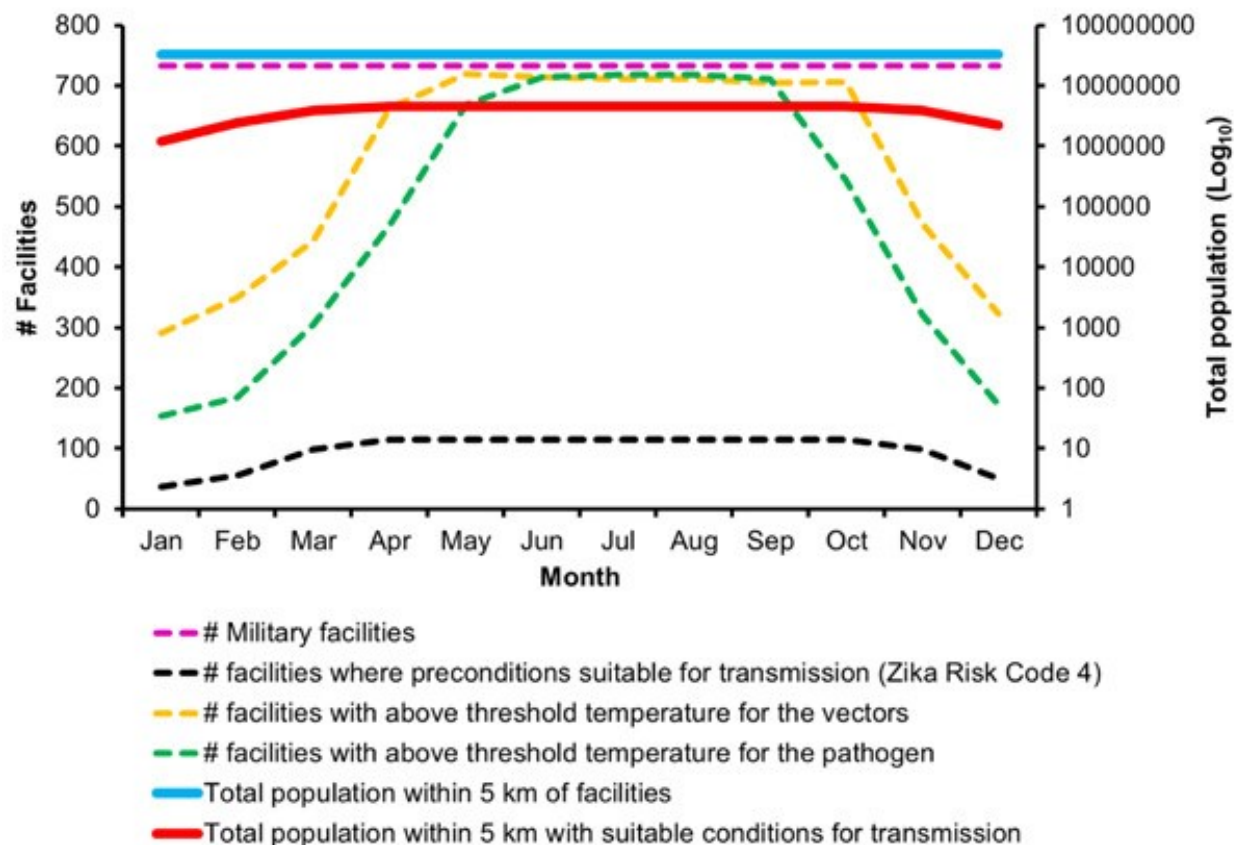
Figure 7. Summary risk data for 733 U.S. military facilities over 12 months.

DISCUSSION

This Excel tool is designed to provide insights into ZIKAV transmission potential at U.S. military facilities, but could be applied to other arboviruses and situations, such as cities (Monaghan et al. 2016), tire dumps or parks. The spreadsheet is flexible in that vector and virus suitability model scores, temperature limits, and the wording of action statements can be replaced depending on the context, and as new information comes to light.

For U.S. military situations, this tool could be used in conjunction with the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) or Medical Situational Awareness in Theater (MSAT), which

319   reports on febrile illnesses and rash in the military population. Coordination of result

320   reporting through the Armed Forces Pest Management Board (AFPMB) and VectorMap

321   may also be desirable. The Navy and Marine Corps Public Health Center's guide

322   (NMCPHC, 2016) states that "each installation's medical personnel should conduct

323   ongoing *Aedes* surveillance during the mosquito season appropriate to their region and

324   take preventive and responsive action to reduce disease risk to active duty, government

325   employees, and family member populations". In addition, the DoD instruction

326   OPNAVINST 6250.4C "requires all Navy and Marine Corps installations to have an

327   Emergency Vector Control Plan (EVCP) for disease vector surveillance and control

328   during disease outbreaks". The spreadsheet described in this study should complement

329   "installation pest management plans, including the EVCP, as a way to assess the risk of

330   vector borne diseases, and implement strategies to reduce the risk to personnel

331   assigned to installations" (NMCPHC, 2016).

332   Knowing when conditions are suitable for vectors is crucial for monitoring the

333   success or failure of any control program. Appendix C of NMCPHC (2016) consists of a

334   chart to determine the risk of infection on an installation and when to apply vector

335   control measures. This four level vector threat response plan relies on information about

336   vector abundance and reports of disease transmission. We see the Excel spreadsheet

337   risk tool as a valuable adjunct to the NMCPHC plan, as it would assist with defining the

338   length of the mosquito season, and the judicious deployment and timing of

339   entomological resources. Each military facility is unique, and varies in size, function,

340   human density, and suitable mosquito habitat, so not all of the 733 facilities addressed

341   in this study will be at risk of mosquito-borne disease and suitable candidates for

342   mosquito surveillance. However, all locations, at worst, should be useful as a point of

343   reference for other nearby locations where mosquito surveillance is conducted.

344   The Zika Risk Code developed here (Figure 1) derived some inspiration from

345   Figure 3 of Fischer et al. (2013), who combined models of vector habitat suitability with

346   temperature categories for CHIKV replication to produce a matrix of climate related risk

347   classes.

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348   It is important to note that each data source used in this analysis has the

349   potential for errors which should be considered when determining risk. For example,

350   habitat suitability models for each vector may not be accurate for all areas, and only

351   predict average yearly suitability. Temperature data refers to the maximum day-time air

352   temperature near the surface (averaged over various spatial resolutions) from daily data

353   for a recent date range, which NASA acknowledges has limitations. Vectors can also

354   seek microclimates (e.g. indoors, subterranean habitats) that may be warmer or cooler

355   than the outside temperature that is estimated by remote sensing data. Temperatures

356   within the suitable range may not effect organisms uniformly. According to Westbrook et

357   al. (2010) adult females reared from immature stages at 18°C, were six times more

358   likely to be infected with CHIKV than females reared at 32°C. Westbrook et al. (2010)

359   noted that climate factors, such as temperature, experienced at the larval stage, which

360   would not be detected by adult trapping programs, can influence the competence of

361   adult females to vector arboviruses.

362   We also do not account for temperature fluctuations; according to Lambrechts et

363   al. (2011), mosquitoes lived longer and were more likely to become infected with DENV

364   under moderate temperature fluctuations, than under large temperature fluctuations.

365   Thangamani et al. (2016) and Ferreira-de-Brito et al. (2016) found that ZIKAV can be

366   vertically transmitted in *Ae. aegypti* but not *Ae. albopictus*. This capability suggests

367   mechanisms for the virus to survive in eggs that can survive for months in a dried

368   dormant state during adverse conditions, e.g. a harsh winter that would normally kill

369   adults.

370   The risk levels calculated in the spreadsheets deliberately uses simplified

371   assumptions about temperature and does not consider precipitation, interspecific

372   competition, anthropogenic factors such as imported cases, built-up areas, vegetation

373   indices, and economic indices that can modify risk in complex and less understood

374   ways. It is recommended that a level of caution be taken when interpreting the data

375   provided by this system. It is wise to monitor activity in surrounding facilities and any

376   reputable information from other sources before acting on any recommendations given

377   here. It is further recommended that the near-real time and forecast analysis should be

378 viewed in conjunction with the monthly average Excel vector hazard files which uses

379 average monthly maximum temperature, to gain further longer term insights into where

380 thermal conditions will support vector activity.

381

382 ## ACKNOWLEDGMENTS

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396 ## REFERENCES

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