Climate change and perceived vulnerability: Gender, heritage, and religion predict risk perception and knowledge of climate change in Hawaii

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ABSTRACT

This study explores climate change related risk perception among residents of the 'Big Island' of Hawaii, an environmentally vulnerable region. Adapting established instruments, we investigated potential links among socio-demographic variables, risk perception, and perceived preparedness and knowledge, as they relate to climate change. Results reveal relationships between risk perceptions for climate change and gender, with females significantly more aware of the risks posed by climate change, but less prepared than men. Additionally, indigenous and native respondents felt that climate change events posed more risk and felt less prepared compared to non-indigenous. Results suggest that an understanding of how risk perceptions vary by gender, knowledge, and other lesser-explored demographic factors may enable decision makers to plan and implement more effective mitigation and adaptation measures in the region.

Keywords: Climate change, vulnerability, risk perception, adaptation preparedness, island nations

INTRODUCTION

Climate change will have numerous impacts on the physical environment and on human society. Adapting to climate change will require responding to the physical effects of global warming and adjusting how we conceptualize, measure, and manage risks. Climate change is creating new risks and it is also impacting the interdependencies among those risks, highlighting the need for research and planning that seeks to understand risks from both the environmental and social arenas (Kousky and Cooke 2009). Risk perceptions are believed to interact with underlying values to form subjective and variable limits that hinder a society's ability to act (Adger et al. 2009). Since the reaction to potential climate change rests on moral, ethical, and

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value judgments, it is important to recognize that different degrees of knowledge, cultural preferences, responsibility and trust, shape individual positions and perceptions (Poortinga et al. 2006). This requires an understanding of which factors contribute to individual and collective risk perceptions of climate change, and how those perceptions are formulated (Leiserowitz 2005; O'Conner et al. 1999; Sjöberg 2003).

Climate change is a phenomenon that is not well understood by the general public. Past research in regions that have experienced obvious physical evidence of climate change indicates that personal exposure significantly increases concern and willingness to take action (Arctic Climate Impact Assessment 2004; Frondel, Simora, and Sommer 2017; Leiserowitz and Broad 2008). However, climate change occurs at various scales; even when individuals experience the effects of climate change personally they still must connect the event with the process of climate change itself (Frondel, Simora, and Sommer 2017; Weber 2010; Whitmarsh 2008). Therefore, individual exposure is insufficient to make wholesale changes in beliefs.

The noticeable divide between the scientific knowledge of climate change and that of the general public, politicians, and policy makers is clear, but may be explained in-part by this causal disconnect between experience and process. Public opinion is a key component of the socio-political context in which decisions are made (Leiserowitz, 2007). Climate change is not a series of isolated events, but instead a process that involves the interactions between humans and the natural system (Frank et al. 2011; Smit and Wandell 2006). Therefore, it is important to understand the ways in which individuals and communities perceive risk, probability, preparedness and responsibility, as well as to gauge which demographic factors contribute to the formation of those perceptions.

In this research project we quesitoned residents of the Big Island of Hawaii about climate change to investigate their understanding, their perceived risks, the perceived probability of climate-change related events, and their perceived preparedness for such. Our results indicate several interesting patterns concerning subject's beliefs and knowledge concerning climate change, as well as the interaction between these two. Additionally, a number of significant, meaningful interactions occurred between the responses and subjects' demographics. We begin the paper by introducing our study area, then review relevant literature on climate change and risk perception, present our research questions, detail our methods, present the results, discuss them, and finally conclude with some recommendations concerning climate change education and intervention.

CLIMATE CHANGE VULNERABILITY IN THE PACIFIC REGION

The Pacific Region is especially vulnerable to climate change due to its remoteness, limited resources, and its increased susceptibility to climate change events such as storm surges, changing weather patterns, ground water salinization, tidal fluctuations, and others (Bettencourt et al. 2006; Grasso 2006; Mimura 1999; Mimura et al. 2007).

THE STATE OF HAWAII

The State of Hawaii presents an interesting case study for the Pacific Region in that it is a full-rights part of a developed nation while possessing similar vulnerabilities to the small nation developing states and dependencies that make up much of the rest of the region. The Hawaiian Islands are located in the North Pacific Ocean, between 19 and 22°N and 155 and 160°W. The archipelago is comprised of eight main islands; elevation throughout the archipelago ranges from sea level to 4,205m at the top of Mauna Kea. As of 2010, Hawaii had an estimated population of 1,360,301, an increase of over ten percent in ten years (U.S. Census Bureau, 2010). It is the most isolated heavily populated land mass on the planet (Baker 2009). The greatest percent change in population between 2000

and 2010 was in Hawaii County, which is made up entirely by the Island of Hawaii (The Big Island), Hawaii's largest island. The State of Hawaii's population is spread over 6,423 square miles (16,640 km^2) (including many unpopulated islands) and results in an average population density of 211.8 persons per square mile. In 2010 the state was 24.7 % Caucasian, 1.6% African American, 38.6% Asian, 10.0% Native Hawaiian or other Pacific Islander, 8.9% Hispanic and 23.6% two or more races (U.S. Census Bureau, 2010).

The political and economic history of Hawaii can be traced through a series of prominent industries including sandalwood, whaling, sugarcane, pineapple, military-related services and finally tourism. Over the past 50 years Hawaii has become increasingly dependent on tourism, and it accounts for as much as 33% of gross state product and nearly half of the total employment in the state (HDBEDT 1999). The tourist area of Waikiki alone is responsible for 8% of gross state product and 11% of all civilian jobs (HDBEDT 2003). Hawaii's real GDP in 2010 was $59.3 billion USD, making it the third largest economy in Oceania after Australia and New Zealand (BEA 2010).

With approximately 10,000 endemic species out of a total biota of approximately 20,000 native terrestrial and marine species (Eldredge and Evenhuis 2003), Hawaii makes up a significant proportion of United States' (U.S.) biodiversity (about 30%) in a very small land area (about 0.002% total area) (PIRAG 2001). Moreover, as part of the Polynesia-Micronesia Biodiversity Hotspot, the state boasts not only the greatest diversity of species in the U.S., but also one of the largest numbers of endemic species in the world. However, this means that invasive species (a potential outcome of climate change) pose a particular threat to the natural environment (Burgiel and Muir 2010; Denslow 2003; Donlan and Wilcox 2008; OTA 1993).

Regional statistics between 1950 and 2004 suggest that climate change could escalate economic problems, since extreme natural disasters such as hurricanes, droughts, and tsunamis, made up 65% of the total economic impact from disasters on the region's economies (Bettencourt et al. 2006). With a great deal of Hawaii's tourism based on the allure of the state's natural environment, including its coral reefs, shorelines and marine life, it is possible that greater climate variability could impact tourism and the state's economy in a number of serious ways.

CLIMATE CHANGE IN HAWAII AND THE PACIFIC REGION

A growing body of evidence has shown that climate change is linked to the growing frequency and intensity of natural disasters in the Pacific Region. This is particularly evident with climate events such as ENSO, droughts, and hurricanes, as well as long-term climate change events like global warming, sea level rise, and increases in sea surface temperature. These events may lead to a collapse of marine species populations, coral bleaching, shoreline erosion, and destruction of coastal infrastructure (Adger et al. 2005; Avagliano and Petit 2009; Harley et al. 2006; PIRAG 2001). A single-model climate change projection, based on the results from both the Hadley model run at the Hadley Center for Climate Prediction and a coupling of the first-generation and general-circulation model from the Canadian Center for Climate Modeling and Analysis, indicates that Hawaii will experience increases in temperature, changes to seasonal variations in precipitation, possible alterations of the ENSO phenomenon, and significant changes in sea levels over the next decade (PIRAG 2001).

Air Temperature. The Pacific Island region is experiencing many changes in prevailing climate conditions with the southern Pacific experiencing a significantly drier and warmer climate (by 15% and 0.8˚C, respectively) and the Central Equatorial Pacific experiencing more intense rain and hotter temperatures (by 30% and 0.6˚C, respectively). Sea surface temperatures across the region have also increased by about 0.4˚C (Hay et al. 2003). Such changes have been linked in part to

an increased frequency of El Niño events (Bettencourt et al. 2006). Studies have also shown there to be a rapid increase in air temperatures across the Hawaiian Islands over the past 30 years (averaging 0.3°F per decade), with significant warming at higher elevations (Giambelluca et al., 2008). Hawaii is expected to experience some of the fastest warming in the region with projected increase in sea surface temperatures of 1.3°C (2.3°F) by the 2025-2034 period and 3.0°C (5.4°F) by the 2090-2099 period (PIRAG 2001).

Sea Level Rise. Sea level rise as a result of climate change is a global phenomenon that is of particular concern for the Pacific Region, which is exceptionally vulnerable given the presence of a large number of low-lying atolls and human settlements at lower elevations. Data measuring the rate of rise for the central and eastern Pacific indicate a sea level rise between 2 and 2.5mm per year with a maximum of over 3mm per year in some places (Church et al. 2004). The Pacific Region is expected to see a rise of between 9 and 90cm by the end of the century, with the eastern Pacific experiencing the largest rise (Bettencourt et al. 2006). Sea levels in the Hawaiian Islands have raised approximately 1.5cm per decade for the last century and mean sea level trends for the eastern side of the Big Island indicate a 0.33cm per year trend over the last; equivalent to a change of 1.07ft in 100 years (NOAA 2011). In addition to gradual sea-level rise, there has also been an increase in frequency of high water level events (Firing and Merrifield 2004; Karl et al. 2009).

Other Climate Change Risks. Additional risks of climate change in this region include increased storm events, drought, and other natural hazards. Hurricanes are expected to increase in intensity and frequency, particularly in the northern Pacific Region (Bettencourt et al. 2006). The effect of these events may be compounded by the widespread degradation of coral reefs, leading to increased coastal erosion. The degradation of reef ecosystems as a result of climate change also means a probably decline in local reef fish, with resultant declines in biodiversity and fishing opportunities (Bettencourt et al. 2006).

Water resources on small islands are vulnerable to climate change due to their limited size, availability, geology and topography, especially in regards to rainfall (Mimura et al. 2007). Studies of Hawaiian rainfall records indicate an approximate 15% decrease since the 1980s (Chu and Chen 2005). While total rainfall in Hawaii has decreased, intensity seems to be increasing (Groisman et al. 2004). Additionally, climate change in Hawaii may increase the possibility of wildfires (Pechony and Shindell 2010; van der Werf et al. 2004), and ocean acidification (Dore et al. 2009).

Climate Change and Human Health. While climate change is projected to have serious implications for human health worldwide, many of the effects are already being felt to some degree throughout the Pacific. From heat waves, increased pollen count (resulting in longer and more severe allergy seasons), and a rise in mosquito-borne infectious diseases, climate change and variability have taken a toll on an already vulnerable region (Ebi et al. 2008; Kolivras 2010).With projections indicating impacts to human health to increase in the near future, it is important to understand how communities perceive this aspect of climate change individually and in comparison to other factors in an attempt to gain an understanding of how to direct adaptation and mitigation initiatives.

LITERATURE

Risk Perception of Climate Change

There have been only a few comprehensive studies of public climate change risk perceptions around the globe (e.g., Bord et al., 2000; Bostrom et al., 1994; Kempton, 1997; Lee et al. 2015; Poortinga et al., 2006; Leiserowitz, 2007; Patt and Schröter, 2008; Frank et al., 2011). This is of concern since public opinion is a key component of the

socio-political context in which policy makers operate (Leiserowitz, 2007). Researchers have described the severity of potential consequences associated with a particular risk to be the most important determinant for risk perception and demand for action (Sundblad et al., 2007), with probability and riskiness of activities that lead to such events as having less importance (Sjöberg, 2000b).

Concerning risk perception of climate change in particular, the belief that global climate change is actually occurring is the most important prerequisite for individuals to be willing to take action (Heath and Gifford, 2006). Additionally, it has been found that knowledge of the causes of climate change is a powerful predictor of behavioral intentions to combat climate change. The more knowledge people have about climate change, the more prepared they are to take actions to reduce the negative consequences (Bord et al., 2000; O'Connor et al., 1999). This suggests that knowledge has a direct and indirect effect on risk perception, and that risk perception has an independent effect on behavior.

Concerning which aspects of knowledge affect risk perceptions, the research indicates that consequences of hazards are the dominating risk element, while events that appear earlier in a proposed causal sequence are viewed as less important (Böhm and Pfister, 2001). This is consistent with non-climate change risk perception research which has found that knowledge of health consequences was most associated with risk judgment, and that knowledge of state was not linked to cognitive or effective risk (Sundblad et al. 2007).

Risk perceptions are influenced by a variety of social and environmental factors that act on the cognitive responses of individuals. Understanding the relationships between these factors and various aspects of risk perception research is a growing goal in the field. Lazo and others (2000) found that risk perception was related to demographic factors, such as gender and age, while others have found that factors such as knowledge and gender are clear determinants (e.g. Sundblad et al. 2007). How these factors relate to perceived probability and preparedness are not well understood, and there is a dearth of studies conducted in areas especially vulnerable to climate change. Demographic factors such as religious affiliation and indigeneity have also been largely overlooked in the risk perception literature.

The most consistently established demographic trend is gender: males tend to perceive risks as smaller than females, and in research conducted in the U.S. this gender difference is particularly strong among Non-Hispanic Whites (Davidson and Freudenburg, 1996; Flynn and Mertz 1995; Frondel, Simora, and Sommer 2017; Lujala, Lein, and Rod 2015; McCright 2010; McCright and Dunlap 2010; Rowe and Wright, 2001; Slovic, 1999). However, it is unclear whether females perceive both general and personal risks differently than males. One study by Sjöberg (2003), concluded that females rated all items as riskier than males for both personal and general risks. In this project, we will examine how gender, and demographics, are associated with these perceptions.

RESEARCH QUESTIONS

This research was guided by four questions:

1) How does risk perception of climate change vary among the general public of Hawaii?
2) What factors influence subjects' individual and collective perceptions of risk?
3) How does the research subjects' knowledge of climate change relate to their judgement of associated risks?
4) What is the relationship between subject's risk perception and preparedness for related events?

DATA COLLECTION AND PROCEDURES

To address the above questions, we collected data using an IRB-approved question-

naire among residents of the Big Island of Hawaii (Appendix A)[2]. The questionnaire was adapted from existing instruments: portions focusing on risk perceptions and responsibility were adapted from Patt and Schröter (2008), and Sjöberg (2003), while sections concerning current knowledge were modified from Sunblad et al. (2007) and Leiserowitz et al. (2010). These instruments were altered to fit the context of Hawaii. A pilot study involving 15 individuals on the Big Island was conducted to assess the clarity of each item as well as the reliability of the instrument. Based on the results of this pilot we made some changes in wording to the questions concerning demographics (Section 1, question 1-8). A revised version was administered between February 1st, 2011 and March 15th, 2011.

The questionnaire (Appendix A) contains 6 short sections, each focusing on a different aspect of climate change risk perception or knowledge. *Section 1* concerns participant demographic information, including age, sex, occupation, ethnicity, marital status, housing tenure, location of home, education, years in community/island/state, household income, migrant status, children, and religion. This section also includes some open-ended questions about climate change and its possible risks. *Section 2* asks participants to indicate whether eight climate change related events will become more or less frequent on the Big Island 0-5 years and in 0-20 years from now. These events are: severe storms; Dengue Fever; invasive species; rising sea levels; drought; airborne illnesses; and temperature increase. These eight phenomena capture four broader categories of risks associated with climate change: marine impacts, terrestrial impacts, natural disasters and health effects. *Section 3* asks participants to rate the personal and general risk these eight events pose on a five point Likert Scale. *Section 4* asks subjects to rate their own preparedness for these events on a 5 point Likert scale ranging from "Extremely Prepared" to "Extremely Unprepared." *Section 5* asks subjects to rate the level of importance that government take steps to alleviate the eight events. Responses are on a 5 point Likert scale from "No Importance at All" to "Very Large Importance". *Section 6* contains 17 'true or false' questions about climate change related knowledge, with adjacent boxes for participants to indicate their confidence in each answer. These questions concern knowledge of climate, causes of climate change, and consequences of climate change.

SUBJECTS

To recruit subjects, we stationed ourselves at several Motor Vehicle Registration offices and randomly selected grocery stores throughout the Big Island[1]. Researchers asked all individuals (time permitting) exiting these locations if they would like to participate in the project. Subjects were approached between 12:00 p.m. and 7:00 p.m. Participants received no compensation for participating. These efforts resulted in 80 usable questionnaires. Table 1 contains subjects' demographic information.

This project is intended to explore attitudes and knowledge regarding climate change among residents of the Big Island using a mix of quantitative and qualitative information. It was not intended to collect a representative sample of residents of the Big Island, but to analyze the relationships in a population living in a region highly sensitive to climate change. One of the limitations of this study is our relatively small sample size (n=80), which preclude us from making observations about Hawaii or the Big Island as a whole. We explore relationships *within* this sample, between attitudes and knowledge of climate change as well as interactions between these and characteristics such as gender, religion, and heritage, which past literature indicates may play a factor.

ANALYTICAL METHODS

We created a bivariate correlation matrix to determine which demographic groups were significantly associated with questionnaire

Table 1. Subject Demographics

	n	%		n	%
Sex			House Location		
M	42	53	Sea Level	27	35
F	38	48	Higher Elevation	52	67
Age			Education		
18-29	26	33	High School Education or Less	31	39
30-39	13	16	Higher Education	49	61
40-49	25	31	Household Income		
>50	16	20	<25K/year	29	36
Ethnicity/Race			≥25K/year	47	59
Caucasian	30	38	Migrant		
Filipino	9	11	Y	13	16
Hawaiian (Any Combination)	16	20	N	67	84
Other Pacific Islander (Any Combination)	7	9	Religious		
Other/Mixed (Non-Pacific Islander)	17	21	Y	36	45
Marital Status			N	44	55
Single	51	64	Religious Association		
Married	18	23	Christian	30	91
Divorced/Widowed	11	14	Eastern or Alternative	3	9
Housing Tenure					
Homeowner	23	29			
Renter	46	58			
Co-Resident/Other	11	14			

responses ($p > .05$ for all tests). We also used a bivariate correlation matrix to examine the relationships between perceived frequency for climate change events at the 0-5 and 5-20 year periods, and perceived risk at both the personal and general level. In addition, risk perception scores from Section II (sums) were correlated with perceived frequency scores from Section III (sums) to determine if an overall relationship existed between perceived frequency and perceived risk. Demographic questions that were significantly correlated to other sections of the questionnaire were used to select demographic groups for further analysis. These subsets were compared to the rest of the sample, or other subsets using two sample T-Tests, or Chi-square tests for non-parametric values (such as the Likert scale responses). To assess whether mean personal and mean general risk perceptions were affected by different variables, two regression analyses were performed. First, mean personal risk perceptions served as the dependent variable, and the demographic factors as well as preparedness, knowledge of the climate system, causes, and consequences of climate change served as the independent variables. The second regression analysis was performed with mean general risk perceptions as the dependent variable and the demographic

factors, preparedness, and knowledge types as the independent variables. Descriptive analysis of all questionnaire responses is available in Appendix B. In the following section, we present the results of analyses that met our significance threshold and demonstrated a consistent pattern.

RESULTS

General Views on Climate Change

96% of participants believed that climate change was happening on the Big Island, while 81% indicated that climate change posed a risk to themselves and/or their community. 91% of respondents felt they should do something about climate change. Concerning specific impacts, 78% indicated that it would have an impact on agriculture, 76% believed that climate change would impact marine life in Hawaii, 74% thought natural disasters were an issue when it comes to climate change in the state, and only 65% of the sample believed that climate change would have an impact on health in Hawaii.

Participants were posed open-ended questions about how climate change was happening in the big island, how it was a risk to their community in particular, and what they could do about the climate change hazards of global warming, invasive species, and sea level rise (Questions 9, 10, 15, Appendix A). These responses were coded into categories of response and are discussed here. Regarding climate change on the big island, temperature (n=23), weather (either in general, or changes in seasonal patterns) (n=18), and changes in rainfall or and increase in drought (n=20) were by far the most common responses to how climate change was occurring. There were few responses concerning biodiversity or the loss of animal or plant species (n=3), and almost no worries about sea level rise or storms (n=1). A number of residents (n=7) discussed volcanic air pollution (VOG) and a few increased volcanic activity (2), both of which are not affected by climate change to our knowledge (Businger et al. 2015).

Among the minority of respondents who did not feel that climate change was a risk to their community (n=15), of the few who responded to the open-ended portion of this question, most felt that climate change was a long term or natural process of change. Those who *did* feel it was a threat to their community, the most common responses to these questions were led by concerns about agriculture (19), followed by drought (8), biodiversity or animal and fishing concerns (6) and SLR (6). This is reflected in participants' responses to Question 12, where 76% indicated that climate change would affect agriculture. Roughly the same percentage indicated that climate change would impact marine resources, however this was nowhere near as common a concern in the open-ended responses.

When participants were asked if they could "do anything about global warming, invasive species, and/or sea level rise?" (Question 15), of those who believed they could not, most indicated that nature would proceed on its course regardless of our efforts, and a few cited lack of knowledge of how to act. The two common ways in which participants thought that they could "do something" were to drive less or change their mode of transportation, and to recycle. Respondents also expressed a general desire to fight invasive species, but offered no specifics on how they would do this.

Perceived Risk Ratings, All Subjects

The categories of climate change perceived as riskiest both personally and generally were: drought, temperature increases, and a rise in invasive species. All of these were rated closest to the "Large Risk" category for general risk and between "Moderate Risk" and "Large Risk" for personal risk. Dengue fever was perceived to pose the least personal and general risk. Overall personal risk was perceived to be less than general risk, although they were highly correlated (R^2=0.6). This is consistent with Sjöberg (2003) found that for all risks examined were perceived as riskier for the general population than for the individual subject.

Perceived Frequency of Climate Change Events, All Subjects

Subjects perceived all climate events as growing in frequency, with temperature increase and rise in invasive species rated highest and dengue fever and airborne illnesses rated lowest. The events with the greatest difference in perceived frequency between the two periods (-2 – +2 scale) were severe storms (0.51), rising sea levels (0.51), and temperature increase (0.52), indicating that subjects believed that the frequency of these events will increase the fastest (See Figure 1).

Perceived Preparedness for Climate Change, All Subjects

As a whole the subjects felt the least prepared for climate change events that were related to health (Figure 2). Additionally, respondents who indicated that climate change posed a risk to them or their community (Question 10) felt less prepared than respondents who did not.

Knowledge of Climate Change

When we examine subjects' scores on the knowledge test and their self-rated confidence in this knowledge (Section VI) a clear pattern resulted: A belief in climate change, climate change risks, or negative effects of climate change was significantly correlated with higher scores on the knowledge test, with no exceptions. If we separate performance on the knowledge test into three categories representing consequences of climate change, causes of climate change, and the climate system, subjects scored highest in the 'consequences' category (80%), followed by 'causes' (75%), and finally 'climate system' (70%). Unsurprisingly, subject's education was correlated with test performance: those who with more than high school education scored significantly better (78%) than those who had not (70%), a pattern which held for all three categories of questions.

Gender

There were a number of significant difference across gender. Female subjects perceived

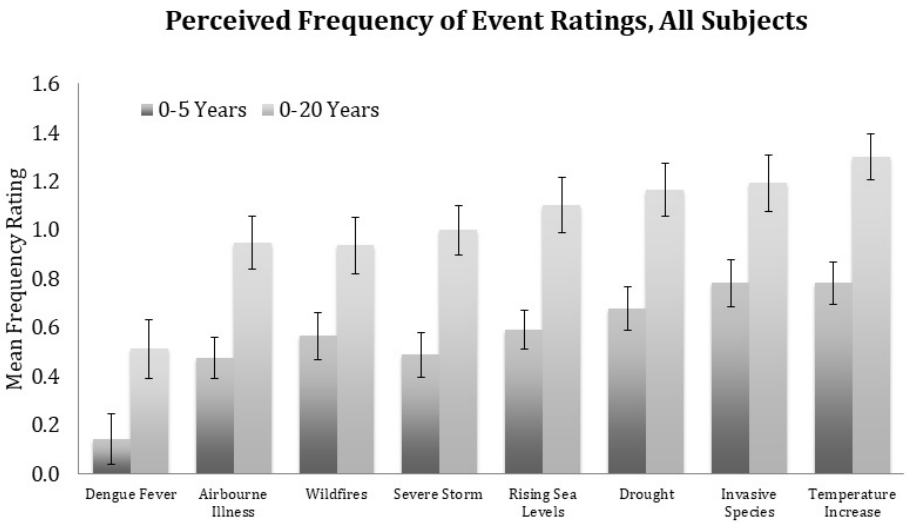

Figure 1. A comparison of mean frequency ratings for both the period between 0-5 years and the period between 0-20 years.

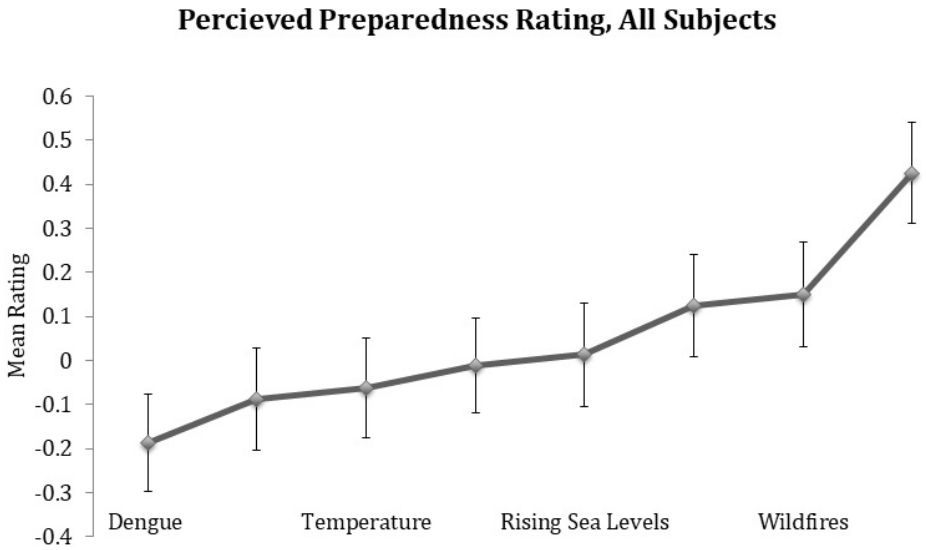

Figure 2. A comparison of mean perceived preparedness ratings (Section IV) by event for all subjects.

personal and general risks to be higher than male subjects (Figure 3), with significant differences for *Dengue Fever* at the personal and general level, *Airborne Illness* at the personal and general level, *Invasive Species* at the general level, and *Rising Sea Levels* at the general level. Significantly more females (76%) recognized health as an issue than males. Significantly more females (87%) recognized that climate change will affect marine life in Hawaii than males (67%). Differences in gender were also found with perceptions of frequency of climate change events, with females believing that frequency would increase more than males for 6 of the 8 events. Also, their perception of which events would increase differed: females perceived the highest change in frequency for temperature increase and rising sea levels, while male's was airborne illnesses.

Regarding perceived preparedness, males indicated that they felt prepared to some degree for every event tested except temperature increase. In contrast, females reported feeling *unprepared* or unsure to some degree for every event tested except severe storm (Figure 4). Additionally, a significantly higher percentage of females (87%) believed that climate change would have an impact on health than males (67%), and a larger percentage of females believed that climate change would increase the risk of mosquito-borne illnesses. Females averaged higher scores than males on the knowledge test, and significantly higher in the 'consequences' category with an average of 86% correct compared to 74%.

Heritage

Subjects who identified as Pacific Islander, Native Hawaiian, or who were born in the Big Island differed significantly in a number of ways. Native Hawaiians and Pacific Islanders perceived the risk of climate change as higher in all categories than other groups at the personal and general levels, excepting only *Rise in Invasive Species* at the personal level. There were notable significant differences for *Airborne Illnesses* at the personal level (0.5 mean difference), *Rising Sea Levels* at the personal (0.4 mean difference) and general (0.4 mean difference) level, and

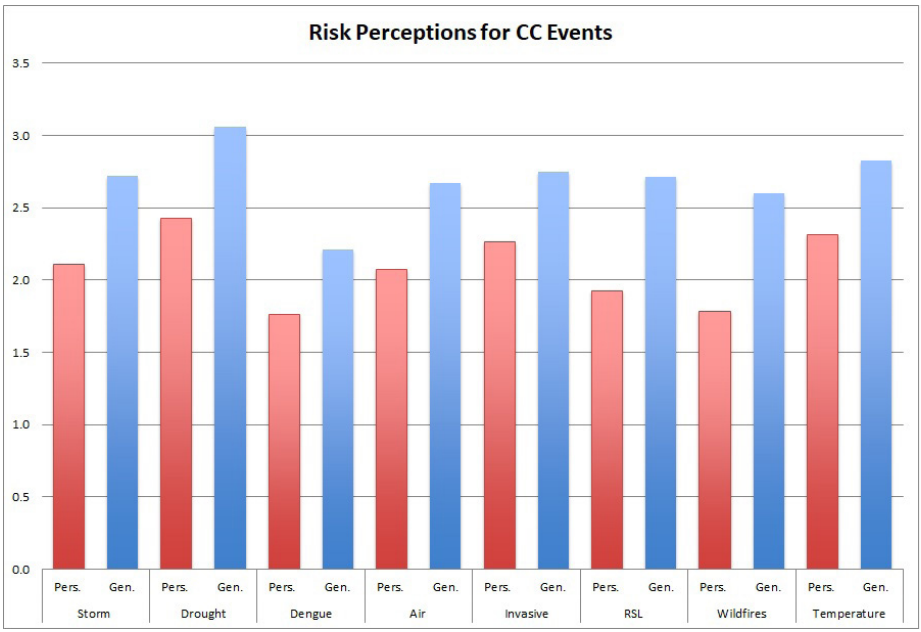

Figure 3. A comparison of mean general risk perception ratings and mean personal risk perception ratings (Section III) by gender.

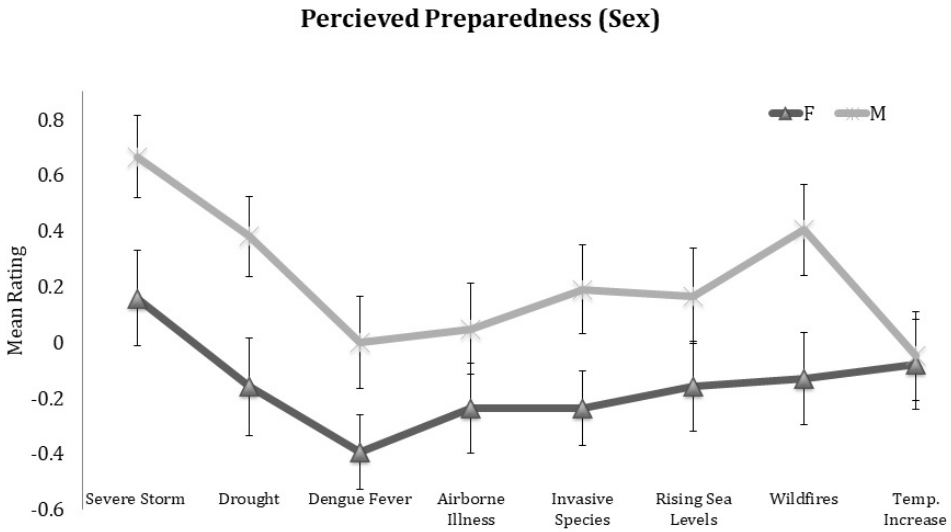

Figure 4. A comparison of mean perceived preparedness (Section IV) ratings by gender and event for the general public.

Temperature Increase at the personal (0.7 mean difference) and general level (0.7 mean difference). Hawaiians also reported higher risk perceptions for the majority of events as opposed to Non-Hawaiians (except *Severe Storms* and *Dengue Fever* at the general level and *Rise in Invasive Species* at the personal level). Non-Migrants or 'local' subjects also reported higher perceived risk than Migrants or 'non-local' subjects for nearly all events (except for *Severe Storms* and *Rise in Invasive Species* at the personal level).

Regarding the perceived change in frequency of events, Native Hawaiians and Pacific Islander subjects were more likely to perceive all events (save drought) as growing more frequent with time than those of different heritage. They also tended to believe that airborne illnesses and rising sea levels were the most likely to increase in frequency, while non-Hawaiian and Pacific Islanders indicated that temperature increase would be the most likely to increase. Finally, Hawaiians felt less prepared for six out of the eight climate change events than non-Hawaiians.

Religion

There were sizable differences between religious categories; 84% of non-religious subjects believed that something could be done about the effects of climate change, compared to only 64% of Religious subjects. Furthermore, only 55% of Christians believed that something could be done about the effects of climate change compared to the 100% of subjects identifying with Eastern and Alternative religions.

Relationship Between Perceived Risk and Perceived Frequency

Significant correlations were found between the perceived risk and the perceived frequency of the events. There were significant correlations between events, time scales, and risk targets, as well as significant correlations between total risk perception scores and perceived frequency scores for all participants.

DISCUSSION

The goal of the present study was to investigate risk perception of climate change, to explore relationships between knowledge and risk perceptions, and to analyze links between risk perception and perceived preparedness for climate change events on the Big Island of Hawaii. We believe that there are a number of important results, most noticeably concerning the association between questionnaire responses and subjects' sex, heritage, religion, and their perceptions of health, and their knowledge.

Gender

Climate change is widely believed to disproportionately affect females. In our study, for every event tested, at both the personal and general level, females perceived risk to be significantly higher and felt less prepared than men. This is consistent with past research on gender differences in general risk perception (Sjöberg 2003) and suggests gendered links between risk perception and perceived preparedness, with higher risk perception equating to lower perceived preparedness and vice versa. It would be easy to assume that this is due to higher confidence among males than females. However, females reported significantly higher knowledge confidence scores for the consequences of climate change[3]. This may indicate that higher confidence in knowledge of climate change consequences could be associated with greater knowledge and more realistic risk perceptions and perceived adaptive capacity. There has been a lack of studies focusing specifically on perceived risks for climate change and how those vary by gender. This is worrisome, considering males are often the primary decision makers within households and social and political institutions. If male's assessments of risk are unrealistic and the knowledge by which they make decisions sub-standard, at a minimum as compared to women, this may result in a magnified lack of participation in mitiga-

tion and adaptation efforts for society as a whole.

Heritage

Native Hawaiians and Pacific Islander subjects perceived risk at both the personal and general level to be higher were more likely to perceive frequency of events as increasing, and felt less prepared. Native communities in general rely more heavily on natural resources for subsistence, have already experienced the stresses of past relocations, and have fewer financial resources for disruptions to daily life (NAST 2000), perhaps explaining these feelings of under-preparedness among the indigenous population. There has been little research on the relationship between indigeneity and risk perceptions for climate change. We postulate that population groups with a longer history in a place will have more accurate perceptions of environmental risk than those new to the environment. It is also possible that native groups have (accurately or not) less certainty of their adaptive capacity than other groups. This is of concern since there is evidence that adaptation in practice may be constrained by both perceived and actual adaptive capacity (e.g. Grothmann and Patt, 2005).

Religion

Past research has demonstrated that religion is associated with perceptions of climate change and decision-making with regard to mitigation and adaptation in the Pacific Region (Mortreux and Barnett, 2009). Our results are support that: religious subjects had lower perceptions of future risk events than non-religious subjects and were markedly more skeptical about mitigation and adaptation possibilities. Religious subject's lower levels of confidence in their knowledge of climate change consequences, despite their relatively equal results on the knowledge test, may indicate less confidence in scientific information. However, simply conflating religious affiliations to beliefs in climate change may be too simplistic as there is a diversity of views on the topic of climate change among Christians (Wardekker et al., 2009). Regardless, the findings here represent interesting connotations beyond acceptance and rejection of the notion of climate change itself, connecting perceptions of risk and confidence in knowledge, two areas that may impact decision making processes when it comes to adapting to, and mitigating the effects of, climate change. We should also point out that, as with males, Christians are over-represented as decision-makers in social and political institutions in the U.S (Paxton and Hughes 2015; Pew Research Center, 2017).

Perceptions of Health

Subjects viewed health concerns as the lowest risk event *and* the one that they felt they felt the least prepared for. With Dengue Fever perceived as the lowest risk at both the personal and general levels, and health related events perceived as the least probable in the next 20 years, it is clear that human health may be an aspect of climate change that is misunderstood by the general public. When asked whether climate change posed a risk, only 8% of those respondents who said "yes" mentioned human health. When testing knowledge of consequences of climate change, health was among the lowest in percent correct, with 76% indicating that climate change would increase the risk of mosquito-borne diseases. This is consistent with research that indicates the level of knowledge for health consequences is lowest for climate change consequences, even though knowledge of health consequences for climate change had the strongest impact on risk judgment (Sundblad et al. 2007; Sundblad et al., 2009).

While testing perceptions and understanding of a specific disease might seem too directed, results from recent studies suggest that there is real concern over the spread of dengue fever across the state based on current climate change models. Kolivras (2010) found that when less than 50% of

average precipitation is received, particularly with periods of climate variability, habitats for dengue carrying mosquitos (*Aealbopictus albopictus*) will reach roughly one third of Hawaii's land area and about 300,000 people. Under some projected climate change scenarios, over three fourths of Hawaii's land area (1.1 million people) will be within the *Aealbopictus'* habitat (Kolivras, 2010). A recent outbreak that began in September 2015 highlights the risk Hawaii faces with respect to mosquito-borne diseases like dengue fever. As of April 2016, State of Hawaii officials confirmed 264 cases of dengue fever on the Big Island. These outbreaks demonstrate the importance of adaptation and mitigation plans that take into consideration the likely spread of mosquito-borne diseases in the future, as well as efforts to increase public awareness of the links between climate change and such events.

Knowledge

Respondents who believed climate change poses risks to the Big Island scored significantly better on the knowledge test than those who did not. Interestingly, when events were not explicitly described as being related to climate change (Sections II, III, and IV), this association was not present. 59% of subjects believed that if we were to stop burning fossil fuel today, the amount of carbon dioxide in the atmosphere would decrease almost immediately, and another 27% believed that it would cause global warming would stop almost immediately. This indicates a lack of understanding of the climate system, perhaps due to miscommunication or mistrust between the scientific community and the general public. This is also demonstrated by the 61% of respondents who felt that scientists' computer models are too unreliable to predict future climate.

Review of the open-ended portions of the questionnaire indicated some common misconceptions regarding climate change. These largely revolved around volcanic eruptions and earthquakes, which is not surprising given the frequency of these events on the Big Island. Ten percent of respondents who said that climate change was happening on the Big Island mentioned "vog" (sulfur dioxide that occurs when lava hits the sea) as one way in which it is occurring while five percent of the respondents who said climate change posed a risk listed vog as one such element. While sulfur dioxide does contribute to asthma in the local population, it has not been widely cited as a major greenhouse gas nor can it be accurately presented as an effect of climate change. Additionally, 38% of subjects believed that climate change is caused primarily by natural variations in sunbeams and volcanic eruptions, which is not accurate.

When asked how climate change posed a risk to themselves or their community, 23% of respondents mentioned agriculture and 15% mentioned rainfall. This is not surprising given the severe agricultural difficulties presented on the Big Island by the many recent droughts over the last decade. When asked how climate change is impacting the Big Island (question 10), 23% mentioned temperature changes and 14% mentioned drought[4]. This is consistent with other responses as temperature increase and drought were the two highest perceived risks at both the personal and general level. Interestingly, invasive species, the third highest ranked event in risk perceptions, was the most common item in terms of mitigation focus and methods mentioned by respondents who said that there was something you could do about climate change (18% of those who said "yes"). Given the threat of invasive species in Hawaii and the often daily battle with many such species, this finding indicates an area of concern and knowledge among the general public.

CONCLUSIONS

The results of our study supports research question three: subjects' knowledge of climate change relates to their judgement of associated risks. This has been an issue for

risk perception studies in the past, since researchers often use an undifferentiated concept of perceived risk that fails to provide a clear distinction of the risk target subjects are expected to judge (Sjoberg, 2003). This study has attempted to resolve that by differentiating between risk targets, and has found there to be significant differences among those targets. Because climate change will bring about various and varied challenges, decisions must be made with "an understanding of the complex interconnections among the physical and biological components of the Earth system as well as the consequences of such decisions on social, economic, and cultural systems." (USGCRP, 2009). This will enable individuals to make better decisions regarding the climate system, while also providing them the knowledge to process new information about climate change.

This study adds to the chorus proclaiming that current levels of climate change knowledge are lacking. Unfortunately, the prospects of achieving a high level of climate literacy in the U.S. seem dim. The issue has become politicized, distorted, and as indicated by recent studies, is being met with dramatic increases in skepticism (Storksdieck, 2010). Science education will need to play a critical role moving forward. Since knowledge confidence has proven to be linked to risk perceptions, finding ways of increasing confidence and/or trust in publicized data could be a positive way forward. Climate change is often ignored at the pre-university level which may be an area of intervention. In addition, studies have shown that personal experience is more likely to capture a person's attention than knowledge (Erev and Barron, 2005; Weber, 2010). Therefore, personal stories and histories of those who have experienced adverse climate events may be an effective tool to increase understanding and acceptance.

In the current study, subjects whose heritage was Hawaiian or Pacific Islander were more aware of the risks posed by climate change, and felt less prepared. Therefore, it is important that the mitigation and adaptation efforts engage ethnicity as an important factor in adaptation management. Many island regions have overlooked the importance of social and psychological factors that could affect the ability and willingness of citizens to participate. The need for inclusion is particularly important for these groups, as there may be valuable traditional knowledge that can aid in the adaptation and mitigation planning process (IPCC 2007). Without sound adaptation policies and initiatives in place, the impacts of climate change are likely to be significant and pervasive and will fall disproportionately on the poor and indigenous.

NOTES

1. This survey was only administered to residents. Interviewers initially orally confirmed that survey participants were residents and were prepared to confirm this given participant's response to Section 1, question 3. However, no non-residents initiated participation in the survey, possibly due to our recruiting at 'local' grocery stores and the DMV, and the Big Island's relatively lower tourist population.

2. This project was reviewed by the Human Subjects Committee at UC Santa Barbara. The IRB letter is on file with *The Geographical Bulletin*.

3. We sought to explore both their confidence in their knowledge and their knowledge of our test questions. We believe that understanding this confidence is valuable, regardless of its association with how "correct" this knowledge is.

4. One reviewer suggested addressing the "why". While we agree the *why* would be interesting, because of the persistently low perception of climate change as a danger in the general public, we also believe that the "why" is beyond what can be supported from the data gathered in this study, and therefore lies beyond the scope of the current article.

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Appendix A: Questionnaire

Hawaii Island Public Survey

Date: _____

Age: _____ **Sex:** (M) (F)

Occupation: _____

Ethnicity (Circle all that apply): (A) Hawaiian (B) Filipino (C) Portuguese (D) Caucasian (E) Japanese (F) Hispanic (G) Other: ___

Marital Status: [Single] [Married] [Divorced] [Widowed] **If Married what is your Spouse's Occupation:** _____

Housing Tenure: [Homeowner] [Renter] [Co-Resident] [Other: ____]

Location of Home (Circle for each set): Set I > [Near ocean] [Near river/stream] [Near cliff] **Set II >** [Higher elevation] [Sea level]

Section I: Please respond to all the following questions as honestly as possible.

1. What is your highest level of education?
A. High School
B. A.S. /A.A.
C. B.S. /B.A.
D. M.S. /M.A.
E. Ph.D. /M.D.
F. None of the above

2. How many years have you lived in your current community?
A. 0-5
B. 6-10
C. 11-20
D. 20-40
E. Entire Life

3. How many years have you lived on the Big Island?
A. 0-5
B. 6-10
C. 11-20
D. 20-40
E. Entire Life

4. How many years have you lived in Hawaii?
A. 0-5
B. 6-10
C. 11-20
D. 20-40
E. Entire Life

5. What is your annual household income?

[Under $25,000] [$25,000 - $49,999] [$50,000 - $74,999] [Greater than $75,000]

6. Are you a migrant to the Big Island? YES NO

If YES, what year did you migrate to the island? _____ Where did you migrate from? _____

7. Do you have any children? YES NO

If YES, how many? _____ What age(s)? _____

8. Do you associate yourself with a particular religious denomination? YES NO

If YES, which denomination? _____

9. Do you believe that climate change is at all happening on the Big Island today OR that it will happen in the future? YES NO

If YES, How? _____

If NO, Why not? _____

10. Do you believe that climate change poses a risk to you or your community? YES NO

If YES, How so? _____

If NO, Why not? _____ ***Skip to Question 15***

11. Do you think that health is an issue when it comes to climate change in Hawaii? YES NO

12. Do you think that climate change will have an impact on agriculture in Hawaii? YES NO

13. Do you think that climate change will have an impact on marine life/the oceans in Hawaii? YES NO

If YES, How? _____

14. Do you think that natural disasters is an issue when it comes to climate change in Hawaii? YES NO

15. Do you think you CAN do anything about global warming, invasive species, and/or sea level rise? YES NO

If YES, What COULD you do? _____

If NO, Why not? _____

Do you think you SHOULD do anything about these threats? YES NO

Section II: Using the scale below, please indicate whether you think the following events will become more or less frequent on the Big Island within the next 5 years, AND between 20 and 25 years from now.

A	B	C	D	E
Much Less Frequent	**Less Frequent**	**No Change**	**More Frequent**	**Much More Frequent**

	Within the next 5 years	20-25 years from now		Within the next 5 years	20-25 years from now
1. Severe Storm Event	____	____	**5.** Rising Sea Levels	____	____
2. Dengue Fever	____	____	**6.** Drought	____	____
3. A Rise in Invasive Species	____	____	**7.** Airborne Illnesses	____	____
4. Wildfires	____	____	**8.** Temperature Increases	____	____

Section III: Using the scale below, please rate the level of risk that each item poses to you personally, then rate the level of risk that each item poses to the people of the Big Island.

0	1	2	3	4
No Risk at All	**Low Risk**	**Moderate Risk**	**Large Risk**	**Very Large Risk**

	Risk to you personally	Risk to the ppl. of the Big Isle.		Risk to you personally	Risk to the ppl. of the Big Isle.
1. Severe Storm Event	____	____	**5.** Rising Sea Level	____	____
2. Dengue Fever	____	____	**6.** Drought	____	____
3. A Rise in Invasive Species	____	____	**7.** Airborne Illness	____	____
4. Wildfires	____	____	**8.** Temperature Increase	____	____

Section IV: Using the scale below, please rate how prepared you are for the following items.

A	B	C	D	E
Extremely Prepared	**Prepared**	**Unsure**	**Unprepared**	**Extremely Unprepared**

____ **1.** Severe Storm Event

____ **2.** Dengue Fever

____ **3.** A Rise in Invasive Species

____ **4.** Wildfires

____ **5.** Rising Sea Level

____ **6.** Drought

____ **7.** Airborne Illness

____ **8.** Temperature Increase

Section V: Using the scale below, please rate the following question. How important do you think it is for the federal and/or the state government to alleviate the following risks?

******If you feel the government is not responsible for alleviating a specific risk, please mark the adjacent box.*

0	1	2	3	4
No Importance at All	**Low Importance**	**Moderate Importance**	**Large Importance**	**Very Large Importance**

	Government not responsible		Government not responsible
____ **1.** Severe Storm Event	☐	____ **5.** Rising Sea Level	☐
____ **2.** Dengue Fever	☐	____ **6.** Drought	☐
____ **3.** A Rise in Invasive Species	☐	____ **7.** Airborne Illness	☐
____ **4.** Wildfires	☐	____ 8. Temperature Increase	☐

Section VI: For each of the following items, please mark either TRUE or FALSE. In addition, please check ONE of the corresponding boxes to indicate how confident you are in your answer.

	TRUE	FALSE	Very uncertain	Fairly uncertain	Fairly certain	Very certain
1. Climate is the average weather conditions of a region	○	○	☐	☐	☐	☐
2. The global average air temperature has remained relatively stable over the last 100 years	○	○	☐	☐	☐	☐
3. Climate change is caused primarily by natural variations in sunbeams and volcanic eruptions	○	○	☐	☐	☐	☐
4. The concentration of carbon dioxide in the atmosphere has increased more than 30% over the last 250 years	○	○	☐	☐	☐	☐
5. Carbon dioxide is emitted by burning fossil fuels	○	○	☐	☐	☐	☐
6. The increased amount of greenhouse gases in the atmosphere is mainly caused by human activities	○	○	☐	☐	☐	☐
7. Scientists estimate that global sea levels have remained stable over the last 100 years	○	○	☐	☐	☐	☐
8. The United States is the country that emits the most carbon dioxide per person	○	○	☐	☐	☐	☐
9. Cooler ocean temperatures cause coral bleaching	○	○	☐	☐	☐	☐
10. Scientists estimate that if no additional actions are taken to reduce global warming, sea levels will rise more than 2 feet by the year 2100?	○	○	☐	☐	☐	☐
11. Climate change will increase the risk in Hawaii for diseases transferred by mosquitos (i.e. dengue fever)	○	○	☐	☐	☐	☐
12. The Earth's climate has been pretty much the same for millions of years	○	○	☐	☐	☐	☐
13. The decade from 2000 to 2009 was warmer than any other decade since 1850	○	○	☐	☐	☐	☐
14. If we were to stop burning fossil fuels today, the amount of carbon dioxide in the atmosphere would decrease almost immediately	○	○	☐	☐	☐	☐
15. Global warming will cause some places to get wetter, while others get drier.	○	○	☐	☐	☐	☐
16. Scientists' computer models are too unreliable to predict the climate of the future	○	○	☐	☐	☐	☐
17. If we were to stop burning fossil fuels today, global warming would stop almost immediately	○	○	☐	☐	☐	☐

THANK YOU