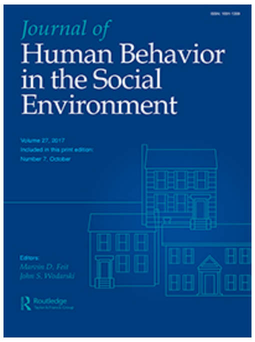

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Evaluating the complex interactions between malaria and cholera prevalence, neglected tropical disease comorbidities, and community perception of health risks of climate change

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ABSTRACT

The burgeoning literature on the climate change–human health nexus has focused almost exclusively on the health impacts of climate change with little attention to how ill-health and disease influence public perception of the health risks of climate change. Based on a cross-sectional survey of 1,253 individuals, linear regression was used to examine the independent effects of malaria and cholera prevalence, and neglected tropical disease comorbidities on perceived health risks of climate change. Individuals who reported more comorbidities had higher scores on perceived health risks of climate change compared with those who did not report any comorbidities. Unexpectedly, at the multivariate level, there were no statistically significant relationships between age of respondents, gender, and educational attainment on the one hand, and perceived health risks of climate change on the other hand. Individuals who were diagnosed with cholera in the past 12 months had higher scores on perceived health risks of climate change but there was no relationship between diagnosis with malaria in the past 12 months and perceived health risks. Individuals who had attained secondary education had lower scores on perceived health risks of climate change compared with those without any formal education. Given that this relationship did not exist at the bivariate level, it indicates that biosocial and sociocultural factors suppressed the relationship between secondary education attainment and perceived health risks of climate change. The findings underscore the complex relationship between perceived health risks of climate change and infectious disease, comorbidities, compositional, and contextual factors at the multivariate level.

KEYWORDS
Climate change; comorbidities; human health; NTD; perception; Tanzania

Introduction

Climate change, together with other natural and anthropogenic health stressors, influences human health and disease in diverse ways. The Intergovernmental Panel on Climate Change (IPCC, 2001; Pachauri et al., 2014) defines climate change as a statistically

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significant variation in either the mean state of the climate or in its variability, persisting for an extended period—typically decades or longer—that may be attributed to natural internal processes, external forcing, or persistent anthropogenic changes in the composition of the atmosphere or in land use. During the last 15 years after this definition was proposed, it has been severally suggested that climate change, environmental sustainability, and human health are inextricably linked. However, the relationship is immensely complex and nonlinear (see Martens, 2014; McMichael et al., 2008; Parham & Michael, 2010; Patz & Olson, 2006). For this reason, although some evidence suggests that global warming may be causing diseases (e.g., malaria) to spread to higher elevations on mountains in East Africa (IOM (Institute of Medicine), 2008; Pascual, Ahumada, Chaves, Rodo, & Bouma, 2006), predicting how climate change will ultimately influence the incidence of diseases transmitted by vectors remains challenging. The complexity of the climate change–infectious disease nexus is partially evidenced in the fact that malaria was once common over much of North America and Europe in the 19th century but is not consistently observed on either continent today, even after the temperature has warmed in the intervening century (IOM (Institute of Medicine), 2008).Yet, there is a growing body of research that demonstrates that climate change may provide the conditions for emerging infectious diseases to spread to new places and new hosts (Mordecai et al., 2013; Pascual et al., 2006; Siraj et al., 2014).

According to Hoberg and Brooks (2015), there are a number of ways to elucidate the magnitude, frequency, and distribution of climate change-induced diseases. Primarily, with the general warming of the earth, disease vectors are able to survive in places where they previously did not or can survive longer than they were able to previously. For example, it has been suggested that tick season in the Midwest of the United States is starting earlier and ending later (Hoberg & Brooks, 2015). Also, extreme weather events associated with global warming such as droughts or flooding can create situations in which disease-carrying insects or animals can flourish. Furthermore, climate change, and deforestation, could be pushing humans especially those in poor communities deeper into the wilderness to find food sources. There, they come in contact with new diseases. That is one of the theories underlying the causation, distribution, and momentum of diseases such as Ebola.

Sampaio et al. (2015) argue that environmental characteristics, together with anthropogenic changes and cultural, social, and climatic factors, are conducive to the formation of breeding sites that promote the maintenance of endemic vector-borne diseases such as malaria. More predictable as climate change unfolds is the spread of so-called waterborne infections. These infections most often cause diarrheal illness and manifest in the aftermath of heavy rainfalls as runoff from land enters into and may contaminate water supplies. Many pathogens that cause diarrheal disease reproduce more quickly in warmer conditions as well.

The transmission of infectious disease is determined by many factors including social, economic, ecological conditions, access to care, and intrinsic human immunity. Many infectious agents, vector organisms, nonhuman reservoir species, and pathogen replication rates are particularly sensitive to climatic conditions. According to Ostfeld (2009, p. 904),

> clear effects of climate change have now been established for several human infectious diseases, including malaria, cholera, and dengue. The complexities of these systems pose enormous challenges for the detection of climate effects, and for the isolation and integration of climatic and non-climatic effects.

The impact of climate change on public health may be far reaching and include deaths and hospitalizations due to heat waves, hypothermia from blizzards, injuries and death from flooding, and potential shifts in the transmission ranges of vector-borne diseases such as hantavirus, West Nile virus, tick-borne encephalitis, Lyme disease, malaria, and dengue. Most importantly, the potential population health impacts of environmental changes extend far into the future, if environmental conditions deteriorate further. Change can be abrupt and unexpected but it can also be protracted and gradual and pose considerable challenges to public health.

According to Semenza and Menne (2009), numerous theories have been developed in recent years to explain the relationship between climate change and infectious diseases: they include higher proliferation rates at higher temperatures, extended transmission season, changes in ecological balances, and climate-related migration of vectors, reservoir hosts, or human populations. Climate change is one of many important factors driving infectious disease spread, alongside human and animal population dynamics, intense global levels of trade and travel, changing patterns of land use, and so on. Thus one important area of research is to further quantify and examine the links between health risks of climate change and other determinants of infectious diseases.

The effects of climate change on human health have attracted increasing attention in recent years and it is widely expected to significantly affect the global spread, intensity, and distribution of infectious diseases. Linking global and regional climate models with mathematical (and statistical) models of disease transmission provides a valuable tool toward improving and quantifying our understanding of how future changes in environmental drivers may affect disease dynamics (see Altizer, Ostfeld, Johnson, Kutz, & Harvell, 2013; Parham et al., 2015; Shuman, 2010). Yet, our capacity to analyze, predict, and respond to changing infectious disease patterns due to global change is currently underdeveloped. Notwithstanding the abundance of environmental and epidemiologic data, they are often not linked, thereby preventing public health and environmental agencies and scientists from gaining more comprehensive understandings of the multicausal pathways that drive environmental and epidemiological changes. To address this shortcoming, several scholars have endeavored to link climatic/environmental and infectious disease data in order to strengthen capacity in forecasting, monitoring, and responding to the threats posed by new and emerging diseases (Pascual et al., 2006). In this context, climate research has focused, almost exclusively, on developing conceptual frameworks for modeling, analyzing, and evaluating the potential impact of global change on disease transmission. Of considerable interest is the question of whether changes in climatic variables may be reliably used to predict the spatiotemporal incidence of diseases such as malaria, dengue, and schistosomiasis. Thus, as well as evaluating the long-term prospects for disease, this strand of research employs seasonal climate data to develop early-warning systems using methods such as data assimilation used in weather and climate forecasting. The foregoing has enriched our understanding of the relationship between climate change impacts and the etiology and distribution of infectious diseases. However, how individual health influences public perception of climate change as a human health risk is conspicuously missing from the burgeoning literature on climate change–human health nexus. In sub-Saharan Africa, few studies have investigated the capacity of people to adapt to the individual and cumulative health risks associated with current climate variability and future climate change and therefore our understanding of vulnerabilities is incomplete. The attention we pay to perception of health risks of climate change is salient given that it can influence mitigation and adaptive responses to climate change, compel or constrain government policies and actions, and contribute to informed policy level decisions. We need to understand, quantify, and improve our knowledge regarding how self-assessed infectious disease morbidity influences how people perceive the health risks of climate change.

Malaria, the world's most important and deadly tropical mosquito-borne parasitic disease, kills approximately one million people and afflicts as many as one billion people in 109 countries throughout Africa, Asia, and Latin America (World Health Organization, 2014). About 3.2 billion people—almost half of the world's population—are at risk of malaria. In 2013, there were about 198 million malaria cases (with an uncertainty range of 124–283 million) (World Health Organization, 2014). People living in the poorest countries are the most vulnerable to malaria. In 2013, 90% of all malaria deaths occurred in the WHO African region, mostly among children under 5 years of age (World Health Organization, 2014). Like malaria, cholera transmission is closely linked to inadequate environmental management. Typical at-risk areas include peri-urban slums, where basic infrastructure is not available. It is estimated that every year, there are approximately 1.4–4.3 million cases, and 28,000–142,000 deaths per year worldwide due to cholera (Ali et al., 2012). The number of cholera cases reported to WHO continues to be high. During 2013, a total of 129,064 cases were notified from 47 countries, including 2,102 deaths (Ali et al., 2012). Using coastal Tanzania as an illustration, this study assesses how malaria and cholera prevalence and comorbidities of neglected tropical diseases (NTDs) independently influence how individuals perceive the health risks of climate change. We focus on these two infectious diseases for a number of reasons.

Our emphasis on the relationship between diagnosis with infectious diseases and perception of health risks associated with climate change (personal perceived risk) has implications for mitigation, adaptation, and control of climate change-induced health effects. It has been found that personal perceived risk has a positive influence on the motivation to adapt to climate change (Do Thi Thanh Toan, Kien, & Hoang Van Minh, 2014; Osberghaus, Finkel, & Pohl, 2010) and by extension, how populations effectively respond to the potential health risks of climate change. In light of the expected health impacts of climatic change that individuals and communities, especially in sub-Saharan Africa, will potentially encounter in the coming decades, a sound knowledge of these expected health impacts and the necessary adaptive responses can be important for their current and future well-being. While adaptation is becoming a topic of increasing importance, there has been limited research examining the factors that reinforce or encumber motivation to adapt to health impacts of climate change, an important precondition of actually undertaking adaptive measures.

Theoretical context

The importance of personal perceived risk, and the consequent influence on climate change adaptation strategies, has recently been identified as an appropriate area for future empirical research (see Armah et al., 2015a; Nigatu, Asamoah, & Kloos, 2014; Osberghaus et al., 2010). Perception of risk is a multifaceted concept, comprising the potential degree of harm of the event (in this case, health impacts of climate change), on its controllability, on the number of people simultaneously exposed, on the familiarity of consequences and effects, and on the degree of subjective control over the risk (Julian-Reynier, Welkenhuysen, Hagoel, Decruyenaere, & Hopwood, 2003; Vlek, 1986). Broadly, risk perception can be summarized in three steps: the acquisition of information, interpretation and synthesis of different pieces of information, and the understanding of that information in light of previous knowledge, perceptions, and attitudes (Burger et al., 2008). Many common health behavior theories, including health belief model, theory of reasoned action, and protection motivation theory, include risk perception but they are not clear on the severity this may play in a person's health behaviors (Brewer et al., 2007).

The perception of disease risks and risky health behaviors are closely associated (Winter & Wuppermann, 2014). According to Williams, Collins, Bauaze, and Edgeworth (2010), risk perceptions determine the efficacy of risk reduction strategies. Although risk is often considered as a communal problem, notions of individual, community, and institutional responsibilities structure the perceptions and attitudes to local environmental quality and infectious disease reduction strategies. Risk perception also plays a mediating role in reducing vulnerability to disease (Williams et al., 2010). Therefore, public perception of climate change-induced diseases will likely influence the adoption of behaviors that will reduce or amplify their risk to such diseases. According to Osberghaus et al. (2010), given that a considerable part of climate change adaptation relies on the actions carried out by individuals in their local environments, it seems important to consider how psychological factors may influence adaptive action. Consistent with the World Development Report (2010), understanding the drivers of human behavior is essential for climate-smart development policy. Besides, adaptation to climate change is an example of human decision-making under uncertainty (Grothmann & Patt, 2005).

Evaluation of health risks of climate change is fundamentally contingent on two independent appraisal processes that can be initiated by environmental and intrapersonal sources of information: threat appraisal and coping appraisal (see Norman, Boer, & Seydel, 2005; Osberghaus et al., 2010; Rogers & Maddux, 1983). The first refers to an individual's assessment of the *severity* of a potential threat stimulus if affected by it, and his or her personal *vulnerability* to the particular threat, i.e., the expectation of being affected by the threat. This means that if a person finds himself/herself to be vulnerable to a perceived risk of climate change-related infectious diseases and assesses the threat as severe, his/her level of fear increases, leading to an increase in the motivation to protect himself/herself. A second cognitive process is subsequently initiated that is concerned with the possible reaction to the threat stimulus. This process is labeled *coping appraisal* and reflects the appraisal of potential coping behaviors in relation to an individual's own abilities and beliefs (Grothmann & Reusswig, 2006; Osberghaus et al., 2010).

The idea of subjective interpretations of risk makes knowledge a necessary but insufficient determinant of risk perception, such that even if new information originates from a credible source, there are several factors that shape how individuals might interpret that information (Huang et al., 2011). An individual's personal experiences, values, priorities, or beliefs have been found to be powerful predictors of risk perceptions, and may even cause people to dismiss or ignore information not consistent with their pre-existing views (Huang et al., 2011). For instance, the extent to which an individual feels in control or effectively able to avoid the negative impacts of a risk relative to others can cause some individuals to believe they are less at risk contrary to their actual vulnerability (Lorenzoni, Pidgeon, & O'Connor, 2005). With regard to climate change, women are found to perceive greater human health risks and are more likely to desire to take voluntary action to address predicted problems (Bord & O'Connor, 1997). These tendencies likely emanate from the fact that women are generally more altruistic and inclined to exhibit helpful or nurturing behavior (Gilligan, 1982), and are therefore likely to demonstrate increased levels of concern in any situation with potential for dangerous or harmful impacts.

Materials and method

Study context

According to the 2012 Population and Housing census, the total population of Tanzania was 44,928,923 compared to 12,313,469 in 1967 (National Bureau of Statistics, 2013), reflecting an annual growth rate of 2.9%. Tanzania lies between longitude 29° and 49° east and latitude 1° and 12° south of the equator (Francis & Bryceson, 2001). The coastline that covers about 15% of the total land area stretches for 800 km and consists of five regions, namely Dar es Salaam, Tanga, Pwani, Lindi, and Mtwara. Overall, the country is sparsely populated with a population density of 51 persons per square kilometer; lower significant variation exists across regions (United Republic of Tanzania, 2013) suggesting wide disparities in population density across regions. More detailed description of the study context and study design is presented in Armah et al. (2015a) and Armah et al. (2015b).

Data collection

The study design was approved by the Committee of Research Ethics of the University of Western Ontario, Canada. Research approval was also granted by the Commission on Science and Technology (COSTECH) in Tanzania. A cross-sectional survey was conducted with 1,253 individuals in three regions (Dar es Salaam, Tanga, and Pwani) along the coastline of Tanzania. The oral survey data were collected between March and September 2013 by locally trained enumerators. The study population included male (606) and female (647) participants between the ages of 18 and 70 years who consented to participate and eventually completed the questionnaire. The study used multistage sampling to obtain representative estimates of the population of residents of the three regions. Within each region, a list of villages based on the 2012 Population and Housing Census was divided further into households (Armah et al., 2015a). The list of villages was divided into clusters ensuring that each cluster would provide adequate numbers of eligible respondents to be included in the survey. This approach both corrects for sampling bias and weights the cases to match census percentages of males and females of various age groups and by ethnicity (Armah et al., 2015a). The enumeration areas (EAs) and their total number of households were listed geographically by urban and rural areas. Where EAs did not include the minimum number of households, then geographically adjacent EAs were amalgamated to yield sufficient households. This provided the frame for selecting the clusters to be included in the survey according to a stratified systematic sampling technique in which the probability for the selection of any cluster was proportional to its size. A sampling interval was calculated by dividing the total number of households by the number of clusters. A random number between 1 and the sampling interval was computer generated (Armah et al., 2015a). The EA in which the random number fell was identified as the first selected cluster. The sampling interval was applied to that number and then progressively until the 20 (urban) and 15 (rural) clusters were identified. These clusters made up the sample for the survey. Households were randomly selected from these clusters for interview.

Measures

Response variable

The outcome variable (perceived climate change-induced human health risk) was derived from 10 questions in the questionnaire each of which is measured on a 5-point Likert scale. Participants were asked whether or not climate change posed a significant risk to their health. Interestingly, all participants answered in the affirmative. Respondents were then asked "on a scale of 1 (lowest risk) to 5 (highest risk)", what level of health risk does climate change pose to coastal populations via each of the following: heat stroke or heat exhaustion; water quality impacts; drowning; water-borne diseases; infectious diseases; air quality impacts; respiratory or breathing problems; sunburn; cancer; and stress or anxiety. We developed a composite variable—perceived climate change-induced human health risk—through principal component and factor analysis. Cronbach's alpha reliability estimate for the composite variable was 0.725. A higher score on the composite variable implies a higher propensity of perceiving climate change as a human health risk.

Predictors

Variables that have frequently been shown to associate with public perception of climate change-induced human health risk such as biosocial attributes (age, sex, and ethnicity) and sociocultural characteristics including level of education, marital status, income, occupation, and region of residence were considered. Also, psychosocial factors, such as self-reporting measures of temperature change, and disease prevalence were included. Besides malaria and cholera, five NTDs (e.g., schistosomiasis, onchocerciasis, whipworm, hookworm, and trachoma) were included in the analysis. An ordinal measure of disease comorbidities was created based on multiple exposure to one or more of these NTDs (see Table 1). Comorbidity score of 0 indicates that an individual has no exposure to any of the five NTDs, whereas comorbidity score of 5 indicates simultaneous exposure to the five NTDs.

Statistical analysis

Multiple regressions were used in this study to evaluate the relationship of diagnosis with infectious diseases and perception of climate change as a human health risk. One of the advantages of multiple regressions is that it focuses on effect size (Keith, 2006). Effect size is reflected in standardized beta weights (β) and the R-squared. An effect size (R-squared) of more than 0.25 is considered strong (see Keith, 2006). The ordinary least squares (OLS) statistical technique was employed for the analysis. Analyses were preceded by diagnostic tests to establish whether variables met the assumptions of the regression model. Bivariate analysis was initially performed to examine zero-order correlations between the dependent variable (perceived human health risk of climate change) and theoretically relevant independent variables. Furthermore, multivariate models were estimated to explore the net effects of the predictor variables using the stepwise selection approach. For analytical purposes, the

Table 1. Distribution of respondents based on reported comorbidities of neglected tropical diseases.

	Number of NTD comorbidities (%)						
Predictors	0	1	2	3	4	5	Inferential statistics
Diagnosis with malaria in the past 12 months							Pearson χ^2 (5) = 886.3148; Pr = 0.000
No	75.7	16.4	6.6	1.0	0.3	0.0	Cramér's V = 0.8414
Yes	0.0	43.7	35.2	17.1	2.4	1.6	
Diagnosis with cholera in the past 12 months							Pearson χ^2 (5) = 14.5309; Pr = 0.013
No	20.6	36.5	29.1	12.1	1.2	0.5	Cramér's V = 0.1077
Yes	16.2	37.7	27.2	14.3	2.7	2.0	
Age of respondents							Pearson χ^2 (15) = 37.5945; Pr = 0.001
18–35	22.2	39.4	24.9	11.3	1.8	0.5	Cramér's V = 0.1000
36–50	20.5	36.7	28.1	11.9	1.4	1.4	
51–65	12.4	37.5	31.6	14.3	2.3	2.0	
Greater than 65 years old	10.8	25.3	33.7	25.3	3.6	1.2	
Gender							Pearson χ^2 (5) = 17.9002; Pr = 0.003
Male	20.1	40.9	25.4	11.4	1.0	1.2	Cramér's V = 0.1196
Female	16.9	33.4	30.8	14.9	2.8	1.2	
Ethnicity							Pearson χ^2 (10) = 26.6220; Pr = 0.003
Zaramo	23.67	24.9	33.47	13.47	3.27	1.22	Cramér's V = 0.1031
Sambaa	16.03	47.33	24.43	10.69	0.76	0.76	
Other ethnic groups	17.35	38.93	27.28	13.47	1.71	1.26	
Region							Pearson χ^2 (10) = 35.4787; Pr = 0.000
Dar es Salaam	16.17	37.67	27.17	14.33	2.67	2.0	Cramér's V = 0.1190
Pwani	24.58	27.57	31.89	13.29	1.99	0.66	
Tanga	17.09	44.16	26.78	11.11	0.57	0.28	
Employment status							Pearson χ^2 (5) = 19.5395; Pr = 0.002
Unemployed	9.78	41.3	20.65	19.57	5.43	3.26	Cramér's V = 0.1249
Employed	19.14	36.72	28.79	12.67	1.64	1.03	
Educational attainment							Pearson χ^2 (15) = 28.1684 Pr = 0.021
No formal education	14.02	33.64	33.64	14.95	1.87	1.87	Cramér's V = 0.0866
Primary education	19.45	36.32	27.19	14.63	1.72	0.69	
Secondary education	15.45	39.07	30.03	12.54	2.62	0.29	
Tertiary education	22.62	37.56	25.34	9.5	1.36	3.62	
Perceived temperature change (past 10 years)							Pearson χ^2 (15) = 39.5239; Pr = 0.001
Never	15.99	40.92	26.83	12.87	1.9	1.49	Cramér's V = 0.1026
1–3 times	14.81	39.51	24.69	19.75	1.23	0.0	
4–5 times	24.43	33.97	31.3	8.02	1.91	0.38	
More than 5 times	21.64	23.98	30.99	19.3	2.34	1.75	
Marital status							Pearson χ^2 (5) = 12.4004; Pr = 0.030
Unmarried	22.2	32.72	28.38	13.27	2.75	0.69	Cramér's V = 0.0995
Married	16.44	39.39	28.1	13.13	1.47	1.47	

Note: The five NTDs are schistosomiasis, onchocerciasis, whipworm, hookworm, and trachoma. Comorbidity score of "0" indicates no exposure to any of these diseases. Comorbidity score of 5 indicates exposure to the five NTDs simultaneously.

unstandardized regression coefficients were estimated. Positive coefficients for any of the predictors indicate higher perceived climate change-induced human health risk, while negative coefficients show lower perceived climate change-induced human health risk. The OLS regression models in this study are built under the assumption of independence of subjects, but the cross-sectional survey has a hierarchical structure with respondents nested within survey clusters, which could potentially bias the standard errors (SEs). STATA 13 (StataCorp, College Station, TX) SE, which has the capacity to address this problem, is used by imposing on our models a “cluster” variable, that is, the identification numbers of respondents at the cluster level. This, in turn, adjusts the SEs producing statistically robust parameter estimates.

Results

Univariate analyses

In this section, the distribution of NTD comorbidities by sample characteristics is presented. As shown in Table 1, all the theoretically relevant factors were associated with the number of NTDs reported, although to varying degrees of strength and statistical significance. All the associations are weak except the relationship between NTD comorbidities and diagnosis of malaria in the past 12 months.

On the whole, women reported more NTD comorbidities (mean = 1.569, *SD* = 1.094) than men (mean = 1.356, *SD* = 1.029). However, on average, women had lower scores on perceived health risks of climate change (mean = −.0152073, *SD* = 1.009) compared with men (mean = 0.016, *SD* = 0.990).

Bivariate analyses

At the bivariate level (Table 2), individuals who were diagnosed with malaria (0.517, $p < .0001$) and cholera (0.377, $p < .0001$) had higher scores on perceived health risks of climate change compared with their counterparts without the two infectious diseases.

On the whole, reporting more comorbidities (3, 4, or 5) was associated with higher scores on perceived health risks of climate change compared with those did not report any comorbidities. Surprisingly, there were no statistically significant relationships between age of respondents, gender, and educational attainment on the one hand, and perceived health risks of climate change. Individuals who belong to the Sambaa ethnic group had lower scores on perceived health risks of climate change compared with those belonging to the Zaramo ethnic group whereas there was no relationship between other ethnic groups and perceived health risks of climate change.

Employed respondents had lower scores on perceived health risks of climate change compared with their unemployed counterparts. Married individuals had higher scores on perceived health risks of climate change compared with those who are unmarried. Individuals who experienced temperature changes (more than once) in the past 10 years had lower scores on health risks of climate change compared with their counterparts who had never experienced any temperature change within the same time frame. Higher income earners had higher scores on perceived health risks of climate change unlike their colleagues who earn low income. In the bivariate model, the order of magnitude of decreasing importance of predictors is as follows: NTD comorbidities >diagnosed with malaria > diagnosed with cholera > marital status > perceived temperature change > region > employment status > ethnicity.

Multivariate analyses

In this section, we present the results after adjusting for compositional and contextual attributes of participants. At the multivariate level, the magnitude, direction, and level of

Table 2. Zero-order relationships between perceived human health risks of climate change and theoretically relevant factors.

Predictors	Coefficient	*SE*	*p*-Value	β
Diagnosis with malaria in the past 12 months (Ref: No)				
Yes	0.517	0.066	**0.000**	0.222
Diagnosis with cholera in the past 12 months (Ref: No)				
Yes	0.377	0.057	**0.000**	0.188
NTD comorbidities (Ref: None)				
1	0.563	0.080	**0.000**	0.271
2	0.511	0.084	**0.000**	0.230
3	0.499	0.102	**0.000**	0.169
4	0.679	0.213	**0.002**	0.094
5	1.065	0.260	**0.000**	0.120
Age of respondents (Ref: 18–35)				
36–50	−0.086	0.069	0.216	−0.041
51–65	0.021	0.078	0.791	0.009
Greater than 65 years old	0.034	0.125	0.784	0.008
Gender (Ref: Male)				
Female	−0.031	0.058	0.590	−0.016
Ethnicity (Ref: Zaramo)				
Sambaa	−0.223	0.111	**0.045**	−0.068
Other ethnic groups	0.120	0.073	0.101	0.055
Region (Ref: Dar es Salaam)				
Pwani	−0.369	0.071	**0.000**	−0.158
Tanga	−0.384	0.069	**0.000**	−0.169
Employment status (Ref: Unemployed)				
Employed	−0.359	0.114	**0.002**	−0.091
Educational attainment (Ref: No formal education)				
Primary education	−0.125	0.116	0.281	−0.062
Secondary education	−0.127	0.121	0.294	−0.057
Tertiary education	0.126	0.127	0.321	0.049
Perceived temperature change in the past 10 years (Ref: Never)				
1–3 times	−0.489	0.120	**0.000**	−0.118
4–5 times	−0.475	0.074	**0.000**	−0.190
More than 5 times	−0.284	0.086	**0.001**	−0.097
Marital status (Ref: Unmarried)				
Married	0.225	0.061	**0.000**	0.107
Income	2.49E-07	6.94E-08	0.000	0.104

Note: Bold values = ($p < 0.05$).

statistical significance of the original relationships changed indicating the complex interaction between infectious diseases, comorbidities, biosocial, and sociocultural attributes in influencing community perception of health risks of climate change.

In the infectious disease and comorbidities model (Table 3), individuals who were diagnosed with cholera in the past 12 months had higher scores on perceived health risks of climate change. However, there was no relationship between diagnosis with malaria in the past 12 months and perceived health risks of climate change. All the relationships between NTD comorbidities and perceived health risks of climate change were not robust and disappeared at the multivariate level except for individuals who reported 1 (0.318, $p < .05$) and 5 NTD comorbidities (0.702, $p < .05$).

None of the biosocial factors was a significant predictor of perceived health risks of climate change at the multivariate level. In this vein, unlike in the bivariate model, none of the age categories was associated with perceived health risks of climate change. Similarly, gender was not a significant predictor of community perception of health risks of climate change. The relationship between the Sambaa ethnic group and perceived health risks of

Table 3. Multivariate relationships between perceived human health risks of climate change and theoretically relevant factors.

	Infectious diseases				Biosocial factors				Sociocultural factors			
	Coef.	*SE*	*p* value	β	Coef.	*SE*	*p* value	β	Coef.	*SE*	*p* value	β
Predictors												
Diagnosis with malaria in the past 12 months (Ref: No)												
Yes	0.241	0.131	0.065	0.104	0.230	0.131	0.080	0.099	0.222	0.131	0.090	0.096
Diagnosis with cholera in the past 12 months (Ref: No)												
Yes	0.326	0.057	**0.000**	0.163	0.305	0.059	**0.000**	0.153	0.317	0.078	**0.000**	0.159
NTD comorbidities												
1	0.318	0.141	**0.024**	0.153	0.337	0.143	**0.018**	0.162	0.341	0.143	**0.017**	0.164
2	0.264	0.150	0.078	0.119	0.272	0.151	0.072	0.122	0.292	0.151	0.053	0.131
3	0.227	0.163	0.163	0.077	0.232	0.164	0.158	0.079	0.236	0.164	0.151	0.080
4	0.360	0.244	0.140	0.050	0.350	0.245	0.154	0.048	0.327	0.245	0.183	0.045
5	0.702	0.287	**0.015**	0.079	0.707	0.289	**0.014**	0.079	0.570	0.290	**0.049**	0.064
Age of respondents (Ref: 18–35)												
36–50					−0.033	0.068	0.626	−0.016	−0.033	0.069	0.628	−0.016
51–65					0.036	0.077	0.643	0.015	0.015	0.078	0.847	0.006
Greater than 65 years old					0.046	0.122	0.708	0.011	−0.061	0.127	0.632	−0.015
Gender (Ref: Male)												
Female					−0.037	0.057	0.522	−0.018	−0.060	0.058	0.303	−0.030
Ethnicity (Ref: Zaramo)												
Sambaa					−0.250	0.109	0.021	−0.076	−0.223	0.123	0.071	−0.067
Other ethnic groups					0.023	0.072	0.750	0.011	0.020	0.082	0.806	0.009
Region (Ref: Dar es Salaam)												
Pwani									−0.008	0.093	0.935	−0.003
Tanga									0	(omitted)		0
Employment Status (Ref: Unemployed)												
Employed									−0.306	0.116	**0.009**	−0.078
Educational attainment (Ref: No formal education)												
Primary education									−0.125	0.116	0.284	−0.062
Secondary education									−0.302	0.127	**0.018**	−0.136
Tertiary education									−0.143	0.150	0.338	−0.056
Income									0.000	0.000	0.135	0.055
Constant	−0.580	0.068	0.000		−0.505	0.129	0.000		−0.053	0.222	0.810	

Note: Bold values = ($p < 0.05$).

climate change also disappeared at the multivariate level likewise the relationship between geographic region of residence and perceived health risks of climate change.

When sociocultural factors were adjusted, the significant relationships between cholera prevalence and NTD comorbidities, on the one hand, and perceived health risks of climate change, on the other hand, persisted. Besides, employed individuals had lower scores on perceived health risks of climate change unlike the unemployed. Individuals who had attained secondary education had lower scores on perceived health risks of climate change compared with those without any formal education. Given that this relationship did not exist at the bivariate level, it indicates that some biosocial and sociocultural factors suppressed the relationship between secondary education attainment and perceived health risks of climate change. In the multivariate model, the order of magnitude of decreasing importance of predictors is as follows: NTD comorbidities > cholera > secondary education > employment status.

Discussion

In the past 10 years, it has become increasingly clear that mankind is progressively facing tremendous challenges associated with climatic change including adverse health effects. Yet, little is understood about the manner in which mental representation of disease conditions by people influences their perceived health risks and climate change response behaviors. This study assessed how malaria and cholera prevalence and comorbidities of NTDs independently influence how individuals perceive health risks of climate change. According to Helgeson, Van Der Linden, and Chabay (2012), given that climate change is a slow, ongoing, largely invisible process, this does not correspond with the traditional way in which humans perceive their external environment, making it difficult for people to accurately estimate climate-related health risks. Perceptions of health risks are fundamentally based on perceptions of the target illness or disability condition, and therefore construals of risk perceptions must integrate, or at least be consistent with, our theoretical understanding of illness or disease representations (Cameron, 2003).

Global attention on infectious disease is primarily focused on HIV/AIDS, tuberculosis, and malaria (i.e., the "big three"), which cumulatively were responsible for over five million deaths in 2007 and account for 39% of all deaths attributed to infectious disease (Daumerie & Savioli, 2010). Unfortunately, this attention has not extended to other lesser-known diseases, sometimes referred to as the NTDs. These diseases are largely overlooked, due to their low mortality rate and the poverty of their sufferers, where over 70% of the affected areas have low to lower-middle income economies (Armah et al., 2015c). They thrive under poor sanitary conditions, where clean water and food are unavailable and where insect vectors are abundant. The WHO estimates that NTDs affect over one billion people and cause about 570,000 deaths each year (Daumerie & Savioli, 2010). Our focus on malaria, cholera, and NTD comorbidities in this study gives impetus to the synergistic interaction of two or more coexistent diseases and social conditions at the biological and population levels.

Our findings reveal several interesting linkages between infectious disease prevalence and public perception of health risks of climate change. In this regard, the alterations in the magnitude, direction, and strength of the relationships between people's perception of the health risks of climate change and infectious disease, NTD comorbidities, compositional and contextual factors at the multivariate level underscore the complex nature of the relationships. This complexity is consistent with the literature. For instance, Helgeson et al. (2012) and Hillson and Murray-Webster (2007) argue that risk perception is an inherently complex process involving five dimensions that generate, influence, and help shape perceptions of risk. At least two of these dimensions, that is, *sociocultural* and *individual factors* are pertinent to this study.

Interestingly, at the multivariate level, income, region of residence, age, ethnicity, and gender of respondents did not influence participants' perception of health risks of climate change. While some studies indicate systematic ethnic and socioeconomic differences in the perception of environmental health risks (e.g., Flynn, Slovic, & Mertz, 1994), other recent research indicates that some variation in individual risk behavior is likely to arise as a result of genetic predispositions (Kuhnen & Chiao, 2009). Not only does cultural background influence risk perception, different demographic groups within a population have also been shown to perceive risk differently (Bickerstaff, 2004; Hillson & Murray-Webster, 2007; Renn & Rohrmann, 2000). One such example is urbanicity wealth disparities (see Armah, Ung, Boamah, Luginaah, & Campbell, 2015d). We found no male–female differentials in perceived health risks of climate change, which is consistent with Olofsson and Rashid (2011) who did not establish any difference in risk perception between men and women in Sweden. Similarly, others indicate that there are no significant differences in risk perception between men and women (e.g., Armah et al., 2015d; Liu et al., 2013) whereas some found evidence to the contrary (see Gustafsod, 1998; Henwood, Anne Parkhill, & Pidgeon, 2008). Except secondary education, all other levels of educational attainment were not significantly associated with perceived health risks of climate. It has been suggested severally that knowledge and education are key determinants of risk perception (see Kane, Vanderlinden, Baztan, Touili, & Claus, 2014; Touili et al., 2014); however, our findings do not support this suggestion. In fact, a growing body of literature now emphasizes that knowledge is, in no way, the fundamental element determining perceptions of risk (Renn & Rohrmann, 2000; Touili et al., 2014). Besides the foregoing, the psychological concept of "self-efficacy" (i.e., an individual's perception of the capacity to bring about change through his or her own behavior) (Bandura, 1977) has been implicated in explaining variation in risk perception. As lower levels of self-efficacy would imply a decreased ability to protect oneself, this is likely to be associated with higher levels of perceived personal risk (Breakwell, 2010; Spence, Poortinga, Butler, & Pidgeon, 2011).

Those who were diagnosed with cholera had higher scores on perceived health risks of climate change. According to Williams et al. (2010), suffering from cholera is associated with higher levels of perceived personal risk and this is consistent with the notion of "availability bias", where individuals are more likely to perceive an event as more probable if they are able to imagine or recall such events easily (Eiser et al., 2012). For instance, if someone has experienced cholera outbreaks they are likely to see one as more probable in the future. Consequently, personal experience can be very important in perception of the level of risk, and reminders of particular risks in the media can also have an effect (Eiser et al., 2012; Wahlberg & Sjoberg, 2000). Moreover, differences in the level of experience and familiarity that individuals hold with regard to certain risks also strongly influence perception (Song & Schwarz, 2009; Whitmarsh, 2008). Individuals who had been diagnosed with malaria in the past 1 year were not different from those who had not been diagnosed with malaria over the same period regarding their perception of health risks of climate change.

Risk perception may play a role in an individual's behavior as an agent of climate change adaptation, for instance, regarding whether or not to initiate steps to reduce climate-related health risks. In this study, there is no evidence to suggest that higher scores on perceived health risks of climate change influence preparedness intentions or actions of respondents. Yet, risk perception, trust, responsibility, emotion, and risk area (e.g., actual risk) have been identified, in the literature, as important factors influencing preparedness intentions or actions (see Renn, 2008). Several scholars underscore knowledge, trust, and experience as key factors influencing the adoption of protective measures, and age, gender, ethnicity, and education as factors influencing preparedness behavior for human infectious diseases. Being female, a member of a minority ethnic group, and being older were positively associated with protective measures (e.g., preparedness) (Kane et al., 2014; Touili et al., 2014). It has been suggested that lower income respondents more commonly practiced avoidance behavior, however, no explanation is offered for this preference.

It is evident from the results that region and district of residence, poverty, and housing conditions were important factors influencing preparedness intentions and actions of participants unlike age, ethnicity, and gender. In the literature, demographic variables such as gender, age, experience, education, and socioeconomic status show "mixed" results for impacting preparedness, e.g., some studies found statistical relationships between risk perception and demographic variables and others did not. Educational attainment (only secondary level) and employment status were significant predictors of perceived health risk of climate change. These findings are broadly inconsistent with the literature given that perceptions may change with age, experience, social context, or as people interact with different social groups (see Irwin, Simmons, & Walker, 1999; Kasperson & Kasperson, 1996; Rogers, 1997; Wilkinson, 2001).

Policy implications

Hitherto, significant effort has been devoted to addressing individual diseases with specific, often curative, interventions. According to McMichael et al. (2008), this tends to culminate in the identification of single technological tools to address new risks, with a relative reluctance to work across sectors to address the root causes of multiple health exposures, including environmental and social determinants. Health-related challenges and vulnerabilities are heightened because the health effects of climate change reside within a broader and very complex policy debate. As an international policy issue, climate change encompasses many highly contentious domains, including the speed and nature of population growth, environmental sustainability, and division of obligations between rich and poor countries, and individual lifestyle choices (IOM (Institute of Medicine), 2008). Within this policy discussion, risks to health usually elicit specific attention because they pose a tangible "human dimension" of the climate change debate (IOM (Institute of Medicine), 2008). Evidence for or against health risks from climate change is therefore often used selectively by parties to promote political agendas that have little to do with the health risk itself (IOM (Institute of Medicine), 2008; McMichael et al., 2008). The specific health risks of vulnerable groups of people at the local level are often in the broader policy debates.

This study indicates that most individuals in coastal communities in Tanzania have been diagnosed, at least once, with malaria in the past 1 year. Only few had been diagnosed with cholera within the same time period. However, most of them have no inkling how climate change will exacerbate their vulnerability or risks to increased frequency and magnitude of either malaria or cholera. It is evident from the findings that concerns about health impacts from climate change do not seem to be affecting perceptions of threat from malaria unlike cholera. Therefore, risk communication should emphasize the effects of a changing climate that pose health risks now (e.g., increases in extreme temperature, shifts in temperature in high altitudes, and the spread of disease vectors), show what health implications these effects have, and delineate the specific actions coastal residents can employ to minimize such risks. To make the need for behavior change both understandable and desirable, attention should be focused on the health aspects of current climate-related risks, rather than the more abstract problem of climate change *per se*. Since most coastal residents in Tanzania are aware of climate change but have little knowledge of specific risks that it poses to health, risk communication efforts to promote climate change and health adaptations will need to address this gap as a fundamental component in outreach undertakings. Most respondents agree that climate change is either a health risk now or will be in the near future; consequently, the potential exists for a strong uptake of messages stressing the need for the increased adoption of protective measures as risks to human health intensify.

Conclusion

Health risk assessment emphasizes the need for monitoring of human diseases in relation to climate and environmental factors. Existing literature has provided valuable information about the potential health risks associated with climate change. Yet, the cumulative evidence has disproportionately emphasized the health effects of climate change. In this context, relatively little is known about the relationship between diagnosis with infectious diseases and public perception of health risks associated with climate change although this knowledge has implications for mitigation, adaptation, and control of climate change-induced health effects. Given that most respondents did not know how climate change will likely exacerbate their vulnerability or risks to increased frequency and magnitude of either malaria or cholera, there is need for implementation of effective risk communication procedures in coastal Tanzania. This procedure will likely involve complex, multidisciplinary, multidimensional, and evolving processes, and may be most efficient when focused on filling knowledge gaps and misconceptions that are most critical to the decisions people encounter. Broadly, this study shows that community perception of the health risks of climate change is influenced by the existing health conditions of the respondents (including infectious diseases and comorbidities), geographical region of residence, and other demographic factors such as poverty, educational attainment beyond the primary level, and employment status. The alterations in the magnitude, direction, and strength of the relationships between perceived health risks of climate change and infectious disease, comorbidities, compositional, and contextual factors at the multivariate level underscore the complex nature missing of the relationships.

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