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Increase in vector-borne disease reporting affecting humans and animals in Syria and neighboring countries after the onset of conflict: A ProMED analysis 2003–2018

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ABSTRACT

Objectives: The protracted and violent conflict in Syria has resulted in large-scale displacement of people and destruction of health and sanitation infrastructure. The aim of this study was to examine epidemiological trends in vector-borne disease (VBD) outbreaks before and following the onset of the Syrian conflict (2011).

Methods: ProMED, a digital disease surveillance tool, was queried for VBD outbreak reports affecting humans and animals in Syria and select bordering countries between 2003 and 2018. Data were normalized by dividing the number of unique VBD events by the total number of unique outbreak events reported by ProMED for each year. Suspected and confirmed case counts and deaths were manually extracted.

Results: Reports on VBDs increased from a mean of 2.9/year pre-2011 to 12.8/year post-2011, a 343.5% ($p < 0.05$) increase. After normalization, reports increased by 485.5% ($p < 0.05$) over the time periods. Post-2011, the most commonly reported VBDs were leishmaniasis, Crimean-Congo hemorrhagic fever, and lumpy skin disease. Reported numbers of suspected and confirmed cases and deaths increased during the conflict period.

Conclusions: VBD outbreak events in ProMED increased in Syria and select bordering countries after the onset of the Syrian conflict in 2011. Enhanced disease surveillance is critical to detect and manage outbreaks in conflict settings.

Background

The protracted conflict in Syria began with peaceful uprisings in March 2011 and escalated to violence by mid-2012. The conflict has led to the "weaponization" of healthcare with widespread, targeted destruction of water, sanitation and hygiene (WASH) and health infrastructure, severe overcrowding, and inadequate vaccination coverage and healthcare access (Fouad et al., 2017; Sparrow et al., 2016). Nearly 500 attacks on healthcare facilities and the deaths of at least 800 healthcare workers have contributed to an environment in which communicable disease outbreaks have increased (Abbara et al., 2019; Alawieh et al., 2014; Al-Salem et al., 2016; Ismail et al., 2016; Omar, 2020; Sharara and Kanj, 2014). Since the beginning of the conflict, half of the 22 million pre-war population has been forcibly displaced (UNCHR, 2020), and communicable disease control in the region has been further compromised due to the strain on medical infrastructure in neighboring countries by those seeking refuge (Fouad et al., 2017; Sparrow et al., 2016). While prior studies have explored the impact of the conflict on individual vector-borne diseases (VBDs) such as leishmaniasis, none to our knowledge have examined trends in all reported VBDs over time as they relate to the Syrian or other conflicts (Al-Salem et al., 2016; Desai et al., 2020; Du et al., 2016; Friedrich, 2016; Mockenhaupt et al., 2016).

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Moreover, the Syrian conflict has not spared animals and farming, and infectious disease outbreaks have been documented involving both during this time period (FAO, 2017; Petersen et al., 2013). Concerns that communicable diseases may spread from Syria to neighboring countries has led the Food and Agriculture Organization of the United Nations (FAO) to conduct vaccination campaigns at the Syria-Lebanon border for sheep, cattle, goats, and other animals to prevent the decimation of the Lebanese livestock industry (FAO, 2015). This points to the need to utilize a One Health approach, which views human, animal, and environmental health as interconnected, to better understand the extent of infectious disease outbreaks (Cross et al., 2019).

Infectious disease surveillance during conflicts is challenging because of the breakdown of public health infrastructure. In Syria, early warning systems for infectious disease outbreaks have been made available in government-controlled areas since 2012 and in non-government-controlled areas since 2013 (Ismail et al., 2016). The World Health Organization (WHO) runs the Early Warning and Response System (EWARS) in Syrian government–controlled areas, and ACU (Assistance Coordination Unit, part of the Syrian opposition government) runs the Early Warning and Response Network (EWARN) in non-government-controlled areas (Ismail et al., 2016). These systems collect data on human infectious disease syndromes from sentinel sites with the aim of responding promptly to potential outbreaks. However, these systems were implemented after the start of the conflict, they have been criticized for delays in reporting (Sparrow et al., 2016), and they do not report outbreaks affecting animals.

Informal digital disease reporting and monitoring tools may be useful adjuncts to traditional disease surveillance during conflicts, as they require fewer resources, report across a wide range of diseases, and often encounter fewer bureaucratic barriers (Gayer et al., 2007). Examples of these non-traditional systems include ProMED, HealthMap, and GeoSentinel (Hamer et al., 2017). In addition, informal reporting offers a mechanism to highlight cross-border infectious disease trends. The aim of this study was to examine reporting of VBD outbreak events affecting humans and animals in Syria and surrounding countries affected by the conflict using a One Health approach.

Methods

We conducted a retrospective analysis to identify epidemiological trends in VBD reporting in Syria and select neighboring countries. We compared the number of VBD reports and reported diseases before and after the onset of the Syrian conflict using ProMED, an internet-based, digital disease detection and monitoring tool.

Data source

Founded in 1994, ProMED is an internet-based, emerging infectious disease reporting and monitoring system which utilizes formal and informal disease surveillance mechanisms, including automated web crawling with manual curation through a collaboration with HealthMap (HealthMap, 2018), to rapidly report outbreak events in animals, humans, and plants globally. ProMED has operated as a program of the International Society for Infectious Diseases since 1999, promoting open-access and transparent data sharing free of political constraints (Carrion and Madoff, 2017). It is comprised of eight regional networks and one global network. Reports posted to all ProMED networks regarding infectious disease outbreaks are reviewed, vetted, and commented on by subject matter experts across a variety of fields. ProMED has been validated as a rapid and accurate tool for determining and describing global outbreaks (Bijkerk et al., 2017; Cowen et al., 2006). ProMED focuses its reporting on emerging and re-emerging outbreaks defined by WHO as “the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area, or season” (WHO, 2020). As with all ProMED reports, the included reports come from a variety of sources, including local health care professionals, official international bodies, local news sources, and national reporting bodies.

Data extraction

ProMED-global and all ProMED regional networks were searched. ProMED datamining followed by manual curation was

Table 1
List of VBDs from the World Health Organization (WHO), World Organization for Animal Health (OIE), or National Institute of Allergy and Infectious Diseases (NIAID). Diseases identified during screening were labeled as VBDs based on these lists.

WHO	OIE	NIAID
Chagas disease	African swine fever	Alkhurma hemorrhagic fever
Chikungunya	Bluetongue disease	California encephalitis
Crimean-Congo hemorrhagic fever	Bovine anaplasmosis	Chikungunya
Dengue fever	Bovine babesiosis	Crimean-Congo hemorrhagic fever
Japanese encephalitis	Bovine ephemeral fever	Eastern equine encephalitis
Leishmaniasis	Crimean-Congo hemorrhagic fever	Heartland virus disease
Louse-borne relapsing fever	Eastern equine encephalomyelitis	Japanese encephalitis
Lyme disease	Epizootic hemorrhagic disease	Kyasanur Forest disease
Lymphatic filariasis	Equine infectious anemia	La Crosse encephalitis
Malaria	Equine piroplasmosis	Omsk hemorrhagic fever
Onchocerciasis	Heartwater	Other rickettsial diseases
Plague	Infection with African horse sickness virus	Plague
Relapsing fever (borreliosis)	Japanese encephalitis	Rift Valley fever
Rickettsial diseases (spotted fever and Q fever)	Lumpy skin disease	Severe fever with thrombocytopenia syndrome
Rickettsiosis	Nairobi sheep disease	St. Louis encephalitis
Rift Valley fever	Rift Valley fever	Tick-borne encephalitis
Sandfly fever (phlebotomus fever)	Surra (*Trypanosoma evansi*)	Tularemia
Schistosomiasis	Theileriosis	Typhus
Sleeping sickness	Trypanosomosis	Venezuelan equine encephalitis
Tick-borne encephalitis	Tularemia	West Nile virus
Tularemia	Venezuelan equine encephalomyelitis	Western equine encephalitis
Typhus	West Nile virus	Yellow fever
West Nile virus	Western equine encephalomyelitis	
Yellow fever		
Zika		

conducted geographically using search terms, "Syria," "Turkey," "Lebanon," "Jordan," and "Iraq," between 2003 and 2018. Duplicate reports were removed after manual review by one investigator (MT) and supervision of data integrity by three investigators (BL, AD, and AA), including multiple reports that chronicled the same outbreak event over time. Given that ProMED reports are posted as outbreaks evolve, only the last chronological report was retained to represent a specific outbreak event as the last chronological report contains the most accurate and complete data. Inclusion criteria were any events involving humans or animals defined as VBD by WHO, World Organization for Animal Health (OIE), or National Institute of Allergy and Infectious Diseases (NIAID) (Stuchin et al., 2016; WHO, 2017). Table 1 is a list of included VBDs. Exclusion criteria were non-VBD outbreaks and those involving plants without human or animal interaction. From the included reports, suspected and confirmed case and death counts, species affected (human or animal), and year of event were manually extracted.

Data analysis

Reports were stratified by year and categorized as prior to onset of the Syrian conflict (taken as 2011) or after. Although the exact timing of onset has been variably reported in the literature, 2011 was applied in this analysis, given its widespread acceptance as a turning point for increasing numbers of forcibly displaced persons leaving Syria (UNHCR, n.d.). Given this, reports were ultimately categorized into two time periods: 2003–2010 or 2011–2018. Mean number of VBD events for the 2003–2010 and 2011–2018 periods were calculated.

In order to account for confounding due to a potential increase in ProMED reporting over time and the introduction of the ProMED-MENA regional network in 2014, the data were normalized by dividing the number of unique VBD events by the total number of unique outbreak events reported by ProMED for each year between 2003 and 2018.

Microsoft Excel and Stata (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP) were used for statistical analysis. Descriptive statistics were summarized, and statistical analysis for categorical variables was conducted using a 2-sample t-test assuming unequal variance. $P < 0.05$ was considered statistically significant.

Results

Of 87,977 total ProMED reports from 2003 to 2018, 1,961 reports pertaining to Syria, Turkey, Lebanon, Jordan, and Iraq were extracted. Of these, 743 reports were retained after removing reports that chronicled the same event and 125 reports met inclusion criteria (Figure 1) reflecting unique VBD outbreak events. The number of VBD reports increased annually after 2011 as compared to the pre-conflict period (Figure 2a and b). There were 23 VBD outbreak events reported in the 2003–2010 pre-conflict period and 102 VBD outbreak events reported in the 2011–2018 period. The average number of outbreak events reported per year during the 8-year periods (pre-conflict and conflict) were calculated for both the non-normalized and normalized data and are represented by the green horizontal lines in Figure 2a and b. The average number of non-normalized outbreak events reported per 8-year period increased by 343.5% ($p < 0.05$) between 2003–2010 and 2011–2018 and by 485.5% ($p < 0.05$) for the normalized data over the same time period.

The most commonly reported diseases in each time period are reported in Table 2. The three most commonly reported VBD outbreaks in the pre-conflict period were leishmaniasis (n = 10; 43%), Crimean-Congo hemorrhagic fever (n = 7; 30%), and West Nile virus (n = 2; 9%). In the conflict period, the most commonly reported VBD

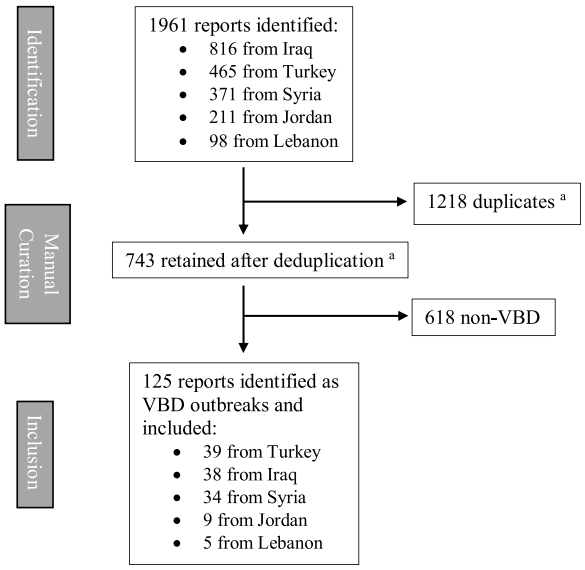

Figure 1. Flowchart showing the selection process for VBD reports used in this paper.
a. Duplicate reports include multiple reports that chronicled the same outbreak event over time. Only the last report was retained to represent a particular outbreak event.

outbreaks were leishmaniasis (n = 63; 62%), lumpy skin disease (n = 14; 14%; a poxvirus affecting cattle and water buffalo believed to be spread by mosquitoes, biting flies, and male ticks) (OIE, 2017), and Crimean-Congo hemorrhagic fever (n = 7; 7%).

Countries with the highest number of reports also changed across time periods. In the pre-conflict period, Turkey (12), Iraq (8), and Syria (2) were the countries with the highest number of VBD reports. During the conflict period however, Syria (32), Iraq (30), and Turkey (27) had the highest number of VBD reports.

In the pre-conflict period, 3 (13%) of VBD reports occurred in animals: two cases of epizootic hemorrhagic fever and one case of bluetongue disease (a reovirus affecting various domestic and wild ruminants spread via culicoides) (OIE, 2013). The number of VBD reports in animals increased to 26% (27) during the conflict period. The most common diseases reported during the conflict period were lumpy skin disease (n = 14; 52%), bluetongue disease (n = 7; 26%), and Rift Valley fever (n = 3; 11%; a bunyavirus affecting various domestic and wild animals spread by mosquitoes) (OIE, 2019).

Leishmaniasis

Leishmaniasis was the most reported VBD in both the pre-conflict and conflict periods. Appendix A shows the number of reports per governorate in the period after the onset of conflict. Out of 31 total reports of leishmaniasis outbreaks in Syria, 19 noted a location. Al-Hassakeh (4), Aleppo (4), and Hama (3) governorates had the highest number of reports; however, the first report that named a governorate was not until 2016. Before the onset of conflict, there were two reports of leishmaniasis outbreaks in Syria. In the bordering countries, there were 10 outbreaks reported before the conflict (8 in Iraq and 2 in Syria) and 63 during the conflict period, in Iraq (26), Syria (29), Jordan (6), and Turkey (2), as shown in Figure 3.

Approximate cumulative suspected and confirmed case counts (and deaths)

The cumulative number of suspected and confirmed cases and deaths rose in reports where numbers were given. The

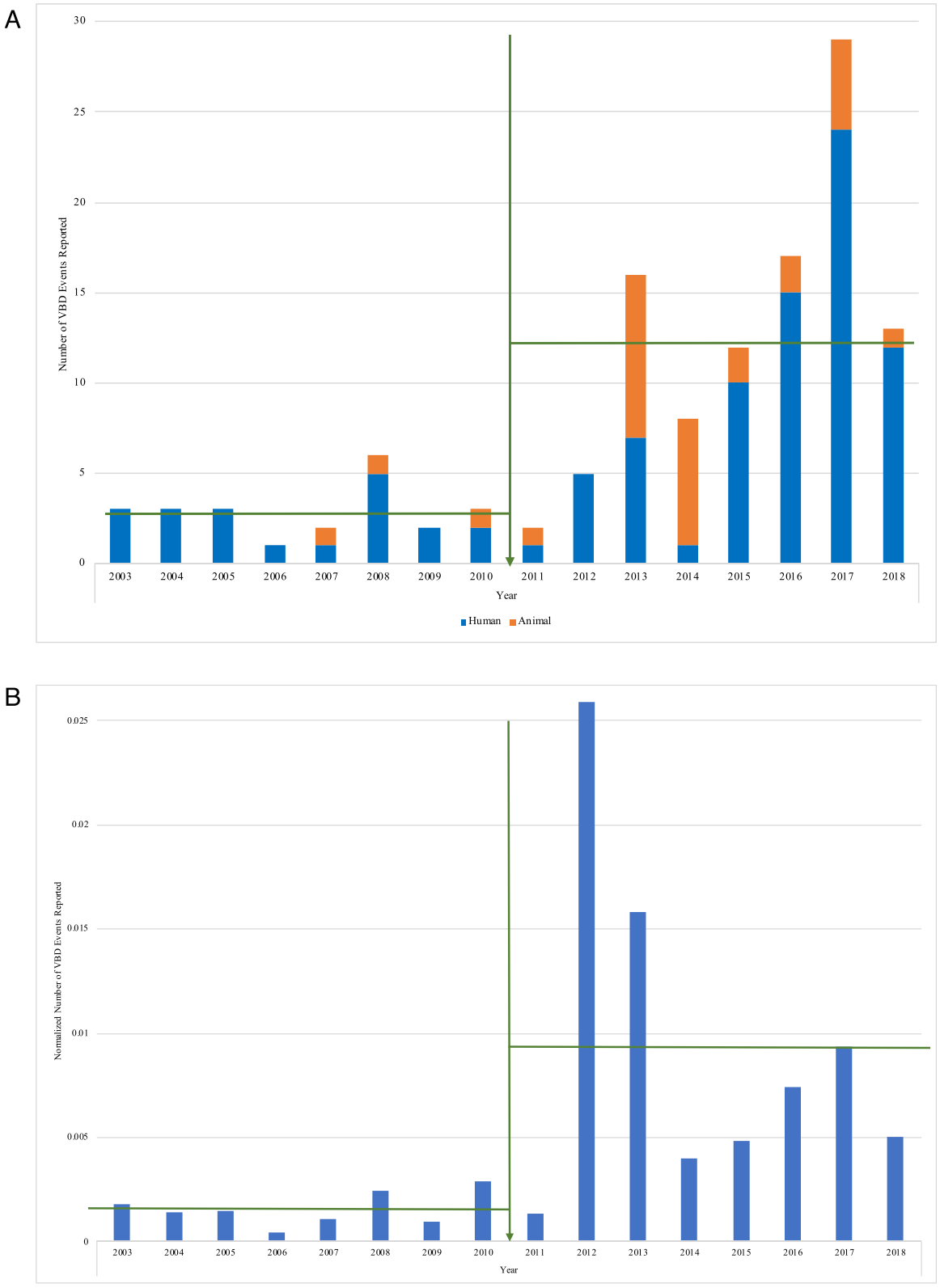

Figure 2. (a) Number of VBD events reported per year stratified by humans and animals. Horizontal lines are the average number of VBD events per year in each time period (2.9 versus 12.75). Vertical line represents the break in the two time periods, 2003–2010 (pre-conflict) and 2011–2018 (conflict). (b) Number of VBD events reported per year after normalization. Horizontal lines are the average number of VBD events per year in each period after normalization (0.00157 versus 0.00921). Vertical line represents the break in the two time periods, 2003–2010 (pre-conflict) and 2011–2018 (conflict).

Table 2
Number of VBD events per disease and country for pre-conflict (2003–2010) and conflict (2011–2018) periods.

Pre-conflict period	
Disease by country	Totals
Iraq	**8**
Leishmaniasis	8
Jordan	**1**
Epizootic hemorrhagic disease [a]	1
Syria	**2**
Leishmaniasis	2
Turkey	**12**
Crimean-Congo hemorrhagic fever	7
West Nile virus	2
Tularemia	1
Bluetongue disease [a]	1
Epizootic hemorrhagic fever [a]	1
Total	**23**
Conflict period	
Disease Disease by country	Totals
Iraq	**30**
Leishmaniasis	26
Plague	1
Malaria	1
Crimean-Congo hemorrhagic fever	1
Lumpy skin disease [a]	1
Jordan	**8**
Leishmaniasis	5
Bovine ephemeral fever [a]	1
Tick paralysis [b]	1
Lumpy skin disease [a]	1
Syria	**32**
Leishmaniasis	29
Lumpy skin disease [a]	3
Turkey	**27**
Lumpy skin disease [a]	7
Crimean-Congo hemorrhagic fever	6
Bluetongue disease [a]	6
Rift Valley fever [b]	3
West Nile virus [b]	2
Leishmaniasis	2
Malaria	1
Lebanon	**5**
Lumpy skin disease [a]	2
Malaria	1
Bluetongue disease [a]	1
Leishmaniasis	1
Total	**102**

[a] VBD reported in an animal that *only affects animals*.
[b] VBD reported in an animal that can *also affect humans*.

number of cumulative reported cases across all diseases rose from 71,182 (animal n = 43; human n = 71,139) in the pre-conflict period to 538,533 (animal n = 8,602; human n = 529,931) in the conflict period. The disease with the highest reported cases in both periods was leishmaniasis, with 66,423 cumulative reported cases in the pre-conflict period and 523,405 cumulative reported cases in the post-conflict period.

Cumulative reported deaths followed a similar pattern; the number rose from 220 (animal n = 0; human n = 220) in the pre-conflict period to 1318 (animal n = 652; human n = 666) in the conflict period. Crimean-Congo hemorrhagic fever had the highest cumulative reported deaths across both periods, with 217 cumulative reported deaths in the pre-conflict period and 664 in the conflict period.

Discussion

This study, using ProMED data, demonstrates that the number of VBD outbreak events reported in both humans and animals increased significantly following the onset of conflict in Syria and select neighboring countries. The reported VBDs changed over time; however, this was more pronounced for human-associated VBD outbreaks. Conflict is associated with an increase in communicable diseases, including zoonotic diseases, due to the disruption of WASH infrastructure, mass displacement, overcrowding in health systems that are not equipped to handle an influx of forcibly displaced persons, and interruption of standard health services including routine childhood vaccination (Mowafi, 2011). Prior studies have characterized a similar effect of the Syrian conflict on emerging and reemerging infectious diseases in the region (Doganay and Demiraslan, 2016; Nimer, 2018; Raad et al., 2018).

The impact of VBDs in conflict has been described in other contexts including leishmaniasis in a number of countries (Berry and Berrang-Ford, 2016), trypanosomiasis in the Democratic Republic of the Congo (Tong et al., 2011), and dengue outbreaks in Yemen (Alghazali et al., 2019). In this study, the majority (n = 73, 58%) of total outbreak reports relate to leishmaniasis, which may be due to the number of cases and its relative importance in the region.

Cutaneous leishmaniasis, a protozoal infection transmitted by the *Phlebotomus* sandfly, is endemic in Syria, particularly in Aleppo and Idlib governorates, and Jordan, but not in Lebanon or Turkey (Gayer et al., 2007). Vector control initiatives had successfully reduced transmission before the conflict to an average of 27,825 cases per year; however, since the conflict, the annual incidence has increased to 64,498 cases per year in Syria and an increase has been noted in neighboring countries (Abbara et al., 2019; Waltner-Toews, 2017). It is a disfiguring and often visible illness with associated social stigma, which, given its long incubation period, may be transported from endemic to non-endemic areas in Syria and surrounding refugee hosting countries (Abbara et al., 2019; Cross et al., 2019; WHO, 2017).

While the numbers of cases and deaths given in this paper are not official counts and are unlikely to be comprehensive or may have duplications, they can serve as a barometer for the severity of VBD outbreak events in the region. The rise in leishmaniasis reports and the corresponding increase in reported cases and deaths found in this paper are consistent with the existing literature (Salam et al., 2014; Youssef et al., 2019). Other studies have cited the breakdown of basic healthcare and WASH infrastructure from the conflict as the primary contributing factors for the stark rise in leishmaniasis cases both in Syria and in neighboring countries, such as Jordan, Iraq, and Lebanon (Salam et al., 2014). The movement of millions of IDPs and refugees has contributed to the rise of leishmaniasis cases in non-endemic areas, which is also exacerbated by poor living conditions and available infrastructures (Youssef et al., 2019). These observed trends in leishmaniasis may be mimicked by other VBDs that have also experienced a rise in reporting and approximate case counts.

Outbreaks of VBDs affecting animals are also known to occur in conflict areas as a result of damaged veterinary public health infrastructure, increased animal migration and displacement, and the health system collapse associated with conflict (Petersen et al., 2013). Animals act as an important reservoir for zoonoses, and conflict may pose an increased threat to humans (Waltner-Toews, 2017). This study, however, mainly identified diseases that only affect animals, such as lumpy skin disease and bluetongue. While these may not pose a direct threat to human health via disease, death or decreased productivity of livestock may result in a loss of livelihood, food and material sources, and valuable transportation (FAO, 2017, 2015). Using a One Health model provides a more global picture of VBDs as they relate to both humans and animals.

There are several strengths to this study. ProMED leverages formal and informal sources of information, providing epidemiological insights in regions that might have compromised health systems

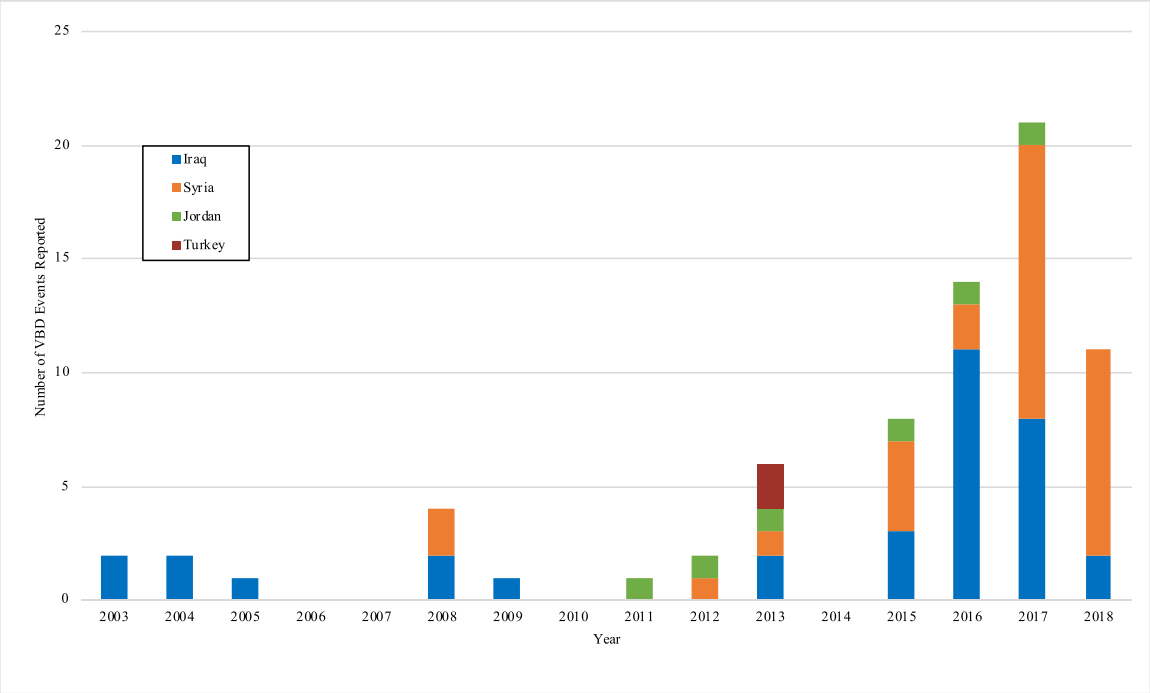

Figure 3. Bar chart stacked by country in which leishmaniasis was reported annually.

due to conflict (Carrion and Madoff, 2017). ProMED reports can support outbreak responses with rapid notification of potential outbreaks. In addition, it is independent of political constraints and supports transparent data sharing, allowing for rich and contextualized reporting in areas where conflict and displacement may otherwise prevent routine surveillance strategies from functioning appropriately. The database also allows for the analysis of trends over time, which can otherwise be challenging.

This study has several limitations. While ProMED leverages several informal sources to report on emerging outbreaks, it is not comprehensive and may not capture all possible events due to its reliance on external reporting. Additionally, the reported case and death counts are approximate and are not official counts. Given that ProMED relies on internet-based event reporting, areas with limited internet penetration may be underrepresented. As such, increased reporting over time driven by the adoption of electronic communication methods may have contributed to the increased number of VBD outbreak reports demonstrated in this analysis. This was mitigated in part by normalization of the data. There is a potential for selection bias due to preferential reporting on certain diseases, as well as the possibility of countries that are not directly affected by conflict having more robust media outlets compared to those enmeshed in conflict. The nature of the conflict and its effects on the region precluded examining an appropriate control, and as such, it is possible that residual confounding exists. Given this and the observational nature of this study, a direct association between the Syrian conflict and the observed increase in VBD reporting cannot be concluded.

As the conflict in Syria continues, it is imperative to understand its effects on communicable diseases. Informal disease surveillance systems, such as ProMED, are useful additions to official reporting systems, as they allow for low-barrier reporting and the capturing of nascent outbreak events. Increases in ProMED reports of VBDs may be a harbinger of increasing disease burdens and breakdown of vector control measures, indicating a crucial area for public health attention.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from ProMED, www.promedmail.org.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MT, AA, BL, and AD conceived of and designed the study. MT, AD, and BL conducted primary data analysis. BL, AA, and AD supervised integrity of the data. All authors contributed to writing and editing of the manuscript.

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Not applicable.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2020.09.1453.

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