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RESEARCH ARTICLE

Impacts of climate change on human health in humanitarian settings: Evidence gaps and future research needs

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Abstract

This mixed-methods study focuses on the evidence of the health impacts of climate change on populations affected by humanitarian crises, presented from the perspective of Médecins Sans Frontières (MSF)–the world's largest emergency humanitarian medical organisation. The Sixth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) was used as the basis of a narrative review, with evidence gaps highlighted and additional literature identified relevant to climate-sensitive diseases and health problems under-reported in–or absent from–the latest IPCC report. An internal survey of MSF headquarters staff was also undertaken to evaluate the perceived frequency and severity of such problems in settings where MSF works. The findings of the survey demonstrate some discrepancies between the health problems that appear most prominently in the IPCC Sixth Assessment Report and those that are most relevant to humanitarian settings. These findings should be used to guide the direction of future research, evidence-based adaptations and mitigation efforts to avoid the worst impacts of climate change on the health of the world's most vulnerable populations.

Introduction

The impacts of climate change on human health have proven to be–and are expected to remain–mostly detrimental [1, 2]. The latest summary of evidence by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report (AR6) makes clear that, overall, these impacts are severe, widespread, generally underestimated and worsening over time [3]. Multiple categories of climate-sensitive health problems are outlined in the report, including vector-borne diseases; water- and food-borne diseases; heat stress; zoonoses; food insecurity and malnutrition; air pollution; hydrometeorological disasters and mental health impacts

[3, 4]. The issue is largely one of amplification of existing problems, rather than the introduction of new problems *per se*, although the contribution of climate change as a driver of emerging infectious diseases, for example, is explicitly acknowledged in AR6 [2, 3]. This phenomenon of amplification, or exacerbation, of existing health problems, can be seen directly, for example as heatwaves increase morbidity and mortality in people with cardiovascular disease and diabetes [5, 6] as well as indirectly, for example the expansion of habitats suitable for mosquitoes that spread diseases such as dengue fever [7, 8], and the impact of more severe droughts on food insecurity and malnutrition [9, 10]. The proportion of annual global deaths estimated to be due to 'climate-sensitive diseases' is 69.9% and the cumulative burden of these impacts is in the order of millions, if not tens of millions, of deaths per year [4].

The IPCC authors make clear that the health consequences of climate change are being unevenly distributed, with certain populations–particularly people at the extremes of age, those living in poverty, people with pre-existing conditions and communities in geographically vulnerable locations (such as low-lying coastal areas)–already suffering a disproportionate burden of climate-change-related health problems [4, 11]. This inequitable distribution of detrimental health consequences will almost certainly continue for the foreseeable future, with the added injustice that for many such populations, while they are among the first and hardest hit by climate change, they are also those who have contributed least to causing the problem (i.e. via greenhouse gas emissions) [3, 12, 13].

What is largely lacking from AR6, however, is consideration of populations affected by humanitarian emergencies. The interaction between climate change and displacement is described in some detail [4], but the specific and combined health impacts of climate change on individuals and communities already affected by crises such as war, famine, epidemics and disasters are notable by their absence in the IPCC literature. This is far more reflective of an absence of evidence than evidence of absence–a gap that this review paper is intended to help address.

This mixed-methods study focuses on populations affected by humanitarian emergencies. For the purposes of this paper, people in 'humanitarian settings' are considered to be those affected by extreme poverty, armed conflict, epidemics, pandemics, disasters (hydrometeorological and others) and exclusion from healthcare. They are, generally speaking, populations that are vulnerable in one or more ways, and thus in need of assistance–beyond what can typically be provided by governments in times of crisis–to meet their health needs, which are often multiple, severe and intersecting or overlapping.

Working with such communities requires special considerations in terms of their health risk profiles (e.g. high rates of maternal and child mortality; low rates of vaccination coverage; food and/or nutrition insecurity; lack of access to improved water, sanitation and hygiene (WASH) facilities; exposure to tropical diseases; experience of physical and/or psychological trauma; and lack of access to care for chronic conditions). The particular challenges involved in trying to provide care for such populations include (but are not limited to): limited resources (of all kinds); obstacles related to geography, transport, access, utilities and/or security; political instability and/or armed conflict; weak, limited or absent infrastructure; fragile supply chains; low levels of trust in the health system; lack of support from governments and/or other health and humanitarian actors; and constraining, excluding or harmful state policies.

The abovementioned factors contribute to the relative scarcity of health research and evidence specific to such populations. So too do the colonial legacies of Western-centred research frameworks, neglect of Indigenous knowledge and the de-prioritisation of knowledge generation from the so-called 'global South' [14, 15]. These, in turn, limit the amount of published literature that is available to be reviewed, whether to inform evidence-based practice and policy implementation, or to include in summaries of evidence such as the IPCC assessment reports.

The purpose of this study is thus to identify some of the most important gaps in the literature regarding the impacts of climate change on human health in humanitarian settings–particularly the evidence summarised in AR6. The findings may then guide further research specifically addressing the needs of populations affected by humanitarian emergencies, including the unique vulnerabilities of such groups, and help determine the most urgent and appropriate adaptation strategies for different kinds of humanitarian settings.

This study is presented from the perspective of a collection of authors, most of whom are employed by Médecins Sans Frontières (MSF–Doctors Without Borders)–the world's largest emergency humanitarian medical organisation. MSF has been providing medical care to largely neglected populations in challenging contexts for almost fifty years. The majority of MSF projects are in sub-Saharan Africa (55%), followed by the Middle East and North African region (20%), Asia-Pacific (11%), Americas (7%), Europe and Central Asia (4%), with 2% 'Other'. Out of these (59%) are in settings of armed conflict, internal instability or post-conflict situations.

Methods

Ethics statement

Approval for this study was provided by the medical department and operational research unit at MSF Operational Centre Geneva.

This study was comprised of two main methodologies. The first was a narrative review, whereby the relevant literature on the health impacts of climate change was synthesised, with a particular focus on humanitarian settings. This technique was considered most appropriate, given the simultaneous assumptions that a) the principal source of up-to-date information on the health impacts of climate change would be the IPCC AR6 [3]; b) additional references would be required to attempt to encompass the evidence specific to the populations of interest (i.e. people affected by humanitarian emergencies); and c) even these sources combined would be unlikely to accurately, comprehensively or appropriately reflect the unique considerations specific to humanitarian settings. These assumptions, and the objectives of this paper to appraise existing literature and identify priorities for further research, made the narrative review method the most logical format in this instance [16].

A list of the diseases and other health problems sensitive to climate (hereunder referred to as climate-sensitive diseases–CSDs) explicitly mentioned in IPCC AR6 was used as the starting point. It must be noted that many such problems–for example heat, air pollution and hydrometeorological disasters–are not technically 'diseases', but in order to align with the prevailing literature, and in the absence of a more accurate alternative, the term 'climate-sensitive diseases' has been used here. To the aforementioned list, several additional CSDs were added that were known (based on annual reports) or suspected (based on previous literature reviews) to occur in MSF projects, for a total of 46 CSDs (see Table 1). A search for titles and abstracts was conducted via PubMed, with each CSD entered as a distinct term (including logical alternatives, such as 'antibiotic resistance' in addition to 'antimicrobial resistance), with the additional terms 'weather', 'environment', 'climate' and 'climate change' all included via the 'and/or' function. Abstracts were then reviewed, as well as full-text articles where necessary, to identify those articles that appeared to include information most relevant to the topic (i.e. climate-sensitivity of specific CSDs) and study populations (i.e. people affected by humanitarian emergencies). Further references were then added by 'snowballing', where deemed appropriate.

The second methodology employed was a voluntary, anonymous survey of staff in the medical and operations departments across MSF's headquarters (the International Office and Operational Centres that together oversee all of MSF projects in over seventy countries). This

Table 1. CSDs included in study.

Category A	Category B		Category C	
Air pollution Allergies (excluding reactive airways disease) Anthrax Cancer Cardiovascular disease Cholera Cold-related illness Conflict Dengue Diarrhoeal diseases Displacement Emerging infectious diseases Heat-related illness Hydrometeorological disasters Japanese encephalitis virus Leptospirosis Lyme disease Malaria Malnutrition Mental health Respiratory diseases (non-infectious) Respiratory infections (excluding measles & tuberculosis) Rift Valley fever Schistosomiasis Tick-borne diseases (excluding Lyme disease) Tularaemia Typhoid fever West Nile virus Zika	Antimicrobial resistance	*Evidence mentioned in IPCC*: Worsening animal health due to changing disease distributions including zoonotic diseases, reduction in feed quality and deforestation. This leads to increased antimicrobial use in livestock and other animal health practices leading to increased AMR (pg 233, 1076, 1381) [4, 17, 18]. *Additional external evidence*: Increased AMR associated with increasing local temperatures and population density for common pathogens across the US [19]. European countries with an increased ambient minimum temperature of 10˚C had faster AMR growth compared with countries with cooler temperatures over a 10-year period [20]. 30-country European observational study found Carbapenem-resistance *Pseudomonas aeruginosa* associated with increased temperature change during summer [21]. 1˚C increase in regional ambient temperature in regions across China positively associated with higher prevalence of AMR for carbapenem resistance *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* [22] and E.coli antibiotic resistance [23]. These links were strongest in areas with fewer health facilities and higher perceived corruption and lower income. Meta-analysis looking at links between increased temperature and AMR in aquaculture from mostly low- and middle-income countries. Increased multi-antibiotic resistance in aquaculture bacteria correlated with increased temperature and also measures of AMR from human bacteria [24].	Ebola	*External evidence*: Patients treated in Ebola Treatment Units tents in Liberia and Sierra Leone during the 2014–2016 epidemic had higher odds of fatality if the average environmental temperature was above 27˚C during their stay than those below [50]. Large fluctuations in climate may increase the population of bats infected with Ebola increasing risk of spillover into human population [51]. Increased risk of Ebola spillover events with modelling taking into account climate change and population growth including more areas of northern, eastern and southern Africa not yet impacted by outbreaks [52].
	Chagas disease	*Evidence mentioned in IPCC*: Increasing range of triatomines into Southern USA and projected to continue further north. (pg 1969) [25] Changes in transmission and distribution of Chagas disease in Central and South America (low confidence evidence). (pg1717) [26] *Additional external evidence*: Using IPCC climate change projections modelling showed possible decreasing exposure to the Venezuelan population to triatomines [27]. Increased areas for potential transmission of Chagas disease in Chile particularly Central and Northern regions with projected climate change scenarios [28]. Geographical range of triatomines in Chile are likely to extend into previously unaffected areas under some climate change projections [29].	Human African trypanosomiasis (HAT)	Rising temperatures in the Zambezi Valley have been linked to a reduction in tsetse flies, however such increases in temperature may increase numbers in cooler areas of Zimbabwe previously unaffected [53]. Under climate change models tsetse fly distribution are likely to move into highland areas of Kenya potentially exposing a new large population of people to risk of HAT [54]. Modelling using tsetse fly catch data and increasing local temperatures, tsetse fly populations are predicted to decrease in lower elevation regions but increase in higher elevation, previously cooler, regions [55]. Modelling to predict distribution of three species of tsetse flies under predicted climate change conditions demonstrated reductions in habitable area however potential movement into areas previously protected from HAT [56]. In Zimbabwe, habitat fragmentation and rising temperatures create conditions leading to higher populations of older tsetse flies, increases the rate of infection and risk of disease [57]. Modelling of temperature impacts on vector ecology predicted 46–77 million more people could be exposed to HAT risk by 2090 [58].

(*Continued*)

Table 1. (Continued)

Category A	Category B		Category C	
	Hepatitis A & E	*Evidence mentioned in IPCC*: High rainfall, warm temperatures and drought increase risk of gastrointestinal infection and waterborne diseases. No specific reference to Hepatitis A and E only as a water-borne disease (WBD) [4]. *Additional external evidence*: High rainfall (>90th percentile) associated with an increase in cases of hepatitis A across Spain between 2010 and 2014 lasting for 2 weeks post rain event [30]. Increased risk of hepatitis A after severe flood event in four cities of Anhui province in China [31]. In a Brazilian municipality cases of hepatitis A increased by nearly 300% in the three months after flood events within urban areas on floodplains over a 2 year period [32].	Lassa	Some models suggests an increased Lassa spillover potential in West Africa attributable to a large extent to climate change [59]. Models from Nigeria also point to a substantial effect of climate in explaining Lassa fever occurrence and incidence patterns across Nigeria [60]. The number of people exposed to Lassa virus could increase by hundreds of million in Central and East Africa using modelling of projected climate, population and land use changes [61]. Studies of field populations of *Culex* mosquitoes have shown that increases in temperature are likely to accelerate mosquito development [62].
	Leishmaniasis	*Evidence mentioned in IPCC*: Leishmaniasis prevalence increase in Central and South America due to higher temperatures increasing the areas suitable for vectors along higher frequency climate related weather events (pg. 1699, 1722) [26] *Additional external evidence*: Increased areas suitable for leishmaniasis vector and reservoirs in Iran when modelled for climate change scenarios [33]. Increasing incidence of cutaneous leishmaniasis predicted in regions of Palestine including Gaza strip and the North West Bank using future projected climate change scenarios [34]. Leishmaniasis incidence higher in regions of Iran with higher rainfall, humidity, evapotranspiration and soil moisture [35]. In French Guiana increases in incidence of leishmaniasis 2 months after a decrease in rainfall [36].	Lymphatic filariasis	Modelling of climate projections predicts the range of risk for lymphatic filariasis infection to increase and could increase the population exposed to between 1.65 to 1.86 billion people [63]. Predicted rising sea levels are likely to increase the area of saline and brackish water in coastal regions thereby increasing the density of mosquito vectors including *Culex* mosquitoes [64].
	Meningitis	*Evidence mentioned in IPCC*: In the western Sahel region with the highest burden of bacterial meningitis is predicted to have increase meningitis case with rising temperatures. (pg. 1375) [18]. *Additional external evidence*: Drivers of meningitis disease in Democratic Republic of Congo are sensitive to changes in climate [37]. Global ecological study found strong association between meningitis incidence and increased temperature variability [38]. Meningococcal meningitis in the Sahel is sensitive to climate with periods of low rainfall and El Niño coinciding with peaks in incidence [39]. Low rainfall, high temperatures and increased aerosols are predictive of meningitis outbreaks in Nigeria [40].	Marburg	Reduced temperature and rainfall seasonality in Uganda are important environmental variables for predicting increased risk of Marburg virus disease outbreaks [65].
	Snakebite	*Evidence mentioned in IPCC*: Snakebites more likely to occur in Costa Rica at higher temperatures (pg. 1699) [26]. *Additional external evidence*: In Sri Lanka snakebite incidence increases with low humidity and likely to increase with climate change [41]. Increased incidence of snakebites requiring medical evacuation in Israel with increased temperature and lower humidity [42]. Increased snakebite incidence correlated with water scarcity and desertification as well as lower Human Development Index (HDI) in Brazilian state of Ceará [43]. In areas of Colombia with marked dry seasons, snakebite incidence increased with increased rainfall. No increase with rainfall in other regions [44].	Measles	Measles cases in Ondo state, Nigeria linked to periods with higher human thermal comfort indices and low rainfall [66]. Both hot and cold temperatures resulted in decreases in the incidence of measles, and low relative humidity is a risk factor of measles morbidity in Guangzhou, China [67]. Experiencing drought at 12 months of age negatively associated with receiving a measles vaccine in Rwanda, Democratic Republic of the Congo, Ghana, and Malawi [68].

(*Continued*)

Table 1. (Continued)

Category A	Category B		Category C	
	Stroke	*Evidence mentioned in IPCC*: Stroke hospitalisation increases in response to higher ambient temperatures (pg. 1073) [4] Increased incidence of stroke linked to heat in some countries in Africa (pg.1377) [18] *Additional external evidence*: Systematic review and meta-analysis examining impact of ambient heat on cardiovascular disease found positive association between incidence of cardiovascular disease mortality, with strongest risk in stroke and CHD. Risk increases with heat exposure for women, 65+ population, tropical climates and LMICs [45]. Across 22 East Asian cities extreme heat was associated with increase mortality due to stroke from 1972 to 2015. The burden attributable to heat increasing under modelled climate change scenarios [46]. Temperature related deaths due to ischaemic stroke projected to increase in Beijing under climate change models of approximately 100% by 2090 [47].	Melioidosis	An association between rainfall events and cases of melioidosis was found in Darwin, Australia between 1990 and 2013 [69]. Higher rainfall correlated with melioidosis case numbers over a 20-year period in Torres Strait Islands region, Australia [70]. Case clusters of melioidosis reported following extreme weather events in Sri Lanka and Australia [71, 72].
	Tuberculosis	*Evidence mentioned in IPCC*: Higher proportions of climate-related infections such as tuberculosis in Indigenous populations compared with non-Indigenous e.g. Torres Strait (pg. 1054) [4]. Tuberculosis contributes 6.5% of deaths and 6% of DALYs due to climate-sensitive diseases (pg. 1060) [4]. For people living with HIV and reduced lung function due to tuberculosis infection could increase their risk from extreme heat (pg.1375) [18]. *Additional external evidence*: Systematic review of association between climate variable and tuberculosis risk factors found positive associations between TB risk factors and climate change including HIV, diabetes, undernutrition, overcrowding and poverty [48]. Systematic review of relationship between meteorological factors and TB showed increased risk of TB correlated with precipitation, temperature and humidity in populations in subtropical climate and with low and middle Human Development Index [49]	Monkeypox (MPX)	Incidence of MPX positively associated with temperature as well as primary forest and economic well-being in Democratic Republic of the Congo (DRC) [73]. Projected shift of regions with suitability for MPX transmission to regions previously unaffected in DRC, Uganda, Kenya, Tanzania, Cameroon, Gabon and Equatorial Guinea with modelling using IPCC projected climate change scenarios [74].

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group was targeted based on their roles and responsibilities in designing and managing projects and providing technical and strategic support for the organisation's medical activities. The survey was limited to headquarters staff in order to try and ensure a moderate to high level of experience working in MSF settings, as per the focus of the questions.

Survey respondents were asked to estimate, on a five-point qualitative scale, how frequent and severe they perceived the 46 CSDs to be in settings where MSF works. The precise questions asked were 'How frequently is the problem of XXX seen or managed in MSF settings?' and 'How severe is the problem of XXX in MSF settings?'. The introductory material at the beginning of the survey explained that respondents were being requested to reply based on their own knowledge and experience, however subjective. The question of 'severity' was left deliberately open to interpretation, given the heterogeneous nature of the CSDs (from rare diseases to large-scale disasters) and the professional backgrounds of the survey respondents.

The survey link was shared via email and completed responses were downloaded for analysis in Microsoft Excel once the survey deadline had passed. The survey responses were then aggregated, with a median score (between 0 and 4) generated for both perceived frequency and severity for each of the 46 CSDs. The results of these analyses were thus used to represent the estimated relative frequency and severity of each CSD. An additional, overall, subjective, qualitative approximation of each CSD's 'relevance' to humanitarian settings was generated by multiplying the average frequency score of each CSD by its average severity score. The survey also included an option of 'I don't know' for the estimated frequency and severity of each CSD, in order to identify potential information and/or knowledge gaps within the organisation.

As the survey was completely anonymous, and the results aggregated prior to analysis, no identifiable data was requested or collected.

Findings

The full list of 46 CSDs included in this study is provided in Table 1, where they are divided into three categories. The first (Category A) is of CSDs for whom the evidence of climate-sensitivity is strong, and which have been described as such in the IPCC AR6. The second (Category B) is of CSDs for whom the evidence of climate-sensitivity in the literature is moderate, but which appears to have been under-reported in AR6. The third (Category C) is of CSDs for which there is some evidence of climate-sensitivity, or at least plausible links, but which are not mentioned at all in AR6. The latter category was identified based on the authors' collective experience, familiarity with the relevant literature and internal discussions within MSF. Of note, the papers cited in Category C differ substantially in scope and methodology, from observational studies to experimental modelling. The key points cited from those papers therefore include different types of data, from epidemiological studies to estimates mapping potential future vulnerabilities, and are referred to variously in those papers as results, discussion and/or conclusions. The most relevant evidence identified in the literature review has been summarised for the respective CSDs in Categories B and C in Table 1.

The aforementioned anonymous survey provided to MSF headquarters medical and operations staff yielded 30 responses. The results of the average estimated frequency and severity (each on a scale of 0–4) of the 46 CSDs, as they were perceived by respondents to occur as problems in MSF settings, is displayed in Fig 1.

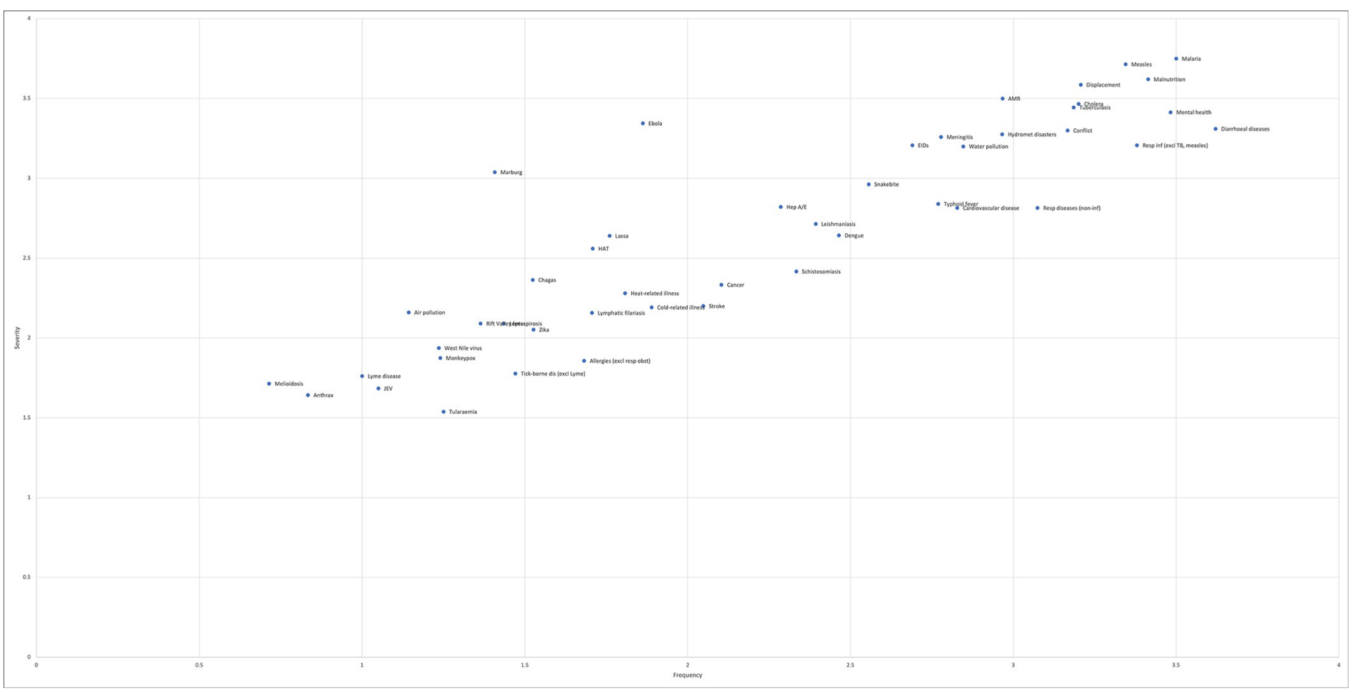

Fig 1. Perceived frequency and severity of CSDs in MSF settings.

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Table 2. Perceived overall relevance of CSDs to MSF (in terms of product of estimated frequency and severity).

CSDs in descending order from highest (top left) to lowest (bottom right) perceived relevance		
Malaria	**Respiratory diseases (non-infectious)**	**Heat-related illness**
Measles	Emerging infectious diseases	Lymphatic filariasis
Malnutrition	Cardiovascular disease	Chagas
Diarrhoeal diseases	Typhoid fever	Zika
Mental health	Snakebite	Allergies (excluding reactive airways disease)
Displacement	Dengue	Leptospirosis
Cholera	Leishmaniasis	Rift Valley fever
Tuberculosis	Hepatitis A & E	Tick-borne diseases (excluding Lyme disease)
Respiratory infections (excluding measles & tuberculosis)	Ebola	Air pollution
Conflict	Schistosomiasis	West Nile virus
Antimicrobial resistance	Cancer	Monkeypox
Hydrometeorological disasters	Lassa	Tularaemia
Water pollution	Stroke	Japanese encephalitis virus
Meningitis	Human African trypanosomiasis	Lyme disease
	Marburg	Anthrax
	Cold-related illness	Melioidosis

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A complementary, yet distinct, perspective on the relevance of these CSDs to MSF settings can be discerned from Table 2, which lists the same 46 CSDs in descending order with respect to the product of their estimated frequency and severity–that is, the average frequency score from the survey multiplied by the average severity score. The CSDs at the top of the list may thus be considered, for this purpose, those perceived to be 'most relevant' at present to the MSF staff participating in the survey, with those at the bottom correspondingly perceived to be the 'least relevant' at present.

An additional, valuable insight is provided in Fig 2, which displays the proportion (expressed as a percentage) of survey respondents who answered 'I don't know' regarding the estimated frequency and severity of each CSD in contexts where MSF works. Fig 2 is displayed with the 'best known' CSDs at the extreme left of the *x* axis, with the overall level of perceived knowledge regarding the frequency and/or severity of the CSDs (specifically in such settings) decreasing towards the right of the *x* axis.

Comparison of Table 2 and Fig 2 highlights an important phenomenon, namely the significant overlap between those CSDs considered to be of relatively low relevance (as represented by the product of their average estimated frequency and severity scores) and those CSDs with a high proportion of respondents who stated they didn't know how frequent and/or severe these problems are in settings where MSF works.

Consideration of the above findings together suggests that there may be some value in grouping the 46 CSDs into five categories, as outlined in Table 3.

Discussion

This study demonstrates that there are some important evidence gaps with respect to the health impacts of climate change on people affected by humanitarian crises. Unfortunately, this is but a small part of a wider problem: the 'overlooking' of the needs of vulnerable populations. The phenomenon highlighted in this paper, whereby issues most relevant to high-income countries are over-represented in the literature, and those most relevant to low-income countries are under-represented, is effectively ubiquitous in academia. However, it is especially poignant for this topic, when one considers that the majority of the research being

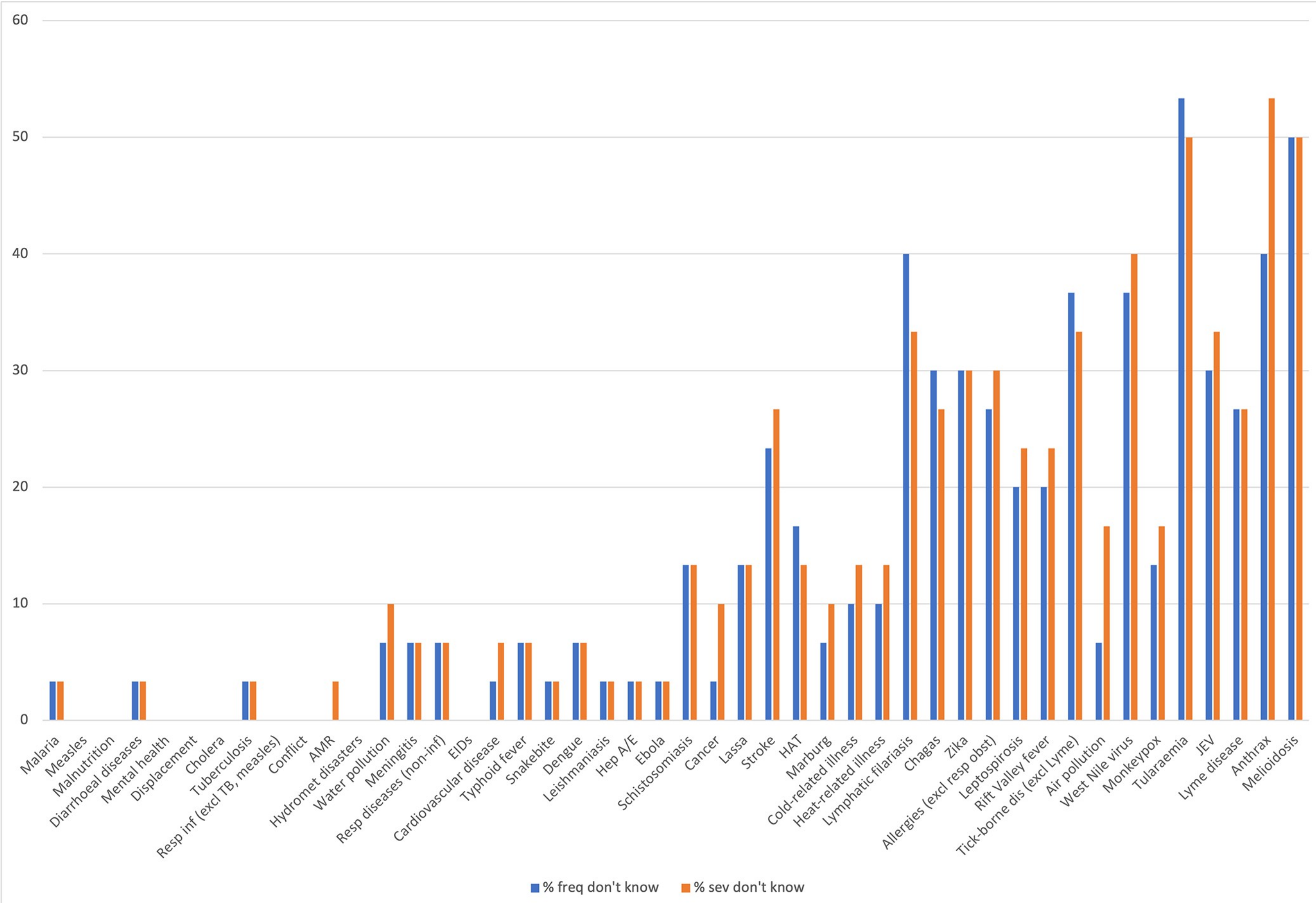

Fig 2. Percentage of survey respondents who answered 'I don't know' when asked to estimate the frequency and severity of each CSD in MSF settings.

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Table 3. Categories of CSDs.

Category	Example CSDs	Significance
CSDs that are highly relevant to MSF settings and are well described in AR6 with appropriate and sufficient supporting evidence	Malaria Cholera Malnutrition	This group represents the diseases most relevant to MSF with the strongest evidence of their climate sensitivity
CSDs that are less relevant (or relatively irrelevant) to MSF settings but are nevertheless well described in AR6	Anthrax Lyme disease West Nile virus	This group represents a possible form of information bias, whereby CSDs more relevant to high-income countries (e.g. Europe, North America) are relatively over-represented in the IPCC review
CSDs that are relevant to MSF settings but are mentioned only briefly or indirectly in AR6	Meningitis Snakebite Leishmaniasis	This group likely represents a combination of bias and evidence gaps, whereby evidence does exist regarding the climate sensitivity of these diseases but the relevant information is not adequately reflected in the IPCC review
CSDs that are relevant to MSF settings but are not mentioned at all in AR6	Measles Ebola Human African trypanosomiasis	This group represents a significant evidence gap, with possible bias, whereby the climate sensitivity of the diseases is biologically plausible or proven but the current evidence is limited or speculative
CSDs that are potentially relevant to MSF settings but about which the level of knowledge (at least regarding estimated frequency and severity) within the organisation is currently low	Melioidosis Air pollution Tick-borne diseases	This group represents a potential knowledge gap for MSF staff, who may be unaware of the burden, climate-sensitivity and/or risk of these diseases

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generated on climate change and health originates from those countries who are both among the largest emitters of greenhouse gases and those with the greatest capacity to take action against climate change.

Many of the populations most affected by climate change, including in terms of health impacts, are already experiencing multiple hardships, such as poverty, violence and displacement, that all have detrimental effects on health. The addition of the burden of climate-related health problems, coupled with the paucity of research on how these manifest, and how such impacts can be minimised, is clearly unjust, particularly considering the negligible contribution that such populations have made to the problem of climate change itself.

Of course, evidence requires research, research requires data, and data is often poor quality, incomplete or entirely absent in humanitarian contexts. The reasons for this are multiple, including discrimination and/or marginalisation of these specific populations; weak or failed health systems, lack of infrastructure (e.g. to generate meteorological and epidemiological information); lack of resources (human, financial, other); and the challenges of access due to conflict, geography, etcetera [75]. Incomplete, inaccurate and fragmented data has contributed to negative outcomes in previous disaster responses [76], and disruptions to health systems compromise the accuracy and efficacy of dissemination and analysis of health information [77]. However, while these obstacles may be understandable, that does not mean they are acceptable.

When it comes to the inclusion–or absence–of such context-specific evidence in the IPCC reports, it must be acknowledged that the complex process of reviewing, synthesising and reporting of evidence in the Assessment Reports requires substantial time and effort, involving strict deadlines. This means that research findings published in the period immediately preceding launch of an Assessment Report are usually not included until the next AR cycle, several years later.

This study also suggests that some significant knowledge gaps may exist within the humanitarian community–at least as it is represented by the small sample of MSF headquarters staff who participated in the survey–with respect to the burden of some specific climate-sensitive diseases. The majority of MSF's work has historically been oriented towards acute emergencies such as epidemics, disasters and conflict, meaning that diseases and other climate-sensitive health problems such as malaria, cholera and malnutrition are those most familiar to MSF staff. Issues that are relatively familiar to many MSF staff extend to otherwise rare diseases such as the viral haemorrhagic fevers Ebola and Marburg, which were identified by survey respondents as infrequent but severe (see Fig 1). However, large-scale health problems such as air pollution and heat stress, whose burdens (in terms of illness and death) are already enormous, and expected to increase due to climate change [78], may become more prominent in humanitarian settings over time and thus represent a different type of emergency that is more chronic in nature. In parallel, climate-sensitive infectious diseases such as melioidosis, whose global burden is thought to be significantly under-estimated at present (but may in fact be greater than several other, better-known diseases such as dengue fever, leptospirosis and schistosomiasis, all of which are included in this review) [79], may evolve from being almost unknown in humanitarian settings to one that is increasingly recognised and treated as epidemiological data and diagnostic capacities improve.

It is not only the health impacts of climate change themselves that are important to better understand through further research, including in humanitarian settings, but the strategies required to minimise those impacts. Analysis of adaptation strategies to protect the health of populations affected by humanitarian crises was outside the scope of this project, but this is an urgent priority for the research community. Ideally, this research should be conducted in partnership with the populations affected and, where useful and feasible, in collaboration with relevant humanitarian actors. Addressing these gaps and identifying the most promising operational adaptations to protect human health in humanitarian settings is an established priority for MSF and was the principal reason for conducting this study.

Such adaptation measures must be not only evidence-based, but acceptable and appropriate. This must include consideration and anticipation of the harmful effects that may result. The phenomenon of 'maladaptation' can be seen, for example, in attempts to address climate-change-related food insecurity through altered agricultural practices, which can lead to unintended negative consequences such as increased exposure to snakebite [80].

No discussion of the health impacts of climate change is complete without reiteration of the fundamental importance of mitigation. No amount of research, evidence or adaptation will enable humanity to avoid the worst impacts of anthropogenic climate change. This is only possible through immediate, evidence-based and sustained actions to slow and halt carbon emissions and draw down previously emitted carbon from the atmosphere. MSF has committed itself to ambitious carbon reduction targets, in line with the Paris Agreements, to attempt to demonstrate a 'best practice' approach, become a more responsible humanitarian actor and adhere to the Hippocratic principle of *Primum non nocere* (First, do no harm).

Strengths and limitations

The authors collectively have decades of experience dealing with the majority of the above-mentioned health problems. However, the organisational scope and collective expertise of the authors may certainly be considered skewed–perhaps even biased–towards low- and middle-income countries, resource-constrained environments and vulnerable populations. Whether this may be considered a strength or limitation of the paper is open to interpretation.

What is a clear limitation of this study, apart from the lack of published literature specific to the populations of interest already highlighted in the paper, is the internal survey. This was a highly subjective tool, whose results–including the semi-quantitative analyses presented in this paper–should be interpreted with caution. This issue of subjectivity is particularly pertinent in relation to the strategy of leaving the definition of 'severity' (of climate sensitive 'diseases') open to interpretation by survey respondents. The logic underpinning this decision was that MSF staff have expertise across a wide range of interdisciplinary areas, including not only medical specialty domains but technical, operational and logistical areas such as water, sanitation, hygiene, energy, transport, supply chain, finance and human resource management. For many of the CSDs included in this review, it may be assumed that what one headquarters staff member considers a 'severe' problem (for example, an Ebola outbreak) would be similarly viewed by other colleagues from their distinct areas of technical expertise. However, this would not always be the case. The level to which an MSF headquarters staff member may consider a problem to be severe would be significantly influenced by their professional profile and training, operational experience and previous exposure to the specific issue in question. A disease that is 'severe' from a medical perspective is not necessarily a severe logistical challenge, and vice versa. The purpose of the survey was thus to capture, in the broadest possible sense, the level of concern with which such senior staff viewed each of these CSDs, in order that their collective expertise could inform the interpretation of the responses and resulting recommendations. To that end, it was decided that attempting to offer an *a priori* definition of 'severity' would influence–and thus potentially inhibit–the variety and richness of possible responses from the broad expertise of staff at MSF headquarters.

The survey was shared only with staff in the medical and operations departments at MSF's International Office and Operational Centres. This decision was based on the assumption that these staff would have a reasonable depth and breadth of experience across a variety of MSF settings, and would be at least somewhat familiar with the majority of the CSDs included in the survey. Such decisions and assumptions come with obvious risks related to bias, including from excluding non-headquarters-based staff, and having no exclusion criteria for respondents based on their perceived or measured knowledge and experience. Only 30 of those headquarters staff responded to the survey, limiting the extent to which the results could be analysed and/or generalised at larger scales. Nevertheless, the authors feel that these results do provide useful indicators as to the required direction of future climate change and health research, and priorities for knowledge-sharing and awareness-raising within MSF and the wider humanitarian community.

It must be acknowledged that the list of CSDs included in this study is far from exhaustive. There is increasing evidence that diseases of significant global importance, such as human immunodeficiency virus (HIV), may have altered transmission in connection to climate-linked phenomena such as drought [81]. Many other emerging or re-emerging diseases, such as Crimean-Congo haemorrhagic fever [82], have also been demonstrated to be sensitive to meteorological and environmental variables. The list of climate-sensitive diseases, while perhaps not infinite, is certainly lengthy.

A final emphasis must be placed on the urgent challenge of establishing more accurate estimates of the global morbidity and mortality related to climate change. The official WHO figure of approximately 250,000 deaths per year for the period 2030–2050 is explicitly limited to only four categories of CSD: malnutrition, malaria, diarrhoeal disease and heat stress [83]. As this study demonstrates, and other authors have highlighted [84], the true scale and burden of the problem is being severely underestimated at present–likely by orders of magnitude–and this must be a priority area for further research.

Conclusions

As evidence regarding the health impacts of climate change continues to grow, the IPCC Assessment Reports remain the ‘gold standard’ sources of expertly synthesised information on this complex topic. However, there are important gaps in the IPCC’s latest Assessment Report, and in the evidence that was available for inclusion within it, particularly in relation to people affected by humanitarian emergencies. Such populations, which are already burdened by multiple layers of health vulnerabilities, are being forced to suffer further due to the lack of evidence available to inform efforts to address their particular health needs, including adaptation measures to protect against the effects of climate change. There are also knowledge gaps within the humanitarian sector which are similarly important to address through research and advocacy.

It cannot be the responsibility of the people affected by humanitarian crises, nor humanitarian actors alone, to address these evidence gaps and put in place the measures required to minimise the harmful effects of climate change on the health of these populations. It is essential that the scientific community collaborates with government and non-government organisations to address the evidence gaps and identify the most appropriate strategies to protect the health of the people most in need.

The voices of people affected by humanitarian emergencies, and the evidence regarding the impacts of climate change that they are experiencing, including on their health, must be more accurately and comprehensively included in future IPCC reports, as well as the global policy agenda.

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article provides a robust perspective from multiple authors affiliated with MSF, but this should not be assumed or portrayed to represent an official position of MSF as an international organisation.

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