Population and Environment (2021) 43:61–81
https://doi.org/10.1007/s11111-021-00377-7

REVIEW ARTICLE

Scales and sensitivities in climate vulnerability, displacement, and health

Lori M. Hunter[1] · Stephanie Koning[2] · Elizabeth Fussell[3] · Brian King[4] · Andrea Rishworth[4] · Alexis Merdjanoff[5] · Raya Muttarak[6] · Fernando Riosmena[1] · Daniel H. Simon[1] · Emily Skop[7] · Jamon Van Den Hoek[8]

Accepted: 9 February 2021 / Published online: 22 April 2021
© The Author(s), under exclusive licence to Springer Nature B.V. 2021

Abstract

Climate change and attendant weather events are global phenomena with wide-ranging implications for migration and health. We argue that while these issues are inherently interrelated, little empirical or policy attention has been given to the three-way nexus between climate vulnerability, migration, and health. In this *Review*, we develop a conceptual model to guide research on this three-way nexus. In so doing, we apply our conceptual model to a range of case studies, including Bangladesh, Mexico, Myanmar, and the USA. They illustrate that climate vulnerability-migration-health interlinkages are context specific, varying by political, economic, demographic, social, and environmental factors unique to each population and place. Even so, the case studies also demonstrate that overarching themes amenable to policy can be identified. Global organizations and researchers from a multiplicity of disciplinary backgrounds have strong imperatives and unique but often overlooked capacity to innovate and experiment in addressing climate vulnerability-migration-health interlinkages. We call for research and policy focus on these issues and suggest targeted efforts to begin mitigating migration and health issues associated with global climate change.

Keywords Climate · Displacement · Vulnerability · Migration · Bangladesh · Mexico · Myanmar · Hurricane Katrina

Introduction

Since 2008, 22.5 million people have moved annually due to climate and weather-related events (Adger et al., 2014). Recent predictions indicate intensified climate and weather-related events may increase rates of environmental movement even

Extended author information available on the last page of the article.

✉ Lori M. Hunter
Lori.Hunter@colorado.edu

Extended author information available on the last page of the article

more, especially in vulnerable regions (Werz & Hoffman, 2016). While movement can act as an important and useful adaptive response to climate impacts, it can also yield a number of health impacts—both positive and negative—at all stages of the migration journey as well as for both origin and host communities (Schwerdtle et al., 2018). Health also influences the ability to move away from climate extremes (Jochum et al., 2018). People with poorer physical, mental, and/or social health are generally less well equipped to respond to climate and weather-related events and are less likely to adapt and more likely to become trapped in place (Schwerdtle et al., 2018). In addition, since poor health is associated with lower socioeconomic status and geographical deprivation (Roubinov et al., 2018), climate events can exacerbate pre-existing and underlying health conditions and pose greater impacts for places with weak infrastructure and social services (Rigaud et al., 2018).

Although climate and weather-related events affect the scope and scale of human movement and health, these concepts and their connections are still often overlooked in academic scholarship and international policy domains (Schwerdtle et al., 2020). The Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (2014) provides arguably the most comprehensive literature review and assessment on climate and health, and climate and migration, yet does not address these three concepts together. More recently, the Lancet Countdown on Health and Climate demonstrates the important health consequences of climate variability but fails to outline specific consequences for migration (Watts et al., 2019). Within academic scholarship, there exists longstanding theoretically and methodologically diverse bodies of research on climate change, migration, and health, separately; however, scholars have only recently begun examining the interlinkages between these three domains (Schwerdtle et al., 2018, 2019, 2020; Jochum et al., 2018; Shultz et al., 2019). Existing research provides important knowledge on these interconnections, demonstrating how climate events aggravate pre-existing vulnerabilities (Schwerdtle et al., 2019), the processes through which climate-related events induce migration decisions (Schwerdtle et al., 2018), and the positive and negative, direct and indirect effects health effects of migration (Jochum et al., 2018).

Yet, despite a shift in scholarship away from single-cause and unidimensional models of migration, many causal chains, triggers, thresholds, and consequences embedded in the climate-migration-health nexus remain uninterrogated. For instance, more work is needed to develop and operationalize climate variables at various spatial and temporal scales (Grace et al., 2020; Schwerdtle et al., 2020). Reflecting this, in a recent review of migration and health in the context of climate change, Schwerdtle et al. (2020; 1; 3) contend that "there is no consistent approach to integrating climate data in studies exploring migration and health in the context of climate change" nor "consideration to specific aspects of the adaptive potential of climate change-related migration, especially in terms of health." Since the "relationships between migration and health in the context of climate change are strongly heterogeneous and global findings unlikely to emerge," each case must be carefully assessed by taking health and its determinants into account, while recognizing that migration is not uniformly an adaptive solution to climate change risk (Schwerdtle et al., 2020; 9; Adams, 2016). The climate vulnerability-migration-health interaction producing this spatial and temporal heterogeneity necessitates conceptual models that do not narrowly center on the specific event but rather situate the case within wider socio-ecological environments and more dynamic processes over time. Elucidating the context-specific

and multiscale processes that produce differential sensitivities is critical for climate vulnerability, health, and migration research. So is the development of overarching analytic and conceptual frameworks that are transferrable across a variety of spatial and temporal scales (Schwerdtle et al., 2020).

In order to address these needs, this *Review* outlines a conceptual model to demonstrate the climate vulnerability-migration-health nexus. We present a range of empirical case studies to establish the salience of these relationships, emphasizing scale, temporal outcomes, health as a driver and outcome of migration, and individual-place–based climate vulnerabilities. Given the limited research on these three-way intersections, we rely on empirical studies of the dyadic relationships, highlighting critical knowledge gaps while demonstrating the value of our model for scholarship and practice. Interpreting case studies through our conceptual model reveals that while climate-migration-health interlinkages are context specific (Black et al., 2011, 2011), overarching conceptual themes can be identified that are amendable to policy. We argue that issues of public health must be central in relocation deliberations and in efforts to mitigate the future effects of climate events. This *Review* concludes with several recommendations for future research and policy interventions.

Climate events and migration

Climate events are projected to increasingly influence human mobility (Warner, 2010). While no universally agreed definition of climate-induced human mobility exists (McLeman & Gemenne, 2018), it broadly refers to movement of people driven by sudden or progressive changes in the weather or climate, with the changes varying along a continuum. This continuum is depicted in Fig. 1, along with the (in)ability of a person or population to stay or leave in response to a climate-related event. While a climate-related event may generate widespread uncertainty among residents of an affected place, those residents experience its impacts in accord with their degree of vulnerability, combined with the vulnerability of their place (Lutz & Muttarak, 2017). More specifically, the propensity of an individual and/or population to move depends on the dynamic interactions between vulnerabilities associated with personal or population characteristics (e.g., socioeconomic status, health conditions, etc.) and with aspects of place (e.g., political institutions, protective infrastructure, public utilities).

Moving horizontally from left to right in Fig. 1 represents an increase in the vulnerability of people and/or place, and a decrease in adaptive capacity that coincides with (im)mobility being more or less voluntary, respectively.[1] Voluntary mobility (top-left of Fig. 1) can be adaptive to climate-related events.[2] This is demonstrated in our case studies highlighting selective movement of certain people out of climate-affected areas in Mexico and Bangladesh.

[1] It is important to note that migration decisions involve a variable degree of agency that inversely corresponds to the strength of the environmental threat. Ultimately, the relationships and tipping points implied depend both on the magnitude of a climate event or threat and the characteristics of the individual and/or population and place affected (Füssel & Klein, 2006).

[2] Underlined text represent concepts presented in Fig. 1.

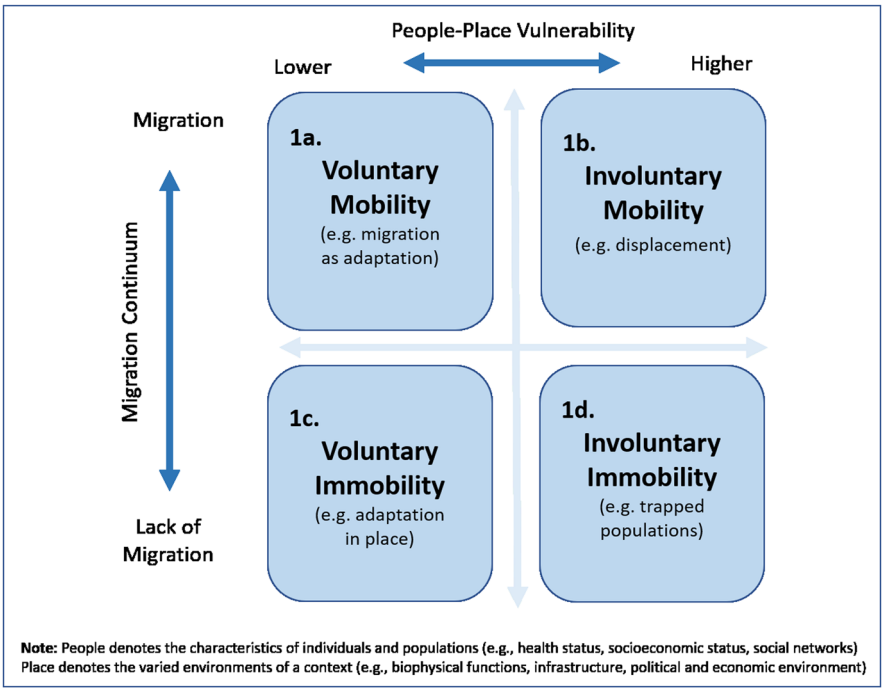

Fig. 1 Climate vulnerability—migration interaction. People denotes the characteristics of individuals and populations (e.g., health status, socioeconomic stat us, social networks). Place denotes the varied environments of a context (e.g., biophysical functions, infrastructure, political and economic environment)

Drawing on the International Migration Organization's definition, we conceptualize involuntary mobility—"displacement"—as forced movement from one geographically defined place to another (top right of Fig. 1). We consider "forced" to also reflect the inability to maintain livelihood functions. While migration in such situations may appear more voluntary, it can actually be characterized by very low levels of volition (Fussell, 2012). We discuss this further in the case study of Hurricane Katrina in which highly vulnerable households were displaced and less likely to return after the event. Immobility decisions are also shaped by the vulnerability of people and places. We conceptualize voluntary immobility (bottom left) as situations in which there is the option to stay and adapt in situ. For example, less vulnerable households affected by Hurricane Katrina were more likely to stay or return as described below.

However, in other cases, migration is not a viable option due to characteristics of the individual, social groups, and/or the places they live. We conceptualize this as involuntary immobility (bottom right), which refers to individuals and groups unable to flee climate-related events due to health status, socioeconomic position, political context and/or biophysical environment, despite potentially having a desire to move (Black et al., 2011, 2011). Examples of such situations emerge in our case studies of Bangladesh and Myanmar, in which highly vulnerable groups have not been able to successfully flee climate-related events due to highly constrained leaving options.

In all, we contend that conceptualizing interactions between populations and places and the particular mechanisms that spur or thwart mobility supports theorization of the multiple ways that climate-related events concomitantly shape dynamics of people and places, their attendant vulnerabilities, and potential movement responses. We now take this understanding to the climate vulnerability-migration-health nexus.

Climate vulnerability, migration, and health

Recognizing the multidisciplinary history of vulnerability studies, ranging from the risk-hazard to social constructivist frameworks, this *Review* is situated broadly in the hazards of place literature (Cutter et al., 2000). The hazards of place approach shift understandings of vulnerability from a narrow focus on either the biophysical vulnerability of a particular place or explanations of vulnerability rooted in individuals, groups, and institutions to the broader socio-ecological factors that shape people and place climate vulnerability across scale. This broader conceptualization allows for the transferability of the growing scholarship in this area across disciplinary and institutional perspectives, an important step for establishing policy relevance (Schwerdtle et al., 2020).

We broadly use the hazards of place approach to propose a new conceptual model of the climate vulnerability-migration-health nexus (Fig. 2) which was informed by the collective expertise of our interdisciplinary author group. Our focus, further elaborated below, emphasizes intersections of the three domains of climate vulnerability, migration, and health and how scales and sensitivities shape, and are shaped by, these intersections.[3] As represented by Fig. 2's smaller internal circles, health is scaled from individual processes to population distributions of physical, mental, and social wellbeing. Climate vulnerability is similarly scaled based on the intersection of people living under given circumstances. Migration is scaled, or modified, by opportunities for, or restrictions on, (im)mobility among people and between places (as detailed in Fig. 1).

Experiences of vulnerability, however, are unevenly distributed across society, varying by social, political-economic, and historical factors operating at multiple scales (Thomas et al., 2019). As climate and weather events intensify, so does population exposure to environmental hazards, exacerbating existing unevenness in vulnerability across axes of social and demographic difference (class, race, ethnicity, religion, caste, gender, age, etc.) (Leichenko & Silva, 2014; Muttarak, 2016). Governance systems also modify people's vulnerability to a climate event. The way local governments, civil society, or external organizations represent, plan, and manage climate events play a fundamental role in reducing or increasing vulnerabilities among social groups (Thomas et al., 2019). Indeed, policy prescriptions are often designed and implemented by governments and non-governmental organizations (NGOs) operating at different spatial scales than specific climate

[3] Our focus on scale allows for consideration of how conditions (including socioeconomic conditions) in communities or otherwise localized environments modify how spatial and temporal exposures matter for climate vulnerability, migration, and health (Grace 2017; Grace et. al., 2020; Wu, Zaitchik, Swarup, Gohlke, 2019).

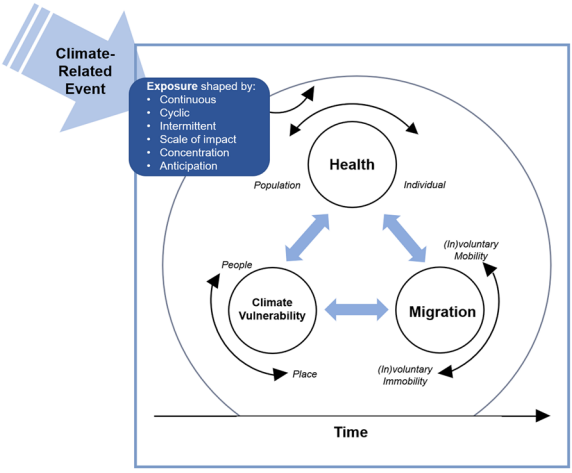

Fig. 2 Conceptual Framework of the climate vulnerability-migration-health nexus. Continuous: a static climate-related event experience that may lead to adverse health outcomes. Cyclic: repeated climate-related events that can be anticipated. Intermittent: climate-related events that occur irregularly but not necessarily infrequently. Concentrated: reflects a major climate-related event that impacts communities and may lead to long-term recover. Unanticipated: seemingly random, extreme events. *The above five characteristics adapted from Grace et al. (2020) Health ranges from the individual, family, community, region, national, and international scale. Migration ranges from voluntary mobility to involuntary immobility as detailed in Fig. 1. Climate vulnerability ranges from the vulnerability of people (i.e., health status, socioeconomic status, social networks, etc.) and the vulnerability of place (i.e., biophysical functions, resources, infrastructure, political and economic environment). *The arrows surrounding each core circle (climate vulnerability, migration, health) represent the scalar dimensions of each

events. Despite policy actors being far removed from impacted populations and places, they often have the capacity to design "solutions" either because such entities have the legal rights, direction from governments, or agreements with local governments or NGOs to intervene or offer assistance (Nightingale, 2017). Hence, when approaching a climate-vulnerability-migration-health analysis, attention to this type of scaling between communities and social groups is essential to account for spatial and contextual variability in nexus outcomes and associations (Grace et al., 2020; Schwerdtle et al., 2020).

Working through Fig. 2, we suggest that understanding the climate vulnerability-migration-health nexus first involves an examination of a specific climate-related event, considering its temporality (continuous, cyclic, intermittent), concentration, and scale of impact, and whether or not the event was anticipated (Grace et al., 2020; Warner, 2010; represented in the upper left corner).[4,5] Such characteristics

[4] While common classification systems often distinguish an event dichotomously by its intensity (i.e., a sudden onset, high severity) and extent (i.e., low severity, high frequency), distinctions between intensive and extensive risks are quite arbitrary since there is no quantifiable threshold between these two classificatory schemes (UNISDR, 2015). Indeed, such classifications miss other types of events that influence migration and health (UNISDR, 2015) such as droughts that may unfold over years, eventually reaching a threshold rendering places uninhabitable. As a consequence, we articulate several dimensions of climate events within our conceptual framework.

[5] Underlined text represent central elements of the conceptual model presented in Fig. 2.

determine the nature and degree to which a social and/or ecological system is exposed to climate-related events, with exposure represented as Fig. 2's outermost circle encompassing the climate vulnerability-migration-health nexus. That said, variations in exposure alone are unable to yield complete insight into the implications of climate or weather-related exposure as attention must also be paid to the spatial and/or temporal scales through which exposures occur (Grace et al., 2020).

To deepen consideration on the intersections between spatial and temporal scales, we draw on Grace et al. (2020) dose-response model to conceptualize temporal scale in climate vulnerability-migration-health interlinkages (the bottom arrow in Fig. 2 represents time). As aptly noted by Grace et al. (2020), it matters when people and places are exposed to climate-related events, migration, and/or changes in health status. In essence, complex socio-ecological interactions at one point lay the foundation for those in the future.

Two dimensions of time can help elucidate the interactions within the climate vulnerability-migration-health nexus as well as the implications of those interactions. First, at the scale of people, consideration of life course stage is essential to the development of a more complete understanding of vulnerability. As an example, consider the heightened vulnerability of a pregnant woman to a climate-related event, and the intensified implications of displacement for the health and well-being of both herself and her unborn child. Here, we have combined dimensions of climate vulnerability-migration-health but understood the nexus as related to an individual's specific place in her life course.

Second, we can also think of time as calendar time. Here, our case study of Myanmar is useful in that it describes how longstanding civil unrest has led to millions of refugees and internally displaced persons. This conflict-ridden historical period laid the groundwork for intensified climate vulnerability in the subsequent years, demonstrating that historical context, representing calendar time, matters to current understandings. Finally, bringing together individual and calendar time allows for further nuance allowing for the intersection of personal biographies with historical moments shaping both people and place (Grace et al., 2020).

Moving to the three cores, smaller circles in Fig. 2, here, we focus on the central dimensions of our nexus. Drawing on the IPCC definition of vulnerability (IPCC, 2001), we conceptualize climate vulnerability on a gradient representing the ability or lack thereof to withstand or successfully adapt to climate events. These dimensions of climate vulnerability are shaped by cross-scalar characteristics, represented by the double-headed arrow which includes characteristics of people (e.g., health status, socioeconomic status, social networks, etc.) and place (e.g., biophysical functions and resources, infrastructure) (Cutter et al., 2008; Füssel & Klein, 2006). In essence, climate-related events act to amplify existing drivers of climate vulnerability, unique to each context and population (Black et al., 2011, 2011).

On migration, climate vulnerability at the scales of people, population, and in between, interact to shape movement which itself ranges from voluntary mobility to involuntary immobility (detail in Fig. 1). For instance, if a population experiences an intense, concentrated climate event, such as a hurricane, the synergistic climate vulnerability of both people and place will determine the movement responses available to an individual/population.

Of course, our overarching argument contends that health is also a cause and consequence of both climate vulnerability and migration. Hence the nexus. Throughout this *Review*, we use the WHO definition of human health—— a "state of complete physical,

mental, and social well-being, and not merely the absence of disease or infirmity"—highlighting distinctions in physical and mental health, immediate and long-term health impacts, and communicable and non-communicable diseases (WHO, 1998). As in the cases of climate vulnerability and migration, the double-headed arrow above the health circle in Fig. 2 indicates scale, specifically arguing that the pathways linking climate-related vulnerability, migration, and health must be conceptualized across scales ranging from the individual to the global population with families, communities, regions, nations, and world regions in between. As an example, due to pre-existing individual characteristics and conditions of the environment, the health-migration link varies with the climate event at hand. This point is well illustrated by our four case studies in which the climate events range from drought to hurricane to sea level rise with their specific migration-health connections influenced by vulnerabilities of both people and place.

While the model is simplified in its presentation, rooting our conceptual model in the hazards of place literature permits a wide application to the study of climate vulnerability-migration-health linkages in multiple contexts and disciplinary backgrounds. To elucidate this nexus, we apply our conceptual model to a range of case studies, some already briefly mentioned above. These cases provide a way to read across studies and garner important theoretical insights transferable across geographical contexts.

Mexican migration to the USA

The case of Mexico-USA migration demonstrates how intermittent, slowly evolving climate-related events (e.g., drought) intersect with existing migration channels and multiscalar people-place factors to strain life sustaining processes, facilitate movements, and impact health. While migration from Mexico to the USA has occurred for well over a century, in recent decades, it has been driven in part by the Mexican recession, currency devaluation in the 1990′s, and global economic recession in the mid-2000s (Chiquiar & Salcedo, 2013; Massey et al., 2003). Today, migration is attributed to a complex mix of factors—growing economic inequality, violence, drug conflicts, and uncertainty, complicated further by trade wars between the USA and Mexico (Fleury, 2016). This situation is compounded by environmental decline and changing climatic events (Feng et al., 2010; Leyk et al., 2017).

Examining these dynamics through our conceptual model illuminates how slowly evolving irregular climate pressures stress pre-existing people-place dynamics to shape the climate vulnerability-migration-health nexus. In Mexico, increasing incidents of severe storms, droughts, and floods impact soil quality, crop's susceptibility to disease, and local economies. These climatic events operate in tandem with other place-based vulnerabilities in local communities and government institutions to inform residents' decisions to move abroad (Fleury, 2016). Since corn—a critical Mexican crop—is sensitive to temperature and rainfall fluctuations, climate events pose threats for farmers' livelihoods (Feng et al., 2010; Schmidt-Verkerk, 2010). Indeed, current evidence indicates that droughts and heat spells in Mexico are influencing patterns of migration to the USA, particularly from rural areas, beyond what historical flows would otherwise predict (Leyk et al., 2017). Although Mexico-US migration might be considered voluntary, we argue that the strain wrought by slowly evolving climate pressures and intersecting political, economic, and

social challenges compel movement, especially in strongly agricultural regions (Cascone et al., 2016). Health is intricately implicated in these dynamics. Since international travel has high costs and can pose physical risks, especially when traveling without a visa, Mexican migrants are often healthier, wealthier, and younger than their non-migrant counterparts—emblematic of positive health selectivity (Riosmena et al., 2013).

Once in the USA, immigrants face barriers to health care access including linguistic barriers, discrimination, and lack of health insurance (Becerra et al., 2015). Forty-seven percent of Mexican immigrants are uninsured, compared with 27% for all immigrant groups and 9% of USA-born residents (Riosmena et al., 2013). Acculturation can lead to adoption of lifestyles typical of destination regions. For Mexican migrants in the USA, this can generate increased rates of chronic conditions and higher mortality (O'Brien et al., 2014). The current social and legal climate in different US host communities creates further barriers to formal and informal social services and limits access to hazard resilient neighborhoods—all undermining physical, mental, and social health. Moreover, migrants lacking permanent legal status face further challenges—fear of arrest, deportation—inhibiting safety net use in disasters (Fussell, 2018).

Understanding climate-movement-health relationships aids efforts to support migrants' health in the sending and receiving communities of Mexican migration. For instance, recent research shows that Mexico-US migrants experiencing health limitations, who are stressed, or experiencing sadness are more likely to return to Mexico than those without these symptoms (Diaz et al., 2016). Mexican return migrants are also more likely to experience severe health problems and depression and have suicidal thoughts compared with their non-migrating peers in Mexico (Arenas et al., 2015). This pattern is intensified for older return migrants who have fewer household

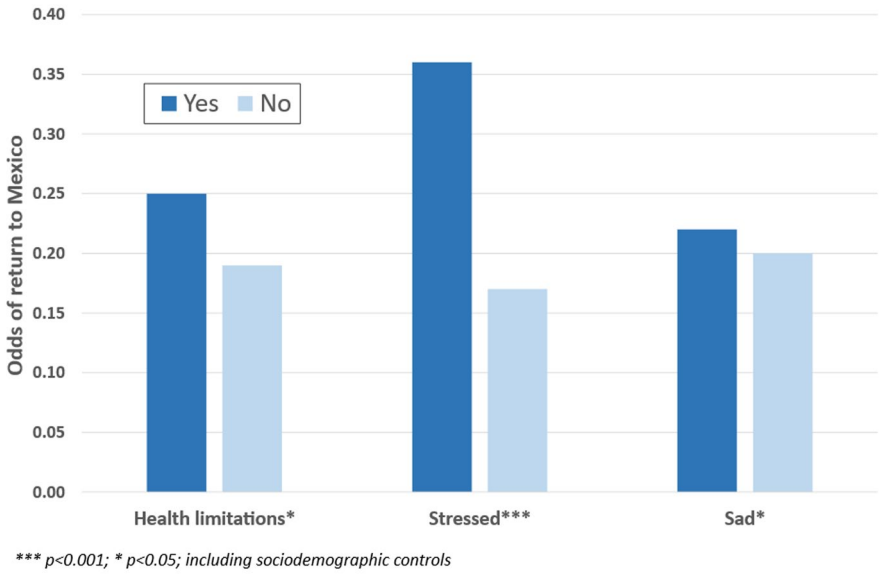

Fig. 3 Predicted probability of returning to Mexico among voluntary migrants

members and less social support (Arenas et al., 2015). Thus, since climate events contribute to stress, anxiety, and depression (Berry et al., 2010), returning migrants in vulnerable places may face a disproportionate health burden in light of climate change projections (Leyk et al., 2017). In sum, this case offers an example of how the climate-migration-health nexus is multidirectional and multi-scaled, involving established and emerging systems that react to, and reproduce, climate sensitivities. The essential nature of calendar time is reflected here, too, in that historical challenges in the political, economic, and social realms have created a longstanding culture of migration particularly within agricultural regions of rural Mexico.(see Fig. 3)

Displacement in Bangladesh

The Bangladesh case study demonstrates how cyclic climate-related events intensify established inequities among populations and places at different geographical scales, producing a range of migration responses and health outcomes. Bangladesh is a low-lying riverine country subject to an annual tropical monsoon season. With a largely agricultural economy, its densely settled rural areas are vulnerable to sea level rise, soil salinization, and groundwater contamination, making rural livelihoods precarious. Bangladeshis use migration as a coping strategy against these climate effects (e.g., Carrico & Donato, 2019). However, as socio-economic, political, and ecological uncertainties intensify in the country under climate change, more citizens are falling into poverty and potentially becoming involuntarily immobile (MOFA, 2018). In low elevation areas, frequent, continuous, and severe climate events—sea level rise, cyclones, droughts, soil salinization—are driving many from their homes (Ginnetti & Lavell, 2015). While studies in Bangladesh suggest these climate-related changes have played only a small role in migration patterns within the country or to neighboring India (see: Carrico & Donato, 2019; Chen & Mueller, 2018; Davis et al., 2018), prospective studies estimate that by 2050, up to 18 million people will be forced from their homes due to floods and sea level rise (Rigaud et al., 2018; Ginnetti & Lavell, 2015).

Important spatial variations exist in the way climate-related events are unfolding across the country, between rural coastlands and urban centers, and between social groups. While Bangladeshi citizens at-large are vulnerable to the effects of sea level rise and related climate-related changes, women, children, people of lower socioeconomic status, and slum dwellers face the greatest risks to their health and their homes (MOFA, 2018). For example, sea level rise has reduced both the yield and nutritional value of crops through soil and water salinization and contamination, leaving millions of people vulnerable to health problems including preeclampsia during pregnancy, acute respiratory infections, malnutrition, food insecurity, and skin diseases (Bhatta et al., 2016; Cooper et al., 2019; Huq et al., 2015; Pinchoff, et al., 2019). Coastal regions experience increased frequency and severity of tropical storms, creating both immediate and long-term health threats (Kabir et al., 2016). At the household scale, evidence suggests the greatest burden of climate-related events fall on lower socioeconomic households, who have neither the luxury to move, nor the ability to sustain livelihoods, signaling the potential involuntary immobility or a trapped population dynamic (Black et al., 2013; Ayeb-Karlsson et al., 2020).

Women are further marginalized as they have less access to land, resources, wages, and decision-making power, facing additional health and survival challenges after climate events and displacement (Ahmed et al., 2019; Bhatta et al., 2016).

The International Organization for Migration estimates that 70% of Dhaka's slum residents settled there after having fled sinking coastlines, cyclones, and flooding (Akter, 2009). Expanding and dense informal settlements create further health challenges impacted by water, air, and sanitation quality (Sverdlik, 2011). Mega-cities like Dhaka, housing many displaced residents, have poor infrastructure and greater risk of flooding, resulting in vector- and water-borne disease outbreaks (McMichael, 2000). Climate-related traumas, losses, and displacement all harm mental health (Scultz et al., 2014) and create physical health vulnerabilities, especially as displaced people travel and settle in unfamiliar environments (Langlois et al., 2016). After displacement, young girls and women are particularly vulnerable to trafficking and sexual abuse, while older women often experience isolation and stress-related health problems (Ahmed et al., 2019; Young & Chan, 2015). Since environmental disasters are projected to become more frequent and damaging in Bangladesh, appropriate steps to mitigate these emerging migration-health issues are needed (MOFA, 2018).

Theorizing these intersections through our conceptual model helps in examining spatial dimensions and supporting policy development for populations at various spatial scales. While Bangladesh is implementing adaptation policy and measures (Rai, et al., 2014), institutional initiatives often fail due to the neglect of cultural factors embedded in local communities (Islam & Nursey-Bray, 2017). Climate measures are often driven by external agents who prefer to allocate funds based on institutional prioritization or government preferences, without addressing the specific geographical dimensions and issues in slums and coastal areas (Islam & Nursey-Bray, 2017; Geun, 2019). This constrains community participation, rendering adaptive measures ineffective due to the inability to create linkages across scales (Biesbroek et al., 2013).

Hurricane Katrina and internal displacement

Climate-related disasters are not restricted to the Global South. The case study of Hurricane Katrina demonstrates how a concentrated climate event can spur processes involving migration and public health responses (or lack thereof) that exacerbate pre-existing inequities in a Global North context. Like Bangladesh, the southern coast of the USA is experiencing more frequent and intense climate-related events (Hallegatte et al., 2013; USGCRP, 2017).

In 2005, Hurricane Katrina struck the US Gulf Coast triggering over 1.5 million residents to leave their homes either in anticipation of the hurricane's landfall or after their homes had been badly damaged (Groen & Polivka, 2010). The below-sea level city of New Orleans was particularly vulnerable due to its reliance on a levee system for protection from surrounding water bodies (Kates et al., 2006). While the government implemented a mandatory evacuation, not everyone was able or willing to leave the city due to limited financial resources, lack of transportation, limited social networks, and distrust in government; those who

remained behind were often the poorest, oldest, and sickest (Barnshaw & Trainor, 2007; Belkhir & Charlemaine, 2007; Elder et al., 2007; Haney et al., 2010).

Roughly 1500 residents of New Orleans died during the prolonged flood after the levees broke; these victims were disproportionately elderly and African-American (Jonkman et al., 2009; Sharkey, 2007). Beyond the immediate impacts of the disaster, the hurricane generated cascading short- and long-term physical and mental health impacts that were also unequally experienced along socioeconomic and demographic lines (Adeola & Picou, 2012; Sastry & Gregory, 2013). The elderly residents of New Orleans, especially African-American residents, experienced elevated rates of morbidity, emergency department visits, and hospitalizations in the year after Hurricane Katrina relative to a national sample (Burton et al., 2009). In the year after the hurricane, while rates of mental and physical disability in the adult population of New Orleans did not change significantly for most groups, the rates for young and middle-aged African-American women increased from 20.6 to 24.6% (Sastry & Gregory, 2013). Mental illness was more widespread in the population in the year after the hurricane: a survey of New Orleans residents found that 39% of residents were classified with probable mild or serious mental illness. However, Black residents, low-income residents, and those with a high school education or less had particularly high odds of mental illness, associations that were strongly related to severe housing damage or loss (Sastry & VanLandingham, 2009). Some research finds that among low-income African-American mothers, mental health problems are still elevated 5 and 12 years later (Paxson et al., 2012; Raker et al., 2019). These findings underscore the social and place-based disparities in Hurricane Katrina's impacts among New Orleans residents, an outcome that hinged on the residential segregation that concentrated African-American residents in some of the hardest hit neighborhoods.

Community institutions and health infrastructure were lost to the disaster as well. Prior to the disaster, Louisiana's health care system had two tiers with the insured population having access to a range of hospitals and physicians while the uninsured receiving health care through state-run public hospitals. The disaster reduced capacity in both tiers, but especially in the public hospitals. A hospital census conducted a year after the hurricane found that staffed inpatient bed capacity fell by more than 50%, from 4083 to 1971, and the number of clinics for the uninsured dropped from 90 to 19 (Rudowitz et al., 2006). Moreover, the disaster closed Charity Hospital, the safety net for many generations of low-income New Orleans residents. Some researchers argue that the destruction of public health infrastructure may have been even more calamitous in the long term, particularly in disadvantaged places (Rudowitz et al., 2006). Prior to the hurricane, Louisiana residents had some of the poorest health statistics in the country, high rates of infant mortality, chronic disease, and AIDS, while one-in-five residents lacked health insurance (Adeola & Picou, 2012; Rudowitz et al., 2006). Without insurance coverage, an injury or illness could financially devastate a person and their family.

Displaced residents faced different types of conditions than those who returned to New Orleans. In the months after the disaster, residents found shelter in nearly all fifty US states (Elliott & Pais, 2006). Black residents and those with lower levels of education returned to New Orleans more slowly than others, in part because of the

disproportionate damage to their homes and neighborhoods (Fussell et al., 2010). For African-Americans in particular, this prolonged displacement or permanent relocation was associated with elevated emotional distress and a hostile reception in many majority white communities during the first years after the disaster (Fussell & Lowe, 2014; Hunt et al., 2009). Yet some residents moved to places characterized by higher incomes and healthier behaviors, and this advantage revealed itself through longer life expectancies among a cohort of such New Orleanians that were also receiving Medicare (Deryungina & Molitor, 2019). In general, however, the effects of displacement on the health and well-being of disaster-affected individuals is not well documented (McMichael, 2015; Uscher-Pines, 2009), illustrating the importance of theorizing and studying climate vulnerability-migration-health relationships.

Viewing the case of Hurricane Katrina and New Orleans through our conceptual model makes several points clear (Fig. 2). First, it demonstrates how climate events stress pre-existing inequities among people and places in the impacted area, undermining opportunities for healthy behavior and healthy environments. Second, it further demonstrates the importance of scale and sensitivities, specifically how climate events have indirect effects outside of affected areas. In other words, climate events generate new and unequal short- and long-term disparities in the impacted and receiving locations that occur across scales. These types of insights generate new avenues for policymakers to develop strategies that support diverse people and/or populations and places in both sending and receiving locations.

Refugees in Myanmar

Finally, we discuss vulnerabilities related to the climate-migration-health nexus uniquely faced by populations that have already experienced both forced displacement and acute restrictions on movement. As of June 2018, there were around 70 million forcibly displaced persons globally under the United Nations High Commissioner for Refugees (UNHCR) mandate—individuals who have left their countries of origin for fear of persecution, violence, or war (UNHCR, 2019). This included 25.9 million refugees, 41.3 million internally displaced people, 5.5 million Palestine refugees, and 3.5 million asylum-seekers (UNHCR, 2019). While reasons for displacement are varied, climate vulnerability and social inequities commonly shape the health hazards faced by millions of displaced persons responding to climate events. The case of Myanmar was chosen to demonstrate how internal forced displacement can be both a cause and consequence of climate vulnerabilities and the social inequities embedded therein.

Myanmar's civil unrest is one of the longest-lasting conflicts worldwide. Civil conflict and regional challenges have generated 3.4 million international refugees, 147,000 internally displaced persons (IDPs), and one million stateless persons, most of whom reside in IDP camps in Rakhine State—one of the wettest areas in the country (UNHCR, 2017). These IDP camps are highly susceptible to flooding, landslides, and other natural hazards (Alam et al., 2020). Moreover, fragile camp settings have limited access to basic infrastructure and aid, intensifying

overcrowded and dilapidated shelters. This not only creates reoccurring health issues but also drives increased vulnerability to natural hazards (Mahmood et al., 2017; UNHCR, 2015). These challenges are disproportionately experienced by women and children, many of whom have suffered violence, rape, and psychological trauma in the northern part of Rakhine State (Hutchinson, 2018).

Recent cyclones, floods, and landslides in the country further amplify the vulnerability of refugees in IDP camps. Between 2007 and 2017, 11 cyclones hit Myanmar, including cyclone Nargis 2008—the eighth deadliest cyclone ever recorded. Nargis resulted in over 140,000 estimated fatalities and spawned two more Category Four cyclones (Mahmood et al., 2017). In 2013, the exact death toll and number of people further displaced by one cyclone remains unknown, but the sheer desperation and anticipation of its approach prompted a group of Rohingya people to flee in makeshift boats that then capsized at sea and resulted in their deaths (Mahmood et al., 2017). This unfortunate event illustrates the complicated and difficult experiences of individuals living in protracted displacement, which commonly coincides with precarious living situations that act as climate traps (Van Den Hoek et al., 2018). Since projections indicate extreme weather worsens pre-existing vulnerabilities, and possibilities for movement and health (Republic of Myanmar, 2017; Horton et al., 2017), more conceptual attention to the dynamic interactions between climate-related vulnerabilities and displacement and the ways they intersect to shape both individual and population movement and health opportunities are needed.

A call for future research and policy agendas

This *Review* contends that climate vulnerability, migration, and health are inherently related, yet little conceptual or policy work has thus far integrated these factors in a coherent manner. Our conceptual model, while simple in design, provides a way for scholars and policy-makers to generate insight into the context-specific and multiscalar processes that produce dynamics and differential outcomes of climate susceptibility and vulnerability, while also generating overarching findings transferrable across spatial and temporal scales. By reviewing a variety of case studies, we maintain that interrogating diverse temporal and multiscale interactions not only yields important insight into the geographical and temporal embeddedness of climate exposure, but also the mechanisms that link exposure to migration and health.

As Grace et al. (2020) contend, consideration of both exposure linkages and the mechanisms that connect climate characteristics and health across spatial and temporal scales is regularly missing from population-environment research, particularly as it relates to climate vulnerability-migration-health linkages (Schwerdtle et al., 2020). We have developed this interdisciplinary conceptual framework in an effort to facilitate these connections in both research and policy. Several conclusions with the potential to inform policy and research emerge from this *Review*. Our Mexican case demonstrates that origins and destinations of displaced populations are often linked by movement in ways that are reflective of, and consequential to, health. Systems thinking is required to move beyond linear origin and destination understandings

"to interrogate complex causal chains, triggers, thresholds, health consequences, and policy and practice significance" (Schwerdtle et al., 2020, p 16). Our Hurricane Katrina case indicates the central element of time in that pre-existing socioeconomic and political vulnerabilities shaped the ways exposure and displacement manifest in health consequences, which often mirror and amplify re-existing inequalities. Further, consideration of time from an individual perspective is illustrated too, in that the heightened vulnerability of the elderly demonstrates the importance of consideration of people's life course stage. Consequently, more theoretical and methodological attention to the underlying (in)equities, marginalization, and allied facilitation processes in post-disaster reconstruction is needed to mitigate the extension and perpetuation of inequities in both movement and health (Kammerbauer & Wamsler, 2017).

Furthermore, it is important to recognize emerging health issues in displacement settings, as indicated by our Bangladesh case, in addition to the way government collaborations can manage and prevent emerging health issues in both sending and receiving regions. A key challenge moving forward is to coordinate institutionalized responses to climate-related events within the complex and multifaceted arena of migration and health. Although essential, such an approach is challenging since multilateral organizations often have different missions and diverse normative frameworks (Yeates & Pillinger, 2013). Political economic contexts also have tremendous influence on the health consequences of climate-related events, as indicated in the Myanmar case. Since climate impacts intersect and amplify other "macro-drivers" of migration to differently affect individuals, households, and communities, future work should examine the formulation, implementation, and efficacy of and between governments, multilateral and nongovernmental organizations in the context of climate vulnerability, migration, and health (Mazhin et al., 2020).

This *Review* and its conceptual model provide a dynamic and concise way for scholars to consider how climate events shape diverse spatial and temporal processes of climate vulnerability, migration, and health, demonstrating the pertinence of examining these three-way relationships for science and society. Whether these issues unfold in Bangladesh, Mexico, Myanmar, the USA, or elsewhere, it is clear that the time to more carefully consider the health aspects of climate-related migration is now.

Acknowledgements Advisory Board Member Dr. Kathryn Grace served as Guest Editor for this Review Article.

Funding This research has been supported by Project Number R13HD078101-05 CUPC Climate Change, Migration, and Health Conference. The project has also benefited from research, administrative, and computing support provided by the University of Colorado Population Center (Project 2P2CHD066613-06), funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development. The content is solely the responsibility of the author and does not necessarily represent the official views of the CUPC, NIH or CU Boulder.

Declarations

Disclaimer The content is solely the responsibility of the author and does not necessarily represent the official views of the CUPC, NIH or CU Boulder. Scales and Sensitivities in Climate Vulnerability, Migration, and Health

References

Adams, H. (2016). Why populations persist: mobility, place attachment and climate change. *Population and Environment, 37*(4), 429–448.

Adger, W. N., Pulhin, J. M., Barnett, J., Dabelko, G. D., Hovelsrud, G. K., Levy, M., ... & Vogel, C. H. (2014). Human security. Cambridge University Press.

Adeola, F. O., & Picou, J. S. (2012). Race, social capital, and the health impacts of Katrina: Evidence from the Louisiana and Mississippi Gulf Coast. *Human Ecology Review, 19*(1), 10–24.

Ahmed, K. J., Haq, S. M. A., & Bartiaux, F. (2019). The nexus between extreme weather events, sexual violence, and early marriage: a study of vulnerable populations in Bangladesh. *Population and Environment, 40*(3), 303–324.

Akter, T. (2009). *Migration and living conditions in urban slums: implications for food security*. Unnayan Onneshan.

Alam, A., Sammonds, P., & Ahmed, B. (2020). Cyclone risk assessment of the Cox's Bazar district and Rohingya refugee camps in southeast Bangladesh. *Science of The Total Environment, 704,* 135360.

Arenas, E., Goldman, N., Pebley, A. R., & Teruel, G. (2015). Return migration to Mexico: Does health matter? *Demography, 52*(6), 1853–1868.

Ayeb-Karlsson, S., Kniveton, D., & Cannon, T. (2020). Trapped in the prison of the mind: Notions of climate-induced (im)mobility decision-making and wellbeing from an urban informal settlement in Bangladesh. *Humanities & Social Sciences Communications* 6: Article number 6.

Barnshaw, J., & Trainor, J. (2007). *Race, class, and capital amidst the Hurricane Katrina diaspora* (pp. 91–105). Perspectives on a modern catastrophe.

Becerra, D., Androff, D., Messing, J. T., Castillo, J., & Cimino, A. (2015). Linguistic acculturation and perceptions of quality, access, and discrimination in health care among Latinos in the United States. *Social work in health care, 54*(2), 134–157.

Belkhir, J. A., & Charlemaine, C. (2007). Race, Gender and Class Lessons from Hurricane Katrina. *Race, Gender & Class, 14*(1/2), 120–152.

Berry, H. L., Bowen, K., & Kjellstrom, T. (2010). Climate change and mental health: a causal pathways framework. *International journal of public health, 55*(2), 123–132.

Bhatta, G. D., Aggarwal, P. K., Poudel, S., & Belgrave, D. A. (2016). Climate-induced migration in South Asia: Migration decisions and the gender dimensions of adverse climatic events. *Journal of Rural and Community Development*, *10*(4).

Biesbroek, G. R., Klostermann, J. E. M., Termeer, C. J. A. M., & Kabat, P. (2013). On the nature of barriers to climate change adaptation. *Regional Environmental Change, 13*(5), 1119–1129.

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global Environmental Change, 21,* S3–S11.

Black, R., Arnell, N. W., Adger, W. N., Thomas, D., & Geddes, A. (2013). Migration, immobility, and displacement outcomes following extreme events. *Environmental Science & Policy, 27*(S1), S32–S43.

Black, R., Bennett, S. R., Thomas, S. M., & Beddington, J. R. (2011). Migration as adaptation. *Nature, 478*(7370), 447–449.

Burton, L. C., Skinner, E. A., Uscher-Pines, L., Lieberman, R., Leff, B., Clark, R., Yu, Q., Lemke, K. W., & Weiner, J. P. (2009). Health of Medicare Advantage Plan Enrollees at One Year after Hurricane Katrina. *American Journal of Managed Care, 15*(1), 13–22.

Carrico, A. R., & Donato, K. (2019). Extreme weather and migration: evidence from Bangladesh. Population and Environment, 41(1), 1-31.

Cascone, N., del Valle Isla, A. E. P., & Milan, A. (2016). Circular Migration and Local Adaptation in the Mountainous Community of Las Palomas (Mexico). In *Migration, Risk Management and Climate Change: Evidence and Policy Responses* (pp. 63–83). Springer, Cham.

Chen, J., & Mueller, V. (2018). Coastal climate change, soil salinity and human migration in Bangladesh. *Nature Climate Change, 8*(11), 981–985.

Chiquiar, D., & Salcedo, A. (2013). *Mexican migration to the United States: Underlying economic factors and possible scenarios for future flows* (No. 2013–20). Working Papers.

Cooper, M., Brown, M. E., Azzarri, C., & Meinzen-Dick, R. (2019). Hunger, nutrition, and precipitation: evidence from Ghana and Bangladesh. *Population and Environment, 41,* 151–208.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change, 18*(4), 598–606.

Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers, 90*(4), 713–737.

Davis, K. F., Bhattachan, A., D'Odorico, P., & Suweis, S. (2018). A universal model for predicting human migration under climate change: examining future sea level rise in Bangladesh. Environmental Research Letters, 13(6), 064030.

Deryungina, T., & Molitar, D. (2019). Does when you die depend on where you live? Evidence from Hurricane Katrina. National Bureau of Economic Research Working Paper No. 24822.

Diaz, C. J., Koning, S. M., & Martinez-Donate, A. P. (2016). Moving beyond salmon bias: Mexican return migration and health selection. *Demography, 53*(6), 2005–2030.

Elder, K., Xirasagar, S., Miller, N., Bowen, S. A., Glover, S., & Piper, C. (2007). African Americans' Decisions Not to Evacuate New Orleans Before Hurricane Katrina: A Qualitative Study. *American Journal of Public Health, 97*(Suppl 1), S124–S129.

Elliott, J. R., & Pais, J. (2006). Race, class, and Hurricane Katrina: Social differences in human responses to disaster. *Social Science Research, 35*(2), 295–321.

Feng, S., Krueger, A. B., & Oppenheimer, M. (2010). Linkages among climate change, crop yields, and Mexico-US cross-border migration. *Proceedings of the National Academy of Sciences, 107*(32), 14257–14262.

Fleury, A. (2016). Understanding women and migration: A literature review. *Washington, DC.*

Füssel, H. M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic change, 75*(3), 301–329.

Fussell, E. (2018). Population displacements and migration patterns in response to Hurricane Katrina. *Routledge Handbook of Environmental Displacement and Migration*, 277–288.

Fussell, E. (2012). Space, time, and volition: Dimensions of migration theory. In *Oxford Handbook of the Politics of International Migration*.

Fussell, E., & Lowe, S. R. (2014). The impact of housing displacement on the mental health of low-income parents after Hurricane Katrina. *Social Science & Medicine, 113,* 137–144.

Fussell, E., Sastry, N., & VanLandingham, M. (2010). Race, socioeconomic status, and return migration to New Orleans after Hurricane Katrina. *Population & Environment, 31*(1–3), 20–42.

Geun Ji, H. (2019). The evolution of the policy environment for climate change migration in Bangladesh: Competing narratives, coalitions and power. *Development Policy Review, 37*(5), 603–620.

Ginnetti, J. & Lavell, C. (2015). The risk of disaster-induced displacement in Southeast Asia. Tehcnical Paper. International Disaster Monitoring Centre (IDMC).

Grace, K. (2017). Considering climate in studies of fertility and reproductive health in poor countries. *Nature Climate Change, 7,* 479.

Grace, K., Billingsley, S., & Van Riper, D. (2020). Building an interdisciplinary framework to advance conceptual and technical aspects of population-environment research focused on women's and children's health. *Social Science & Medicine, 250,* 112857.

Groen, J. A., & Polivka, A. E. (2010). Going home after Hurricane Katrina: Determinants of return migration and changes in affected areas. *Demography, 47,* 821–844.

Hallegatte, S., Green, C., Nicholls, R. J., & Corfee-Morlot, J. (2013). Future flood losses in major coastal cities. *Nature Climate Change., 3,* 802–806.

Haney, T. J., Elliott, J. R., & Fussell, E. (2010). Families and hurricane response: Risk, roles, resources, race, and religion. In D. Brunsma, D. Overfelt, & J. S. Picou (Eds.), *The Sociology of Katrina: Perspectives on a modern catastrophe* (2nd ed., pp. 77–102). Rowman & Littlefield.

Horton et al. 2017 with citation below: Horton, R., De Mel, M., Peters, D., Lesk, C., Bartlett, R., Helsingen, H., & Rosenzweig, C (2017). Assessing climate risk in Myanmar: Technical report. Center for Climate Systems Research at Columbia University, WWF-US and WWF-Myanmar: New York, NY, USA.

Hunt, J. S., Armenta, B. E., Seifert, A. L., & Snowden, J. L. (2009). The other side of the diaspora: Race, threat, and the social psychology of evacuee reception in predominantly white communities. *Organization & Environment, 22*(4), 437–447.

Huq, N., Hugé, J., Boon, E., & Gain, A. K. (2015). Climate change impacts in agricultural communities in rural areas of coastal Bangladesh: A tale of many stories. *Sustainability, 7*(7), 8437–8460.

Hutchinson, S. (2018). Gendered insecurity in the Rohingya crisis. *Australian Journal of International Affairs, 72*(1), 1–9.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Climate change 2001: Impacts*. Adaptation and Vulnerability.

Intergovernmental Panel on Climate Change IPCC. (2014). AR5: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.

Islam, M. T., & Nursey-Bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. *Journal of environmental management, 200*, 347-358.

Jochum, B., Devine, C., Calain, P., Guevara, M., Nayna Schwerdtle, P., Biorklund Belliveau, L., et al. (2018). 'Climate Change and Health: An urgent new frontier for humanitarianism', *The Lancet Countdown on Health and Climate Change.*

Jonkman, S. N., Maaskant, B., Boyd, E., & Levitan, M. L. (2009). Loss of life caused by the flooding of New Orleans after Hurricane Katrina: Analysis of the relationship between flood characteristics and mortality. *Risk Analysis, 29*(5), 676–698.

Kabir, M. I., Rahman, M. B., Smith, W., Lusha, M. A. F., & Milton, A. H. (2016). Climate change and health in Bangladesh: a baseline cross-sectional survey. *Global Health Action, 9*(1), 29609.

Kammerbauer, M., & Wamsler, C. (2017). Social inequality and marginalization in post-disaster recovery: Challenging the consensus? *International Journal of Disaster Risk Reduction, 24,* 411–418.

Kates, R. W., Colten, C. E., Laska, S., & Leatherman, S. P. (2006). Reconstruction of New Orleans after Hurricane Katrina: A research perspective. *Proceedings of the National Academy of Science, 103,* 14653–15660.

Langlois, E. V., Haines, A., Tomson, G., & Ghaffar, A. (2016). Refugees: towards better access to health-care services. *The Lancet, 387*(10016), 319–321.

Leichenko, R., & Silva, J. A. (2014). Climate change and poverty: vulnerability, impacts, and alleviation strategies. *Wiley Interdisciplinary Reviews: Climate Change, 5*(4), 539–556.

Leyk, S., Runfola, D., Nawrotzki, R. J., Hunter, L. M., & Riosmena, F. (2017). Internal and international mobility as adaptation to climatic variability in contemporary Mexico: Evidence from the integration of census and satellite data. *Population, Space and Place, 23*(6), e2047.

Lutz, W., & Muttarak, R. (2017). Forecasting societies' adaptive capacities through a demographic metabolism model. *Nature Climate Change, 7*(3), 177–184.

Mahmood, S. S., Wroe, E., Fuller, A., & Leaning, J. (2017). The Rohingya people of Myanmar: health, human rights, and identity. *The Lancet, 389*(10081), 1841–1850.

Massey, D. S., Durand, J., & Malone, N. J. (2003). *Beyond Smoke and Mirrors: Mexican Immigration in an Era of Economic Integration*. Russell Sage Foundation.

Mazhin, S. A., Khankeh, H., Farrokhi, M., Aminizadeh, M., & Poursadeqiyan, M. (2020). Migration health crisis associated with climate change: A systematic review. *Journal of Education and Health Promotion*, *9*.

McMichael, C. (2015). Climate change-related migration and infectious disease. *Virulence, 6*(6), 544–549.

McMichael, A. J. (2000). The urban environment and health in a world of increasing globalization: issues for developing countries. *Bulletin of the world Health Organization, 78,* 1117–1126.

McLeman, R., & Gemenne, F. (2018). Environmental migration research. *Routledge Handbook of Environmental Displacement and Migration*, 3.

Ministry of Foreign Affairs (MOFA) (2018). *Climate Change Profile Bangladesh.* Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/Burundi_1.pdf

Muttarak, R., Lutz, W., & Jiang, L. (2016). What can demographers contribute to the study of vulnerability? *Vienna Yearbook of Population Research, 2015*(13), 1–13.

Nightingale, A. J. (2017). Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum, 84,* 11–20.

O'Brien, M. J., Alos, V. A., Davey, A., Bueno, A., & Whitaker, R. C. (2014). Peer Reviewed: Acculturation and the Prevalence of Diabetes in US Latino Adults, National Health and Nutrition Examination Survey 2007–2010. *Preventing chronic disease*, *11*.

Paxson, C., Fussell, E., Rhodes, J., & Waters, M. (2012). Five years later: Recovery from post traumatic stress and psychological distress among low-income mothers affected by Hurricane Katrina. *Social Science & Medicine, 74*(2), 150–157.

Pinchoff, J., Shamsudduha, M., Hossain, S. M. I., Shohag, A. A. M., & Warren, C. E. (2019). Spatiotemporal patterns of pre-eclampsia and eclampsia in relation to drinking water salinity at the district level in Bangladesh from 2016 to 2018. *Population and Environment, 41,* 235–251.

Rai, N., Huq, S., & Huq, M. J. (2014). Climate resilient planning in Bangladesh: a review of progress and early experiences of moving from planning to implementation. *Development in Practice, 24*(4), 527–543.

Raker, E. J., Lowe, S. R., Arcaya, M. C., Johnson, S. T., Rhodes, J., & Waters, M. C. (2019). Twelve years later: The long-term mental health consequences of Hurricane Katrina. *Social Science & Medicine, 242,* 112610.

Republic of the Union of Myanmar (2017). Myanmar climate change policy.

Rigaud, K. K., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., & Midgley, A. (2018). *Groundswell: Preparing for Internal Climate Migration*. World Bank.

Riosmena, F., Wong, R., & Palloni, A. (2013). Migration selection, protection, and acculturation in health: a binational perspective on older adults. *Demography, 50*(3), 1039–1064.

Roubinov, D. S., Hagan, M. J., Boyce, W. T., Adler, N. E., & Bush, N. R. (2018). Family socioeconomic status, cortisol, and physical health in early childhood: the role of advantageous neighborhood characteristics. *Psychosomatic medicine, 80*(5), 492.

Rudowitz, R., Rowland, D., & Shartzer, A. (2006). Health Care in New Orleans Before and After Hurricane Katrina: The storm of 2005 exposed problems that had existed for years and made solutions more complex and difficult to obtain. *Health Affairs, 25*(Suppl1), W393–W406.

Sastry, N., & Gregory, J. (2013). The effect of Hurricane Katrina on the prevalence of health impairments and disability among adults in New Orleans: Differences by age, race, and sex. *Social Science & Medicine, 80,* 121–129.

Sastry, N., & VanLandingham, M. (2009). One year later: Mental illness prevalence and disparities among New Orleans Residents displaced by Hurricane Katrina. *American Journal of Public Health, 99*(S3), S725–S731.

Sharkey, P. (2007). Survival and death in New Orleans: An empirical look at the human impact of Katrina. *Journal of Black Studies, 37*(4), 482–501.

Schmidt-Verkerk, K. (2010). 'Buscando la vida'–How Do Perceptions of Increasingly Dry Weather Affect Migratory Behaviour in Zacatecas, Mexico?. In *Environment, Forced Migration and Social Vulnerability* (pp. 99–113). Springer, Berlin, Heidelberg.

Schwerdtle P, Bowen K, & McMichael C. (2018). The health impacts of climate-related migration. *BMC Medicine*, Dec;16(1):1.

Schwerdtle, P. N., Bowen, K., McMichael, C., & Sauerborn, R. (2019). Human mobility and health in a warming world. *Journal of Travel Medicine*, *26*(1), tay160.

Schwerdtle, P. N., McMichael, C., Mank, I., Sauerborn, R., Danquah, I., & Bowen, K. (2020). Health and migration in the context of a changing climate: A systematic literature assessment. *Environmental Research Letters*.

Shultz, J. M., Garfin, D. R., Espinel, Z., Araya, R., Oquendo, M. A., Wainberg, M. L., & Neria, Y. (2014). Internally displaced "victims of armed conflict" in Colombia: the trajectory and trauma signature of forced migration. *Current psychiatry reports, 16*(10), 475.

Shultz, J. M., Rechkemmer, A., Rai, A., & McManus, K. T. (2019a). Public Health and Mental Health Implications of Environmentally Induced Forced Migration. *Disaster Medicine and Public Health Preparedness, 13*(2), 116–122.

Sverdlik, A. (2011). Ill-health and poverty: a literature review on health in informal settlements. *Environment and Urbanization, 23*(1), 123–155.

Thomas, K., Hardy, R. D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., & Winthrop, R. (2019). Explaining differential vulnerability to climate change: A social science review. *Wiley Interdisciplinary Reviews: Climate Change, 10*(2), e565.

Uscher-Pines, L. (2009). Health effects of relocation following disaster: A systematic review of the literature. *Disasters, 33*(1), 1–22.

United Nations High Commission on Refugees (UNHCR). (2017). *Climate Change and Disasters.* Geneva, Switzerland. [updated 2019; cited 2019 Oct 2]. Available from: http://www.unhcr.org/en-us/climate-change-and-disasters.html

United Nations High Commission on Refugees (UNHCR) (2015). *Displacement and Disaster Risk Reduction.* Available: https://www.unhcr.org/5665945e9.pdf

United Nations Office for Disaster Risk Reduction. (UNISDR). (2015). Global Assessment Report on Disaster Risk Reduction. Available: https://www.preventionweb.net/english/hyogo/gar/2015/en/home/index.html

United Nations High Commissioner for Refugees (UNHCR). (2019). *Global Trends: Forced Displacement in 2018*. 1211 Geneva, Switzerland; 20 June (76 p.).

USGCRP (2017). Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp, https://doi.org/10.7930/J0J964J6

Van Den Hoek, J., Murillo-Sandoval, P., Crumley, R. L., Devenish, A., Fein, F., Kennedy, R. E.,... & Harris, T. (2018). Refugee Camps as climate traps: Measuring the Enviro-Climatic Marginality of 922 Global Refugee Camps with Satellite Time Series Data. (Vol. 2018, pp. IN44A-04).

Warner, K. (2010). Global environmental change and migration: Governance challenges. *Global Environmental Change, 20*(3), 402–413.

Watts, N., Amann, A., Ayeb-Karlsson, B., & Boykoff, … Ekins. . (2019). The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *The Lancet, 394*(10211), 1836–1878.

Werz, M., & Hoffman, M. (2016). Europe's twenty-first century challenge: climate change, migration and security. *European View, 15*(1), 145–154.

World Health Organization (WHO). (1998). World Health Organization definition of health.

Wu, C. Y., Zaitchik, B. F., Swarup, S., & Gohlke, J. M. (2019). Influence of the spatial resolution of the exposure estimate in determining the association between heat waves and adverse health outcomes. *Annals of the American Association of Geographers, 109*(3), 875–886.

Yeates, N., & Pillinger, J. (2013). Human resources for health migration: global policy responses, initiatives, and emerging issues.

Young, M. Y., & Chan, K. J. (2015). The psychological experience of refugees: A gender and cultural analysis. In *Psychology of Gender Through the Lens of Culture* (pp. 17–36). Springer, Cham.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Lori M. Hunter[1] · Stephanie Koning[2] · Elizabeth Fussell[3] · Brian King[4] · Andrea Rishworth[4] · Alexis Merdjanoff[5] · Raya Muttarak[6] · Fernando Riosmena[1] · Daniel H. Simon[1] · Emily Skop[7] · Jamon Van Den Hoek[8]

Stephanie Koning
stephanie.koning@northwestern.edu

Elizabeth Fussell
Elizabeth_fussell@brown.edu

Brian King
bhk2@psu.edu

Andrea Rishworth
azr5858@psu.edu

Alexis Merdjanoff
Alexis.merdjanoff@nyu.edu

Raya Muttarak
muttarak@iiasa.ac.at

Fernando Riosmena
Fernando.Riosmena@colorado.edu

Daniel H. Simon
Daniel.H.Simon@colorado.edu

Emily Skop
evogt@uccs.edu

Jamon Van Den Hoek
vandenhj@oregonstate.edu

[1] University of Colorado Boulder, Boulder, CO 80309, USA

[2] Northwestern University, Evanston, IL 60208, USA

[3] Brown University, Providence, RI 02912, USA

[4] Pennsylvania State University, State College, PA 16801, USA

[5] New York University, New York, NY 10003, USA

[6] University of East Anglia & International Institute for Applied Systems Analysis, Norwich NR4 7TJ, UK

[7] University of Colorado Colorado Springs, Colorado Springs, CO 80918, USA

[8] Oregon State University, Corvallis, OR 97331, USA