Public perceptions of threats from mosquitoes in the U.S. using online media analytics

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ABSTRACT

Mosquito-borne illnesses present a public health threat. This analysis quantifies general online mosquito media, and the Zika virus (ZIKV) specifically, from 7–20–2016 to 10–20–2018 in five U. S. geographies. The ZIKV sub-search comprised a shrinking share of online media about mosquitoes over time. Net sentiment, numerical scoring of search result positivity/negativity bounded between –100 and +100, was assessed. Mean net sentiment for the general mosquitoes search was –51; –55 for ZIKV. The ZIKV search revealed more variation in weekly net sentiment with a standard deviation of 14, compared to 10 for mosquitoes. Seventy-seven percent of the weeks had a net sentiment for the mosquito search that was more positive than the ZIKV search. For the 23% of the time the ZIKV search net sentiment was more positive than the general mosquito search, there were mentions of scientific advances, such as the potential for vaccine development associated with the post. Greater emphasis on public health threats from mosquitoes may be necessary to stimulate public action on mosquito-borne illness control. This analysis serves as an illustration of the potential for online/social media analysis to inform health officials of public interest/focus, and perhaps inform effective communication campaigns to combat public health threats.

KEYWORDS

Public health; Zika virus; mosquito; public perceptions; social media listening

1. Introduction

‘The deadliest killer in human history might not be guns or bombs, cancer, or car accidents. It’s a pesky insect that most of us don’t think twice about: the mosquito.’ wrote Hope [1]. The book *The Mosquito*, opens with Chapter 1: Toxic Twins, The Mosquito and Her Diseases [2]. Popular press is increasingly echoing what doctors have long proclaimed, ‘When we think of deadly animals, we tend to think of sharks or snakes. But the deadliest animal in the world, in terms of how many people it kills every year, is by far the mosquito’ [3]. Zika virus (ZIKV), an *Aedes* mosquito-borne arbovirus, was declared a Public Health Emergency of International Concern by the World Health Organization (WHO) in February 2016 [4, 5, 6, 7, 8, 9, 10, 11]. When symptoms of ZIKV infections manifest they are most commonly reported to be similar to signs of other arboviral infections [12]. Thus, a greater awareness of disease risk and associated symptoms may aid in diagnoses and reporting of cases.

The ZIKV outbreak resulted in an increase in related social media posts that directly correlated to the number of Associated Press news articles being published about the outbreak [13]. Social media has become a primary source of news and health information for the majority of adults in the U.S. [14], with more than

90% of physicians reporting the use of social media for circulating information and education about health [15]. Social media has also been employed in health interventions such as preventing smoking [16] and may be harnessed to improve awareness of foodborne illness [17]. Investigations comparing online news to Twitter about genetically modified (GM) mosquitoes revealed that Twitter discussion was more benefit-oriented whilst news media was more balanced [18]. Although not all the information being posted on social media outlets was accurate, there were significantly more evidence-based and informative posts than not [19]. While social media data are questioned due to the lack of control with regard to spreading of potentially false information, it has been shown that false rumors tend to be questioned more than confirmed truths [20]. Social media data, in particular analytics of quantity and sentiment of social media over time, has been studied with respect to ZIKV vaccine misconceptions [21], ZIKV-related health crisis communication [22], and even in tracking ZIKV cases by proxy of geo-tagged Twitter data [23, 24]. Significant focus has been placed on studying perceptions of various mosquito-borne diseases, and even on acceptance of GM mosquitoes to reduce human health risks.

This study of public perceptions related to mosquitoes summarizes what aspects of mosquitoes are most commonly mentioned in online media. The purpose of this work is to quantify the volume and sentiment associated with social and online media about mosquitoes broadly, and ZIKV specifically. The study time period surrounds the 2016 Zika virus outbreak. Given the amount of public health attention on ZIKV during the 2016–2018 time period it was hypothesized that media related to ZIKV comprised a significant portion of total media dedicated to mosquitos in the U.S. Fundamentally this analysis sought to identify what share of online chatter about mosquitoes during this time period was focused on ZIKV. This study uniquely focuses first on mosquitoes generally, and then determines the proportion of those search results specific to ZIKV media coverage. It was hypothesized that the demographics of people posting about ZIKV would be reflective of those likely to be most impacted, including women of childbearing age and those in warmer climates. Understanding the data surrounding how mosquitoes are discussed broadly on social media platforms can inform educational campaigns and public health efforts with respect to communicating about the general risks of mosquitoes relative to communicating specifically about ZIKV or other mosquito-associated diseases/risks. The use of social and online media listening and analysis has the potential for informing health campaigns and communication more broadly.

2. Methods

Data collection facilitated by in-depth Internet/web searches, often focused on media sources and news outlets, has long been utilized in social science research [for example, via platforms such as LexisNexis 24]. Vast quantities of online media are now available for analysis for use in marketing, research, brand monitoring, and other purposes. Social listening tools have been developed to aid in search, surveillance, and analytics and are perhaps most commonly used in marketing where lists such as ‘top 20 social media listening tools for 2020’ present pros and cons of various platforms [25]. This analysis employed the Netbase platform, which offers search and analysis capabilities for online media, including blogs, forums, consumer reviews, Twitter, Instagram, News, and other media (Netbase, 2018). Netbase ranks among the top social listening platforms, and has been used for research purposes as well as quantifying interest and sentiment for product development [26]. Searches across countries and in multiple languages

are technologically possible, although limitations surrounding language interpretation, like slang, shorthand, sarcasm, and cultural context must be acknowledged. For this analysis, the geographic area for all searches employed was limited to the United States and the U.S. Virgin Islands; posts in English were studied exclusively.

Online search results related to keywords associated with mosquitoes and ZIKV were studied during the time period of 7–20-2016 through 10–20-2018. The 27-month time period studied offers sufficient time for positive and negative news-worthy events related to mosquitoes and associated illnesses, along with seasonality. The dates on which data were formally collected were documented, which is important given the fluidity of data collected through social media posts as they may appear, be removed, and/or be reinstated. Data were downloaded and summarized on October 20th, 2018.

Primary search terms were developed by the interdisciplinary research team using knowledge of subject matter and top media articles related to the topics of interest to quantify online and social media related to mosquitoes generally and included terms such as mosquito, #mosquito, and #AedesAegypti. Additional primary search terms included references to ZIKV, including #mosquitoborne, ZIKA, zikv, and #Zika, and mosquito bites/prevention including #NoWaterNoMosquitoes, #BiteFree, and #FighttheBite were included. In total there were 102 primary search terms employed to populate the general mosquitoes search (Appendix 1). The general search related to mosquitoes was conducted for five geographies. First, the United States and the U.S. Virgin Islands were searched.¹ Second, the 29 states plus Puerto Rico region which is home to the *Aedes Aegypti* mosquito, as defined by the Center for Disease Control and Prevention (2017)² was identified as a sub-search. Data specific to the states Texas and Florida individually, as well as the U.S. Virgin Islands, were collected due to their prominence in the news/media with respect to ZIKV risk. Each of the five geographies was searched with and without with an additional filter designed to aid in quantifying the media hits specifically related to ZIKV. In total, 61 search terms, including Zika, Zikv, #VirusZika, #Zikafever, and microcephaly were used to develop the ZIKV-specific searches (Appendix 2).

Opinion mining and sentiment analysis are research tools being used across a multitude of topical areas. A sentiment score was assigned for search results returned within the inclusionary and exclusionary search terms outlined; sentiment was analyzed for every subject in a sentence using the natural language processing capabilities in Netbase [27]. Net sentiment is a construct of the comparison of positive versus

¹The general United States and U.S. Virgin Islands search included the continental United States and the U.S. Virgin Islands, but did not include all U.S. territories, specifically American Samoa, Guam, Northern Mariana Islands, and the United States Minor Outlying Islands.

²<https://www.cdc.gov/zika/vector/range.html>

negative posts. As presented throughout this analysis, the net sentiment is the percentage of positive posts less the percentage of negative posts, thus resulting in a net sentiment that is necessarily bounded between -100% and $+100\%$. Neutral posts are accounted for although they are not used in the net sentiment calculation. Net sentiment, or general positivity/negativity for each of the searches – in addition to the total numbers of posts, mentions, and potential impressions – were all analyzed to provide insight into the scale and tone of online media conversations focused on mosquitoes and ZIKV.

3. Results

Figure 1 depicts both the general mosquito and ZIKV-specific mentions for the U.S. and the Virgin Islands, as well as the *Aedes Aegypti* mosquito zone. While the

late summer of 2016 has the largest total volume of social media mentions, a seasonal pattern of increased summertime mentions is evident across the study time period. The summertime spikes in mosquito search mentions seen in the larger dataset were mimicked using only the Florida and Texas search results (Figure 2).

Search hits about ZIKV decreased over time, as did the proportion of mentions about ZIKV in the mosquitoes search results. The Virgin Islands search resulted in a much smaller dataset than the other searches. These data are visualized in Appendix 3 for completeness, but the distinct increased summertime mentions pattern is not evident, which could be due to the small dataset or differences in climate/weather seasonality.

The demographics of people posting on social media, when known (from posts on Twitter), are displayed in Tables 1 and 2, which show the gender,

Figure 1. Total numbers of monthly mentions for general mosquito and Zika-specific searches in the United States and Virgin Islands and the *Aedes Aegypti* mosquito zone searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

Figure 2. Total numbers of monthly mentions for general mosquito and Zika-specific searches in the Texas and Florida searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

implied age, day of the week, and time of the day for posts included in the mosquitoes and ZIKV searches. Throughout [Tables 1 and 2](#) the sample size (n) is displayed for each demographic and/or summary provided. The gender of social media posters was roughly evenly split with 48% male and 52% female for the general U.S. and *Aedes Aegypti* region searches, while females comprised 55% of known posters in the Texas dataset. The whole U.S. search revealed that most posts were from people within the age groups of 25–34 and 55–64. Similarly, the largest proportion of contributors were in the 25–34 age bracket for the mosquito region and Texas. The ages of social media contributors in Florida were a bit different than the others with 19% being 45–54 years of age and 18% (the 2nd highest proportion) being in the 25–34 years of age bracket.

The timing of posts for both the general mosquito searches and the Zika-specific searches revealed that

the smallest proportion of posts occurred on the weekends across all regions, except the Virgin Islands ([Table 1](#)). Looking specifically at Zika-related posts, all five geographic search regions also revealed the relative lull of posts on Saturdays and Sundays. Notable in the Virgin Island specific searches about ZIKV, the lowest proportion of posts occurred on Saturday, Sunday, Monday, and Tuesday, all with 8% of total posts (n = 130 total). The timing of posts is difficult to interpret in terms of whether post timing is more related to the timing of internet and social media access, or is actually related to the topic being posted about.

[Table 3](#) (general mosquito searches) and [Tables 4](#) (ZIKV searches) outline top words used by social media contributors to self-describe their profession and interests. Most notable in terms of differences in professions between the general mosquito and the Zika-specific searches is the rise of health and medicine being in the top five mentioned professions for all

Table 1. Demographics of posters for general mosquito searches using Twitter data only (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

	U.S. and Virgin Islands	Aedes Aegypti Mosquito Region	Texas	Florida	Virgin Islands
Gender (n)	1,871,726	1,187,509	176,802	165,805	199
Male	48%	48%	45%	51%	84%
Female	52%	52%	55%	49%	16%
Implied Age (n)	1,825,595	1,166,262	180,407	157,990	200
<18	10%	10%	12%	10%	6%
18–24	13%	14%	15%	13%	10%
25–34	18%	18%	19%	18%	12%
35–44	15%	15%	15%	15%	14%
45–54	15%	15%	14%	19%	17%
55–64	18%	17%	15%	15%	28%
65+	11%	11%	9%	11%	14%
Posts by Day of Week (n)	1,795,410	1,239,450	150,350	193,180	240
Monday	14%	14%	15%	15%	22%
Tuesday	16%	16%	16%	17%	22%
Wednesday	15%	15%	15%	16%	22%
Thursday	16%	16%	15%	16%	22%
Friday	16%	16%	15%	17%	22%
Saturday	11%	11%	11%	10%	22%
Sunday	11%	11%	12%	10%	22%
Posts by Time of Day (n)	1,795,410	1,239,450	150,350	193,180	240
12 am–6 am	14%	13%	13%	12%	21%
6 am–12 pm	35%	34%	31%	36%	25%
12 pm–6 pm	39%	39%	38%	42%	21%
6 pm–12 am	29%	30%	34%	27%	38%
Mentions (n)	8,056,383	2,648,770	391,173	46,901	549
All Posts (n)	5,106,727	2,632,003	389,418	378,841	537

Table 2. Demographics of posters for Zika-specific searches using Twitter data only (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

	U.S. and Virgin Islands	Aedes Aegypti Mosquito Region	Texas	Florida	Virgin Islands
Gender (n)	809,333	500,230	48,481	91,486	124
Male	51%	52%	49%	55%	3%
Female	49%	48%	51%	45%	97%
Implied Age (n)	767,242	475,049	49,408	85,252	
<18	8%	8%	9%	8%	
18–24	11%	11%	11%	11%	
25–34	16%	16%	16%	16%	
35–44	15%	15%	15%	15%	
45–54	17%	17%	16%	16%	
55–64	20%	21%	20%	21%	
65+	13%	13%	13%	13%	
Posts by Day of Week (n)	1,034,560	675,590	66,210	127,620	130
Monday	14%	14%	15%	15%	8%
Tuesday	16%	16%	16%	17%	8%
Wednesday	16%	16%	16%	16%	25%
Thursday	17%	17%	16%	17%	17%
Friday	18%	18%	19%	19%	25%
Saturday	10%	10%	10%	9%	8%
Sunday	8%	8%	8%	7%	8%
Posts by Time of Day (n)	1,034,560	675,590	66,210	127,620	130
12 am–6 am	13%	12%	11%	11%	31%
6 am–12 pm	37%	37%	36%	38%	31%
12 pm–6 pm	41%	41%	41%	43%	31%
6 pm–12 am	26%	25%	27%	25%	15%
Mentions (n)	4,513,018	1,030,206	101,733	200,802	271
All Posts (n)	2,157,068	1,024,975	101,328	199,606	267

but the Virgin Islands searches when searching for ZIKV. Looking at the general mosquito searches, the top interest in every one of the five geographies searched was ‘family.’ In the Virgin Islands posts, ‘travel’ was the number one interest, with ‘family’ a close second.

The top things mentioned in posts in the general mosquito searches are summarized in Table 5. Looking across all five geographical areas, ZIKV surfaces as the top two negative things mentioned about mosquitoes generally. Negative verbiage about mosquito bites

themselves comprised the top five terms for each region. In terms of positive sentiments, mosquito repellents, curtains/nets, and some mentions about mosquito control and even GM mosquitos in Florida appear consistently across all searches about mosquitoes.

Table 6 depicts the top terms identified for the ZIKV searches. The ZIKV searches are more targeted to verbiage/mentions about ‘virus,’ ‘infection,’ and ‘Zika’ than about mosquito bites more generally. ‘Zika funding’ is among the top five words in both the Aedes Aegypti

Table 3. Top words used for interests and professions as self-descriptors for posters from general mosquito searches using Twitter data only (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

Top Words Used For:	U.S. and Virgin Islands	Aedes Aegypti Mosquito Region	Texas	Florida	Virgin Islands
Interests	n = 916,726 Family Politics Music Food and Drink Religion	n = 644,666 Family Politics Music Travel Food and Drink	n = 82,517 Family Religion Politics Music Food and Drink	n = 86,903 Family Politics Food and Drink Religion Music	n = 187 Family Travel Sports Food and Drink Music
Professions	n = 547,205 Creative Arts Journalism Blogging Education Student	n = 399,192 Creative Arts Journalism Blogging Student Education	n = 44,397 Creative Arts Education Journalism Student Health and Medicine	n = 2,331 Journalism Sales and Marketing Blogging Law and Order	n = 145 Creative Arts Farming and Fishing Blogging
	25% 17% 14% 13% 12%	26% 16% 15% 12% 12%	25% 19% 17% 12% 11%	25% 19% 17% 12% 11%	28% 19% 12% 12% 10%
	38% 10% 8% 8% 8%	38% 10% 8% 8% 8%	40% 12% 9% 9% 8%	40% 12% 9% 9% 8%	19% 8% 8% 6%
					97% 7% 1%

Table 4. Top words used for interests and professions as self-descriptors for posters from Zika-specific searches using Twitter data only (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

Top Words Used For:	U.S. and Virgin Islands	Aedes Aegypti Mosquito Region	Texas	Florida	Virgin Islands
Interests	n = 464,600 Family Politics Food and Drink Religion Travel	n = 316,288 Family Politics Food and Drink Religion Travel	n = 33,744 Politics Family Religion Food and Drink	n = 52,665 Family Politics Food and Drink Religion Travel	n = 146 Travel Family Sports Photo and Video Arts and Crafts
Professions	n = 303,348 Creative Arts Journalism Health and Medicine Blogging Student	n = 219,903 Creative Arts Journalism Health and Medicine Executive Management Blogging	n = 20,649 Music Creative Arts Journalism Education Health and Medicine Student	n = 40,967 Law and Order Sales and Marketing Blogging Health and Medicine	n = 122 Creative Arts Farming and Fishing Banking and Finance Construction Education
	27% 24% 14% 11% 10%	28% 23% 13% 11% 10%	27% 25% 15% 13%	28% 25% 12% 12% 10%	79% 76% 75% 8% 7%
	33% 13% 9% 8% 8%	33% 13% 9% 8% 8%	10% 33% 14% 12% 10%	8% 8% 8% 5%	99% 8% <1% <1%

Table 5. Top things mentioned in general mosquito searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

Top Words Used For:	n	Things – General Mosquito Search			
		Positive		Negative	
U.S. and Virgin Islands	352,305	Zika virus	4%	Zika virus	35%
		mosquito repellent	3%	mosquito bite	15%
		mosquito net	1%	Zika infection	7%
		mosquito bite	1%	mosquito-borne virus	3%
		Zika vaccine	1%	Florida	2%
Aedes Aegypti Mosquito Region	2,648,770	Zika virus	4%	mosquito bite	25%
		Mosquito repellent	3%	Zika virus	18%
		Bug Mosquito	3%	Florida	6%
		mosquito bite	2%	Bug Mosquito	3%
		Door Window Curtain Net Mesh Screen Protector	1%	fucking mosquito	3%
Texas	11,570	Mosquito repellent	6%	mosquito bite	28%
		mosquito bite	5%	Zika virus	12%
		depression Mosquito good ass raspas	3%	fucking mosquito	5%
		depression	3%	damn mosquito	5%
		Zika virus	2%	Texas	3%
Florida	12,023	Zika virus	4%	Florida	30%
		Mosquito repellent	4%	Zika virus	21%
		mosquito control	2%	mosquito bite	10%
		Zika funding	1%	Zika infection	3%
		genetically modified mosquito	1%	zika virus fear spread	2%
Virgin Islands	5	mosquito repellent	20%	ZIKA VIRUS	20%
		lotion	20%		
		mosquito net	20%		
		tanning oil	20%		

region and Texas searches as a negative term; however, it also appears as a positive term in the *Aedes Aegypti* region and Florida searches. Positive mentions about 'vaccines,' 'repellent,' and the 'genetically modified mosquito' (in the *Aedes Aegypti* region) and the 'zika fighting GMO mosquito' (in Texas) are also present.

Domains and sources for the general mosquito searches are presented in Table 7, while Table 8 displays this information for the Zika virus subsearches. The top domain for posts about mosquitoes and ZIKV was twitter.com. The net social media sentiment over time is presented graphically for the U.S. and the Virgin Islands searches in Figure 3. Over the entire time period studied, the mean net sentiment for the general mosquitoes

search for the U.S. and the Virgin Islands was −51; the mean net sentiment for ZIKV was −55. The ZIKV search revealed more variation in weekly net sentiment values with a standard deviation of 14, relative to a standard deviation of 10 for mosquitoes. The net sentiment for the ZIKV sub-searches was generally more negative than the general mosquito searches. Seventy-seven percent of the weeks for which data were recorded had a net sentiment for the mosquito search that was more positive than that for the ZIKV search. For the 23% of the time that the ZIKV search net sentiment was more positive than the general mosquito search, there were often mentions of positive aspects associated with scientific advances, such as the potential for vaccine development. Oftentimes negative

Table 6. Top things mentioned in Zika-specific searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

Top Words Used For:	n	Things- Zika-Specific Search			
		Positive		Negative	
U.S. and Virgin Islands	266,095	Zika virus	6%	Zika virus	44%
		mosquito repellent	1%	Zika infection	9%
		Zika vaccine	1%	mosquito bite	4%
		novel #zika protection	1%	mosquito-borne virus	3%
		Zika testing	1%	Zika virus infection	2%
Aedes Aegypti Mosquito Region	1,029,872	Zika virus	9%	Zika virus	42%
		Zika funding	2%	Zika infection	6%
		Zika vaccine	2%	Zika funding	3%
		best Indoor Mosquito Repellent	2%	Florida	2%
		genetically modified mosquito	1%	mosquito bite	2%
Texas	3,604	Zika virus	9%	Zika virus	39%
		mosquito repellent benefit	2%	Zika infection	6%
		Texas Medicaid	2%	Texas	3%
		Zika vaccine	2%	Zika threat	3%
		zika fighting GMO mosquito	1%	Zika funding	2%
Florida	6,700	Zika virus	7%	Zika virus	37%
		Zika funding	2%	Florida	5%
		Zika drug breakthrough	1%	Zika infection	5%
		fsu research team	1%	zika virus fear spread	3%
		Zika vaccine	1%	Zika undercount	2%
Virgin Islands		Insufficient Data			

Table 7. Domains and sources for general mosquito searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

	Mosquito General U.S. and Virgin Islands		Aedes Aegypti Mosquito		Texas Mosquito		Florida Mosquito		Mosquito General Virgin Islands	
Domains	twitter.com	87%	twitter.com	98%	twitter.com	98%	twitter.com	97%	twitter.com	80%
Sources	reddit.com	5%	instagram.com	2%	instagram.com	1%	instagram.com	2%	instagram.com	19%
	tripadvisor.com	2%	tripadvisor.com	1%	tripadvisor.com	<1%	tripadvisor.com	<1%	forum.bodybuilding.com	<1%
	instagram.com	2%	topix.com	<1%	ar15.com	<1%	topix.com	<1%	forum.woodenboat.com	<1%
	booking.com	1%	ar15.com	<1%	influenster.com	<1%	ar15.com	<1%	bedbathandbeyond.com	<1%
	Twitter	44%	Twitter	97%	Twitter	98%	Twitter	96%	Twitter	80%
	News	37%	Instagram	2%	Instagram	1%	Instagram	2%	Instagram	19%
	Forums	10%	Forums	1%	Forums	1%	Forums	1%	Forums	<1%
Domains (n)	Blogs	8%	Consumer Reviews	1%	Consumer Reviews	<1%	Consumer Reviews	<1%	Consumer Reviews	<1%
	Instagram	1%								
Domains (n)		4,084,388		2,648,770		389,434		377,910		549
Sources (n)		8,055,446		2,648,770		391,173		378,841		549

Table 8. Domains and sources for Zika-specific searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

	Mosquito Zika U.S. and Virgin Islands		Aedes Aegypti Zika		Texas Zika		Florida Zika		Mosquito Zika Virgin Islands	
Domains	twitter.com	88%	twitter.com	99%	twitter.com	99%	twitter.com	98%	twitter.com	92%
Sources	reddit.com	2%	instagram.com	<1%	instagram.com	<1%	instagram.com	1%	instagram.com	8%
	rssfeeds.wtsp.com	2%	tripadvisor.com	<1%	tripadvisor.com	<1%	tripadvisor.com	0%		
	community.babycenter.com	2%	topix.com	<1%	ar15.com	<1%	ar15.com	0%		
	rssfeeds.khou.com	1%	ar15.com	<1%	topix.com	<1%	topix.com	0%		
	News	52%	Twitter	99%	Twitter	99%	Twitter	98%	Twitter	92%
	Twitter	34%	Forums	1%	Forums	1%	Instagram	1%	Instagram	8%
	Blogs	9%	Instagram	<1%	Instagram	<1%	Forums	1%		
Domains (n)	Forums	5%	Consumer Reviews	<1%	Consumer Reviews	<1%	Consumer Reviews	<1%		
	Instagram	<1%								
Domains (n)		1,703,629		1,029,872		101,477		200,381		271
Sources (n)		4,513,023		1,029,872		101,733		200,802		271

Figure 3. Net sentiment for United States and Virgin Islands general mosquito and Zika-specific searches (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018).

spikes in mosquito sentiment without corresponding dips in ZIKV subsearch sentiment were associated with negative news coverage about mosquito-borne diseases aside from ZIKV.

4. Discussion

There has long been medical and public health knowledge of the threats that mosquitos pose to human health and well-being. Then ZIKV introduced a novel mosquito-related threat into U.S. mass media headlines prominently beginning in 2015–2016. Mosquitoes are a known and present danger to public health even in the U.S., where the population is at a lower risk of mosquito-borne disease outcomes as compared to many other places in the world. For instance, Eastern Equine Encephalitis (EEE) had more documented cases in the U.S. in 2019 than in previous years. EEE has a case fatality rate of 30% and many of those who survive the initial disease develop severe neurological complications (CDC, 2019).

The first reported local transmission of ZIKV in the Region of the Americas occurred in May of 2015 [28]. News media about mosquito-borne viruses was abundant in 2016 and [29], reported 84% of respondents to a national survey were aware of the 2016 ZIKV outbreak. The rate of concern regarding mosquito-borne illness may vary from state to state. Focusing on the state of Arizona specifically, Brown et al. (2019) found that half of the respondents were concerned about the West Nile and/or ZIKV. Thus, the majority of U.S. residents were likely exposed to some media about mosquitoes and ZIKV during the study period. Given the severity of disease caused by ZIKV and the amount of news media coverage

devoted to the Zika outbreak, it was hypothesized that ZIKV would represent a large proportion of the total mosquito chatter identified on social media. In actuality, chatter specific to ZIKV decreased over time in absolute numbers as well as the total proportion of mentions about mosquitoes in general. A similar pattern was observed during the 2014 Ebola virus outbreak which resulted in a large number of social media posts initially that rapidly decreased once the outbreak was no longer being publicized in traditional media outlets [30].

Widmar et al. (29) stated that although knowledge about ZIKV was reasonably high, few people were taking steps in 2016 to reduce mosquito bites. The relative lack of mosquito bite prevention during the height of focus on ZIKV combined with the now documented shrinking share of attention on ZIKV within mosquito chatter could indicate potentially troubling public health implications since preventing mosquito bites is about more than avoiding itchy skin irritations. Greater understanding of this relative shrinking of the proportion of chatter about mosquitoes devoted to ZIKV, or more generally a graduate decline in public attention on novel public health threats, is critical for crafting effective public health communications. Whilst the testable hypothesis presented in this analysis is specific to identifying the share of chatter about mosquitoes devoted to ZIKV, the concept of tracking public interest and/or attention by posters of varying demographics and/or interest groups could be explored more broadly. In particular, as public health globally is impacted by the ongoing COVID-19 pandemic there is concern about COVID-fatigue or pandemic-fatigue in which there is the waning capacity to keep up the focus on and participation in effective protective practices [31]. Given the ability to track waning public

chatter on other health threats, it is conceivable that fatigue and burnout are involved; whilst not directly tested it may be explored whether measuring the volume and tone of online media chatter can aid in diagnosing fatigue, or even potentially combatting it.

A lack of demographic representativeness among people posting to social media is one characteristic that may limit the generalizability of data to a larger audience. The number of posts for which demographic data were available is much smaller than the total number of posts included in the searches conducted as part of this study. It may have been hypothesized that ZIKV posts may have more female interest, due to the possibility of birth defects resulting from ZIKV, yet the search results failed to support that hypothesis. The attention from people within the 25–34 and 55–64 years age brackets may be due to demographics of those in various states, demographics of those active on social media, and/or those with increased interest in/attention to the topic.

The demographics of posters and information about the posts themselves are both of interest to researchers seeking to glean insights into public perceptions of public health threats or issues. Day of the week and time of the day were summarized for posts for which that information was available. Given the intersection between ZIKV interest and interest in travel, along with the lack of specific ‘time of the day’ factors associated with ZIKV the relatively benign results regarding the timing of posts is not unexpected. However, the ability to discern and effectively quantify time of day and/or day of the week among search results may be of interest in the investigation into other health-related topics. One could imagine day of the week impacts associated with childhood illnesses spread in schools, for example, or concern about worsening coughs from parents in the nighttime hours when coughs tend to worsen with croup [32], for example.

An interest in ‘travel’ was expected given the attention placed on ZIKV awareness and education for those traveling to/from impacted regions [33]. In addition to general information for travelers, the CDC has ‘special precautions for specific groups’ including (1) pregnant women, (2) the partners of pregnant women, and (3) those considering pregnancy [33]. Given the attention placed on educating residents around the risks surrounding pregnancy and ZIKV, the common interest of family among posters of ZIKV social media hits is indicative of the interest of this potentially impacted group.

Collection of top words and associations (positive versus negative) allows for greater depth of understanding about the conversations taking place online, beyond the scale of chatter in the form of search hits. Not surprisingly,

mosquito bites and negative verbiage about mosquitoes generally rounded out the top five terms for each region. The pathogenesis of the itch that is associated with mosquito bites is not well understood considering the commonality of the occurrence [34]. Given the discomfort from mosquito bites, the negativity associated with the bites themselves is unsurprising. The presence of social media posts regarding GM mosquitoes in the top five terms in Florida is unsurprising given that in 2016 residents voted on a measure related to the implementation of the use of a GM mosquito for mosquito population control.³ According to a 2016 report by M. Rozansky, 60% [10] of Florida residents favor the use of GM mosquitos as compared to 50% of the total U.S. While 57% of residents in Monroe County Florida voted in favor of the trial with GM mosquitos, 65% of the 643 residents who voted in Key Haven (the study site) were opposed [35, 36].

The specific platforms on which information is shared, for example, Twitter versus a blog post, is of interest in many veins of social media listening. Indeed, Twitter was the dominant domain in the searches conducted. The authors of Ref. 36 identified differences in sentiment about GE mosquitoes specifically between Facebook and Twitter, with Facebook being more negative. The domains and sources for information found in searches are of interest in developing a complete picture of the search terms on the web.⁴ While perhaps not making for the most attractive photos or imagery, it was found that Instagram is a reasonably popular medium for communicating/posting about mosquitoes generally. Also noteworthy is the difference in sources; for the general mosquito searches Twitter remains the largest source, but with only 44%, while News was the source for 37% of results. For the ZIKV searches News was the source for 52% of posts, whereas Twitter was the source for only 34% of posts, even though Twitter still dominated the domains on which search hits were found. Given the increasing interest in public health topics and scrutiny on where the information originates and gets shared it is more important today than ever before to inspect the sources of the data.

Given the nature of the subject matter of mosquitoes, which bite, cause discomfort, and act as a disease vector, and ZIKV, the expectation was for a negative overall sentiment in both the general mosquito search and the ZIKV sub-search. Whilst negative net sentiment is expected, insights in the movement of net sentiment, as well as quantity of posts, over time, aid in the understanding of the news events or media that occurred when net sentiment increases/decreases.

³There currently exists the option of using a GM mosquito to mitigate the spread of ZIKV. The GM mosquito (*Aedes Aegypti*) which mates to bear terminal offspring could be employed to fight the spread of ZIKV by being released to mate, thereby baring terminal offspring and significantly reducing the mosquito population.

⁴Domains refer to the specific web address of the material while sources generalize the specific domains to a category. For example, cbs.com would be considered a domain, while all news sources such as cbs.com or abc.com would be categorized within sources as news.

5. Conclusions

Attention to mosquitoes returned during the warmer months annually, while attention to ZIKV was highest at the start of data collection in 2016 and trended generally downward throughout the time period studied. Net sentiment for ZIKV was generally more negative than for mosquitoes, except when positive advances in ZIKV control, such as vaccine development potential, were discussed. Mosquito-borne illnesses other than ZIKV were responsible for dips in sentiment in the general mosquito search, highlighting the need for public education on mosquitoes and associated risks from mosquitoes broadly. In-depth understanding of the role of social media, over time, in keeping residents aware of and educated about public health threats can aid policy makers and public health officials in crafting messaging that resonates with individuals and spurs them to action.

A number of social listening platforms, employing various algorithms and natural language-processing tools, exist for use by marketers, researchers, and brand managers. Advances in search capabilities and data analytics continue, yet the variation between methods and the short-lived nature of social media data offers challenges in reproducibility as posts may be removed and/or changed over time. Limitations of social media data, including the self-reported nature of the data, casual sharing/reposting, propensity toward attention-getting posts or photos of itchy or unsightly bites, and the noisy nature of the data complicating interpretation are all valid criticism of the analysis conducted. However, the same search terms were employed over the entire time period studied and it is not believed that the quality of the data would/should change over the study time period. Future studies may wish to focus on additional mosquito-borne illnesses, or to incorporate alternative means of online data collection such as through search data, which may offer alternative insights given the private nature of search terms relative to social media.

It is noteworthy that in considerations of public health the tone or sentiment associated with conversations or posts is likely to be negative overall. Yet, as highlighted in this analysis, positive aspects of the public conversation do arise around treatment breakthroughs, vaccine development, and/or improvements in public health related to the disease/situation. In contrast to much of the online media scraping devoted to brand management, marketing, and/or sentiment tracking associated with various products or companies, monitoring conversations and sentiments toward public health has notably different intents necessitating alternative approaches and/or framing. In this case a variety of descriptive statistics were amassed to aid in the contextual interpretation of the findings surrounding the share of chatter about mosquitoes devoted to ZIKV. There may be continued benefits to monitoring public health topics of interest broadly to discern what

the public, or groups of invested individuals, are highlighting as related points and/or noteworthy topics, in addition to seeking specific terms or subsearches deemed important by researchers. Change or evolution of public interests, top words or things mentioned, or news coverage related to public health threats such as ZIKV, or the now critical COVID-19 pandemic, could potentially be assessed and responded to using understanding derived from online and social media data analytics. Informing of messaging campaigns, conducting analytics to track new or emerging issues within the context of a specified topic or threat, and/or tailoring messaging for individuals with varying interests are all possible uses of insights derived from online and social media analytics which would be incorporated into a public health campaign portfolio.

Disclosure statement

The authors declare there is no conflict of interest.

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Appendix 1. Search terms for the primary search surrounding mosquitoes

Primary Terms:

mosquito, Mosquito, #mosquito, #mosquitoes, #Mosquito, #Mosquitoes, #mosquitobite, #MosquitoBite, #mosquitoesbite, #MosquitoesBite, #bitefree, #BiteFree, Aedes, #AedesAlbopictus, #AedesAegypti, #MosquitoControl, #mosquitocontrol, #mosquitorepellant, #MosquitoRepellant, #mosquitorepellants, #MosquitoRepellants, #FighttheBite, #FightTheBite, #DrainandCoverMiami, #Dumpanddrain, #DumpandDrainAftertheRain, #NoWaterNoMosquitoes, #mosquitoborne, #MosquitoBorne, #mosquitoillness, #MosquitoIllness, #mosquitodisease, #MosquitoDisease, #MosquitoTransmitted, #mosquitotransmitted, arbovirus, arboviruses, arboviral, Arbovirus, Arboviruses, Arboviral, #Arbovirus, #arbovirus, mosquitoes, Mosquitoes, Mosquitoes, mosquitoes, #Mosquitoes, #mosquitoes, #mosquito, #Mosquito, #MosquitoesBite, #mosquitoesbite, Zika, ZIKA, zika, Zikv, ZIKV, zikv, ZIKv, #Zika, #ZIKA, #zika, #ZIKV, #zikv, #ZikV, #ZIKV, #zikavirus, #ZikaVirus, #VirusZika, #viruszika, #ZIKAVirus, #ZikaMosquito, #zika-mosquito, #MosquitoZika, #mosquitozika, Flaviviridae, flaviviridae, #flaviviridae, #Flaviviridae, #zikafever, #ZikaFever, #ZikaFlorida, #ZikaTexas, #TexasZika, #CaliforniaZika, #CaliZika, #ZikaCalifornia, #ZikaCali, Zica, zica, #Zica, #ZICA, ZICA, #zica, #zicavirus, #ZicaVirus, zicv, ZICV, ZICv, zicV, ZicV

Exclude Domains:

boards.4chan.org, steamcommunity.com

Exclude Terms:

porn, #porn, #amreading

Exclude Authors:

GargoyleWaiting:actuarialoutpost.com, chudnofsky_bot:twitter.com, GRossSharp:twitter.com, GetOnTopWithUs:twitter.com

Appendix 2. Search terms filtering the primary search related to mosquitoes to document media hits specific to the Zika virus

Zika, ZIKA, zika, Zikv, ZIKV, zikv, ZikV, ZIKv, #Zika, #ZIKA, #zika, #Zikv, #ZIKV, #zikv, #ZikV, #ZIKv, #zikavirus, #ZikaVirus, #VirusZika, #viruszika, #Zikavirus, #ZIKAVirus, #ZikaMosquito, #zikamosquito, #MosquitoZika, #mosquitozika, Flaviviridae, flaviviridae, #flaviviridae, #Flaviviridae, #zikafever, #ZikaFever, #ZikaFlorida, #FloridaZika, #ZikaTexas, #TexasZika, #CaliforniaZika, #CaliZika, #ZikaCalifornia, #ZikaCali, Zica, zica, #Zica, #ZICA, ZICA, #zica, #zicavirus, #ZicaVirus, zicv, ZICV, ZICv,

zicV, ZicV, microcephaly, Microcephaly, microcephally, Microcephally, #microcephaly, #Microcephaly, microcefaly, Microcefaly

Appendix 3.

Total numbers of monthly mentions for general mosquito and Zika-specific searches in the Virgin Islands search (data collected and summarized on October 20th, 2018 encompassing the time period July 20th of 2016 through October 20th of 2018)