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Perceptions of severe storms, climate change, ecological structures and resiliency three years post-hurricane *Sandy* in New Jersey

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Abstract

Global warming is leading to increased frequency and severity of storms that are associated with flooding, increasing the risk to urban, coastal populations. This study examined perceptions of the relationship between severe storms, sea level rise, climate change and ecological barriers by a vulnerable environmental justice population in New Jersey. Patients using New Jersey's Federally Qualified Health Centers were interviewed after Hurricane [Superstorm] *Sandy* because it is essential to understand the perceptions of uninsured, underinsured, and economically challenged people to better develop a resiliency strategy for the most vulnerable people. Patients ($N = 355$) using 6 centers were interviewed using a structured interview form. Patients were interviewed in the order they entered the reception area, in either English or Spanish. Respondents were asked to rate their agreement with environmental statements. Respondents 1) agreed with experts that "severe storms were due to climate change", "storms will come more often", and that "flooding was due to sea level rise", 2) did not agree as strongly that "climate change was due to human activity", 3) were neutral for statements that "*Sandy* damages were due to loss of dunes or salt marshes". 4) did not differ as a function of ethnic/racial categories, and 5) showed few gender differences. It is imperative that the public understand that climate change and sea level rise are occurring so that they support community programs (and funding) to prepare for increased frequency of storms and coastal flooding. The lack of high ratings for the role of dunes and marshes in preventing flooding indicates a lack of understanding that ecological structures protect coasts, and suggests a lack of support for management actions to restore dunes as part of a coastal preparedness strategy. Perceptions that do not support a public policy of coastal zone management to protect coastlines can lead to increased flooding, extensive property damages, and injuries or loss of life.

Keywords

Climate change; Concerns; Environmental justice; Evacuation; Dunes; Salt marshes; *Sandy*; Hurricanes

Introduction

Over half of the US population lives along coasts, and this proportion is expected to grow (NOAA 2012; Crosset et al. 2013). For example, coastal development has continued at a rapid rate from Washington to Boston, and people have continued to move to the Atlantic coast. The Washington-Boston corridor is highly urbanized, with high-rise buildings, residential communities, bulkheads, piers, jetties, marinas, boardwalks and other types of shoreline structures. Many people live in old residential housing at low-elevations, vulnerable to flooding. With global warming and sea level rise, storms and hurricanes are predicted to increase in frequency and intensity (Lane et al. 2013, NPCC2 2013), increasing the risk to human communities. Damages from storms can be high because of increases in vulnerability and exposure to coastal flooding (USGS 2010). Storms threaten the health and safety of local residents, destroy property and infrastructure, stress emergency services and food supply lines, and pollute water supplies (Genovesa and Przyluski 2013). Weather-related disasters result in several days to weeks of electricity outages, displacement of people, breakdown of information sources, and lack of resources to survive (food, water, shelter, medicines, transportation, Burger and Gochfeld 2014a, 2015). Severe disasters result in emotional distress, posttraumatic stress, and other serious health effects (McLaughlin et al. 2010; Shear et al. 2011; Lurie et al. 2015; Ryan et al. 2015).

In late October 2012, Hurricane [Superstorm] *Sandy* hit the Northeastern United States, affecting an estimated 60 million people living in 24 states (Neria and Shultz 2012). It caused severe damage in New Jersey and New York because of an unprecedented storm surge, and because the storm stalled over the region (USGS 2013). The storm caused over 150 deaths, destroyed over 345,000 housing units, and resulted in \$3 billion in damages to NJ transit roads and bridges. Many people who refused orders to evacuate before the storm, faced emergency evacuation because of storm surges, flooding, and loss of power (BBB 2012; Freedman 2013; Hsu 2013; Burger and Gochfeld 2015). Some people are still displaced, and others left their homes permanently. Serious health conditions, emotional distress, and grief follow such disasters, as they did *Sandy* (Brackbill et al. 2014; Burger and Gochfeld 2014a; Swerdel et al. 2016).

This storm highlighted the need for preparedness and resiliency, both for individuals and institutions (Greenberg et al. 2013). *Sandy* also was transformational in that some places along the Atlantic coast, including New York City, began explicitly to include climate change risks in their rebuilding efforts (Rosenzweig and Solecki 2014; O'Neill and Van Abs 2016). This storm also highlighted the need to understand how people perceived climate change, sea level rise, and storm frequency and severity, as well as the relationship among these factors. Coastal resiliency partly depends upon intact, functioning dunes and marshes, and their maintenance depends upon public policies that commit funds to this purpose (Nordstrom and Lotstein 1989; Psuty and O'Fiara 2002).

In a study within the first 100 days of Hurricane *Sandy*, over 700 people residing in coastal and inland New Jersey were interviewed about their perceptions and concerns (Burger and Gochfeld 2014a, 2015). Findings were that 1) stress level was a better predictor of ratings of ecological structures and services than geographical location, 2) Whites rated ecological

services higher than others, and 3) only 20% of respondents listed ecological services as one of their three most important concerns about *Sandy*. The study did not specifically explore whether people understood the relationship between ecological structures (dunes, salt marshes) and damage, climate change, sea level rise, and personal impact from the storm.

In the present study we interviewed patients at Federally Qualified Health Centers (FQHCs) to determine: 1) their access to health care and medicines during and after Hurricane *Sandy*, 2) their personal impacts from *Sandy*, 3) their perceptions of the relationship between impacts and global warming, sea level rise, dunes and salt marshes, and storm damage, and 4) whether they knew about fracking (as a measure of environmental awareness). This paper addresses the latter two issues. We were particularly interested in ethnicity/race, age, gender, education and personal storm experience and impact differences that may help scientists, managers, and public policy makers address the information gaps and needs of groups that are more vulnerable than others to increased storm frequency and intensity, and sea level rise. We wanted to determine if, after a period of time, respondents had made the connection between ecological structures (e.g. dunes, salt marshes), and global warming, sea level rise, severe storms, and personal impacts and damages. Despite disinformation campaigns and political viewpoints, the occurrence of global warming is not in dispute, nor is the role of humans in causing global warming (IPCC 2007, 2014). Yet some people still believe there is no connection or that predicted impacts are exaggerated, and this correlates with political view (Newport and Dugan 2015). Such beliefs, divorced from science, can influence public policy on a local and national scale.

Interviewing in FQHCs ensured access to a socially vulnerable environmental justice (EJ) population, the uninsured and under insured. Addressing the needs of vulnerable populations, whether from physical or mental illness, special needs (e.g. elderly), low income, or environmental justice, is a high public health and societal goal. It is often the vulnerable populations that do not have access to cars or other methods to evacuate, do not have resources to prepare properly before a disaster, and are of particular concern to health agencies. Even removing the obstacles of shelter and transportation will likely be insufficient for improving the disaster plans of the impoverished (Eisenman et al. 2007). Following *Sandy*, several federal agencies funded projects particularly aimed at vulnerable communities (often low-lying), but also low income, minority, elderly, and otherwise disadvantaged. The results reported in this study were part of a larger NJ Department of Health project aimed at understanding the public health consequences of environmental disasters, in conjunction with the New Jersey Medical School, NJ department of Human Services, and Rutgers University, funded by the Center for Disease Control. Our component involved interviews of vulnerable populations (reported in this paper). The project and protocol were approved by the New Jersey Primary Care Association and Rutgers Institutional Review Board (Protocol EI 4–319, Notice of Exemption).

Background

Two aspects are critical to developing a resiliency strategy: 1) understanding the relationship between intact coastal ecosystems (dunes, beaches, marshes), and 2) perceptions of climate change, sea level rise, and the effects of humans on these. Communication, early warning,

and emergency preparedness can partly protect human shoreline communities, but long-term resiliency of coastal communities to severe storms and hurricanes depends on both engineered barriers to flooding (jetties, bulk-heads, seawalls) and ecological barriers (dunes, salt marshes) (Psuty and O'Fiara 2002; Plant et al. 2010). In some places in the Northeast, salt marshes and dunes are eroding away (Hartig et al. 2002). Coastal dunes, sand beaches, and salt marshes are valued for their aesthetics, as well as for their ability to protect human and ecological communities (Nordstrom and Mitteager 2001; Pries et al. 2008). However, many coastal residents fight the construction of dunes that block their view of the sea and access to the beach. The effect of storm surges and flooding on dune ecosystems, and therefore on human communities behind the dunes, depends upon surge elevation relative to dune height (Houser et al. 2008). Salt marshes provide a partial barrier to islands and coastal communities, and they control the responses to sea level rise by sedimentary deposition dynamics (Nyman et al. 1995; Feagin et al. 2009).

While ecologists may appreciate the role of salt marshes, beaches and sand dunes in protecting ecological and human communities, the public rarely does (Nordstrom and Lotstein 1989; Koutrakis et al. 2011; Burger 2015). Only 34% of people interviewed in a recent Gallup poll said they “worried a great deal about global warming or climate change” (Gallup 2015). The connection between barrier islands, dunes, and personal and community safety during storms is often unclear to urban and suburban dwellers. Based on 28 years of New Jersey shoreline assessments, Barone et al. (2014) showed that the extent of erosion of beaches and dunes, and damage to structures and infrastructures, were dependent upon the elevation of the storm waters, volume, extent of the berm elevation, and width of the dunes. Further, during *Sandy*, communities that suffered the greatest damages were those where dunes were non-existent, or where elevations of the beaches and dunes were low or narrow (Barone et al. 2014; Burger 2015). Understanding whether people made the connection between stable, high dunes and salt marshes, and damage from severe storms is important because people make personal decisions filtered through perceptions, values, culture, and their ability to act or influence other decisions (Casagrande 1996; Gallup 2015), and their values in turn impact public policy. Following *Sandy*, most studies focused on damages and injuries, infrastructure and power outages, health effects (Freedman 2013; Brackbill et al. 2014; Abramson et al. 2015; Burger and Gochfeld 2014a, 2015), and geophysical processes (Hsu 2013; Forbes et al. 2014; Gruebner et al. 2016), and much less on ecological protection of human communities (Barone et al. 2014; Burger 2015). Yet, ecological structures (e.g. dunes, marshes) are critical for protection of both human and ecological communities.

In some studies, knowledge, concerns, and perceptions are examined as a function of physical proximity to a stressor (Kunreuther et al. 1990; Greenberg et al. 2007), such as a wind facility, airport, or nuclear power plant (Burger et al. 2004; Burger 2005, 2011; Kirschenbaum et al. 2012). Perceptions and concerns are also examined with respect to a distressing event, such as a devastating hurricane (Shear et al. 2011; Trumbo et al. 2011), chemical explosion, or an oil spill (Safina 2011). Temporal proximity may also influence perceptions, beliefs, and even knowledge. In most cases, understanding perceptions is aimed at reducing concerns, developing an educational or outreach program to address concerns, and developing strategies to cope with future events to prevent or reduce exposures and

damages. The latter falls under the category of increasing resiliency of communities, and enhancing future recovery from stressful events, such as a hurricane.

Perceptions of climate change and sea level rise, and the relative effect of human activities on these two factors, are critical to developing a resiliency strategy. If people do not believe that climate change and sea level rise are occurring, they are less likely to encourage public officials to fund activities to reduce their effects, and if they do not believe that human activities play a role in increasing climate change or sea level rise, they are less likely to fund environmental programs to halt these changes. In a very practical sense, a public that understands sea level rise is aware that damages may increase to homes located in low lying areas. Homes may need to be elevated; homes that are elevated may need to be raised even higher, and homes located in some places may need to be abandoned (planned retreat, Alexander et al. 2012). That global warming is occurring is not in dispute, nor is the role of humans in causing global warming (IPCC 2007, 2014). The threats posed by climate change persist despite discussions about the drivers. Some people, however, still believe there is no connection between global warming and human activities (Hansen et al. 2012; Newport and Dugan 2015), and their beliefs can influence public policy, and thereby effect the funding of coastal zone management (restoration and enhancing ecological structures). Climate change risks need to be considered in rebuilding efforts and in developing resiliency strategies (Rosenzweig and Solecki 2014). Further, protecting environmental justice communities from the detrimental impacts of climate change is a national priority (Martinez and Sheats 2015).

Methods

Our overall protocol was to interview respondents at 7 clinic sites run by 6 Federally Qualified Health Centers in New Jersey from Lakewood in the south to Jersey City in the north, three years after Hurricane *Sandy*. This area of New Jersey was very hard hit by the storm, with whole communities devastated, requiring wide-scale evacuations and either rebuilding or abandoning houses and whole blocks. The Centers selected were: 1). Eric B. Chandler Health Center in New Brunswick, Middlesex County, 2). CHEMED in Lakewood, Ocean County, 3). Horizon Health Center in Jersey City, Hudson County, 4). Monmouth Family Health Center in Long Branch, Monmouth County, 5). Neighborhood Health Center in Plainfield 6) Neighborhood Health Centers in Elizabeth (5 and 6 in Union County), and 7). Ocean Health Initiatives in Toms River, Ocean County (Fig. 1). These sites were select to represent different levels of storm impact, from coastal communities where most houses were flooded or destroyed, to more inland communities that experienced power outages, downed trees, and some riverine flooding. All the areas experienced power outages, some as long as two weeks.

Interviews were conducted by well-trained and experienced interviewers, half of whom spoke fluent Spanish. For Hispanic/Latinos, 83% of the interviews were conducted in Spanish. The interview questions were developed based on prior studies (Burger and Gochfeld 2014a, 2014b, 2015), were tested prior to implementation, and modifications were made to the format as a result of the pilot study. The questionnaire was translated into Spanish, and contained the following sections: 1) demographics, 2) concerns during *Sandy*, 3) normal center use and transportation to the center, 4) overall *Sandy* impact on the

respondent, 5) existing medical conditions, health care and access to care, 6) ecological statements (only asked on half the sample), and 7) whether they knew what fracking was. The focus of the present paper is on the responses to the ecological statements dealing with the relationships between global climate change, sea level rise, dunes and salt marshes, and personal impact from *Sandy*. This study represents a quantitative analysis of qualitative interviews based on the same questionnaire administered to all subjects. Interviews were conducted from 7 January 2015 to 7 July 2015, and represent a sample of patients attending the Federally Qualified Health Centers. Out of 599 interviews 355 were asked the ecological questions.

Patients arriving at the Health Centers were interviewed while waiting for their appointments. Interviewers approached respondents in the order they came into the waiting area, identified themselves from Rutgers University, and asked for permission to interview them about access to the center, effects from *Sandy*, and their rating of ecological statements. Prospective respondents were informed that it was voluntary, that no individual identifiers would be recorded, that they could terminate at any time, and that information would be available on our web site or they could contact us or the Rutgers University Institutional Review Board. Interviewers conducted the interview in a secluded place. Over 85% of patients (= respondents) approached were interviewed; refusals (2%) were usually due to lack of time or attention to children or elderly charges, and interruptions (7%) were due to being called for their appointments. When an interview was interrupted after the demographic section was completed, it was included in the sample if the appropriate questions were answered.

The interview normally required about 20 min, although some lasted longer because people wanted to talk about their storm experiences or frustration with lack of government response to their plight (inability to rebuild, new government flood standards, delayed action on monetary claims, mold in their house, harrowing experiences). Respondents were asked to rate the six ecological statements on a Likert scale (1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, and 5 = strongly agree). Each statement began with “Some experts say that” (“more frequent and stronger storms are due to climate change”, “storms like *Sandy* will come more often”, “flooding from *Sandy* was mainly due to rising sea level or sea level rise, changing climate is due to human activity and is not natural”, “damage from *Sandy* along the Jersey shore was due to loss of sand dunes”, and “damage from *Sandy* along the Jersey shore was due to loss of natural salt marshes”). They were also asked whether they had heard of fracking.

Analysis involved determining whether there were differences in the level of agreement with the ecological statements as a function of demographics (self-identified ethnicity/race, US-bom, gender, age, education), effects from *Sandy* (evacuation, days without power, days to return to normal), center location, self-identified impact (on a scale of no impact [0] to major impact [5]), and community impact. Few of the State’s FQHC facilities were in “low impact” communities as determined by Halpin (2013). Ethnicity/racial status conformed to the U.S. Census Bureau categories, and respondents were asked to self-identify as either “Caucasian” (White alone = White non-Hispanic), “African American (Black alone” = Black, non-Hispanic), or “Hispanic” (Hispanic or Latino). In this paper they are referred to

as “Whites”, “Blacks”, and “Hispanics”. Analyses included calculating frequencies and percentages, means and standard errors, Kendall tau correlation, Kruskal-Wallis One Way Analysis of Variance (ANOVA) analysis, and 95% confidence intervals to distinguish differences among categories (e.g. male/female, racial groups) (SAS 2005). We then developed the best multivariate models (SAS 2005; PROC GLM) to explain variations in respondents’ evaluations as a function of the different variables (e.g. demographics, center location, birthplace, personal impact rating).

Results

Demographics

Of the 355 respondents, 54% were Hispanic, 22% were Black, and 24% were White. There were an additional 6 people who were Asian or other ethnic groups, and they were excluded from the analysis. The respondent population was 65% female, and the mean age was 41 ± 0.6 years. Mean education was 12.3 years; 76% were high school graduates compared with 88% in New Jersey overall (US Census Bureau 2011). Only 43% were born in the U.S., about 16% were from the Caribbean, 16% were from South American, 11% were from Mexico, and 10% were from Europe (those who were not U.S. born were in the U.S. for an average of 16.5 ± 0.7 years). Where respondents lived also varied significantly; more Hispanic/Latinos lived in apartments (60%), compared to Blacks (48%) or Whites (41%; $X^2 = 14.8$, $P < 0.0006$).

Overall ecological ratings

Levels of agreement with expert opinion for the ecological statements varied significantly (Fig. 2). The highest agreement was for “storms are due to climate change”, followed by “storms will occur more often”, and “flooding was due to sea level rise”. *Sandy* damage attributed to loss of sand dunes or salt marshes were rated much lower than the other ecological statements.

Factors accounting for variation in ratings

Models were used to identify the independent variables (sex, age, education, birthplace, days of power outage, how soon life returned to normal, *Sandy* self-impact rating, center location, visits/year) that contributed to explaining variation in the ecological ratings given by respondents. The best models explained only 24 to 30% of the variation in the ratings of the ecological statements by the independent variables, although there were no significant models for “storms will come more often”, and “damage were due to loss of dunes or salt marshes” (Table 1). The model for “more frequent and stronger storms are due to climate change” explained 30% of the variability by center location, birthplace (US or other places), and knowing about fracking. “How soon life returned to normal” and sex approached significance ($P < 0.08$). The variation in “changing climate is due to human activity and is not natural” was due mainly to sex, followed by “have you heard of fracking” and *Sandy* impact rating (Table 1).

In general, the ratings for the ecological statements were not highly correlated with the independent variables (Table 2). The highest correlation was between age and “flooding was

due to sea level rise" ($P < 0.0001$), followed by "damage was due to loss of salt marshes" ($P < 0.001$); both ratings increased with age.

Males and females were equally likely to have been evacuated and equally likely to have lost electricity. Males showed significantly stronger agreement with the ecological statements than females for three of the six ecological statements, and significantly lower agreement for one (Fig. 3). When gender differences were examined by ethnicity, Hispanic and Black males rated the ecological statements higher than females (Table 3). In contrast, White females rated the statement that damages from *Sandy* along the shore were due to loss of sand dunes higher than did White males. Education did not enter the models as a significant variable.

Center location entered the model for "more frequent and stronger storms are due to climate change", and for "flooding from *Sandy* was mainly due to sea level rise" (Table 1). The ratings by Center were significantly different for 5 of the 6 ecological statements (Table 4). Ratings from Plainfield were among the highest for "storms being due to climate change", "they will come more often", "flooding is due to sea level rise", and "damages were due to loss of salt marshes." The highest rating for "*Sandy* damage was due to loss of sand dunes" was for respondents from Toms River, which is located near the shore, and where the importance of dunes protecting communities received great publicity. Center visits/year was positively associated with the "sand dunes" and "salt marshes" agreement, and negatively related to "storms are due to climate change" (Table 2).

Birthplace was a significant variable for explaining variation in agreement scores for "more frequent storms are due to climate change", and "damage from *Sandy* along the shore was due to loss of sand dunes". The differences in ratings as a function of birthplace were not great (although this was an important contributor to explaining variation in the models, Table 1). Ratings seemed to relate to geography. Respondents born in the Western Hemisphere rated the statements that "storms were due to climate change", and "changing climate was due mainly to human activity", higher than people from Europe. Respondents born in the U.S. (mainly NJ) and those born in the Caribbean countries rated the importance of dunes higher, and those from South America and Europe rating them lower than did others (Table 5).

Respondents provided a rating of their personal impact from *Sandy*, which varied from a mean of 3 to 4.4 (5 = very impacted). There were significant differences among self-impact categories only for "storms will come more often"; "flooding is due to sea level rise might have been significant with larger sample sizes" (Table 6).

Knowledge of fracking (yes or no) was a significant variable in three of the models (Table 1), was related to gender (more males knew about fracking; 31% vs 13%, $X^2 = 14.4$, $P < 0.0002$), and there were significant differences in the ratings of the ecological statements (Table 7). People who knew about fracking rated all the ecological statements, except for "damage due to loss of salt marshes", higher than did people who did not know about fracking.

Another factor that might affect responses to ecological statements is whether *Sandy* resulted in respondents deciding to prepare in the future, or not. People who plan on doing nothing rated “flooding is due to sea level rise” higher than did those who plan on preparing (mean of 4.2 ± 0.1 vs 3.8 ± 0.1 , $X^2 = 8.3$, $P < 0.004$). Otherwise there were no differences as a function of respondent’s views on preparing for future storms.

Discussion

Perceptions of ecological relationships

We used level of agreement with statements as an indication of perception, and understanding or knowledge of scientific issues for this vulnerable population of interest, analyzed by demographics and experiences with *Sandy*. Coastal zone scientists have achieved a high level of consensus about the relationships between climate change, sea level rise, increased storm potential (frequency, intensity), and the damages that can occur to human and ecological communities along the coast (Roessler and Wells 2001; Stockdon et al. 2007; Forbes et al. 2014). However, there is less knowledge, understanding and agreement among the public, which is strongly influenced by disinformation and political affiliations (Klinenberg 2013; Burger 2015; Gallup 2015). The relationship between information (factual and disinformation) and perceptions is an important research area, and deserves examination, but was outside the scope of the current study.

Sea level rise can lead to erosion of sand dunes and salt marshes (Hartig et al. 2002), which buffer coastlines and communities against devastating storm surges, which in turn cause huge property damage as well as mortality (Bascom 1980; BBB 2012). Hurricane *Sandy* was transformational, forcing cities and suburban communities to integrate a flexible adaptation pathway approach to rebuilding and recovery (Rosenzweig and Solecki 2014; O’Neill and Van Abs 2016; Burger and Niles 2016).

Following *Sandy*, the importance of maintaining intact and functioning ecosystems along coasts became very clear. Communities with high, stable dunes experienced less flooding and storm damage than those without (Houser et al. 2008; Plant et al. 2010). In the present study we aimed to understand people’s perceptions about the relationships among global warming, sea levels rise, ecological barriers along coasts (e.g. dunes, salt marshes), flooding, and with respect to their own personal experience with *Sandy* three years earlier. Respondents had the highest agreement with the statement “some experts say storms are due to climate change” followed by “storms will come more often”, and “flooding is due to sea level rise.” (see Fig. 2). These data indicate that respondents made connections between climate change, storms, and increasing frequency of storms, and that they also made connections between flooding and sea level rise. These findings reflect a national trend. Recent Gallup polls indicated that 63% of interviewees said that the winter of 2015–2016 was warmer than usual, and most attributed this increase in temperature to climate change (Gallup 2016). Thus the public, as well as the study sample, recognize that there is climate change, and that it is affecting weather and storm events.

The mean rating for “climate change being due to human activity” was only slightly lower (mean of 3.85, refer to Fig. 2) than the highest ratings. This rating is similar to a sample of

New Jersey residents interviewed in 2012 and 2014. The mean rating was 3.87 in 2012 before *Sandy*, and 3.89 in 2014, after *Sandy* (Burger et al. 2016). These ratings are remarkably similar, regardless of whether it was a general population or a vulnerable population, 100 days after *Sandy* or 3 years after *Sandy*. This may be a result of both study populations being located along the Jersey shore and inland areas where *Sandy* had a major impact.

The agreement levels for damages from *Sandy* being due to loss of dunes or salt marshes were comparatively low, which was unexpected given that, at the time of *Sandy*, the press frequently mentioned that communities that were buffered by dunes or extensive marshes had significantly less damage than those without such soft barriers. This is cause for concern because it indicates that there is not general public support for preservation and restoration of dunes, or for construction of new dunes that could serve as soft barriers against flooding. When these ratings are compared to the general coastal population interviewed 100 days after *Sandy* (Burger 2015) they are higher and show no ethnic differences (Fig. 4). Thus, it appears that perceptions of the importance of the protective value of dunes and salt marsh may be increasing, especially among more vulnerable populations.

Perceptions of the occurrence, trajectory, and importance of climate change to everyday life have varied over the last couple of decades, based on an evaluation of several perception surveys around the world (Ratter et al. 2012). The greatest barrier to public recognition of human-made climate change may be the natural variability in local weather (Hansen et al. 2012). The average person cannot perceive a long-term trend, given the monthly and yearly variations in local weather. People are more concerned about risks to the physical environment (e.g. drinking water, drought, sea level rise) and economics (beach loss, property damage, insurance increases), than to biological ones (fish population declines, plant population declines, invasive species) (Carlton and Jacobson 2013). Further, in the present survey, some people had a fatalistic viewpoint. The interviewers noted that some people answered “no opinion” because they said “I don’t know, it will be God’s will”, “God will determine if there will be more storms”, and “There have always been storms.” In this case, they were ceding their opinion to a higher source, and removing themselves from responsibility, both for themselves and for their community. This requires further exploration.

Factors affecting ratings of ecological statements

While the significant models only accounted for 24% to 30% of the variation in ratings (see Table 1), this was useful given that the study population was from a narrow economic and geographical strata (those using Federally Qualified Health Centers), and from areas with medium to very high damages from *Sandy* (Halpin 2013). The factors that entered were center location (a surrogate for proximity to the Jersey shore), sex, *Sandy* impact, birthplace, and age. Although ethnicity did not enter the models, there were significant gender differences within ethnic groups. For Blacks and Hispanics, males gave a higher rating for agreement with the statements than did females. There was only one significant difference for Whites (females rated the importance of sand dunes higher than males). Although there were some significant correlations between the independent variables and the ecological

statements, the correlations were low and usually positive (with increasing age came increasing agreement with the statements).

Location (e.g. center location) was one of the primary factors associated with ecological ratings. Most respondents used health centers that were located near their homes. The damage people suffered was clearly a result of where they lived, since shore communities were devastated by flooding that surged through whole communities, in many cases flooding the entire first floor of homes. However, other factors also affected damages following *Sandy*, including the elevation of their home relative to the ocean, whether they were in homes or apartments, and whether their communities were buffered from the sea by extensive salt marshes and sand dunes. Length of time without electricity and wind damage varied as a function of location. In many communities large trees fell down, cluttering roads, bringing down electrical wires, and making cleanup impossible until the dangers from downed electrical wires was past.

Respondents from Plainfield, for example, gave higher ratings for “storms are due to climate change” and to “flooding was due to sea level rise” than others. Their ratings might partly reflect the massive destruction of trees and neighborhoods by wind and lack of electricity, rather than the extensive flooding experienced by respondents living in Toms River. Since the community of Toms River is adjacent to the coast, respondents seemed more aware of the importance of dunes to community protection. In contrast, Chandler Health Center in New Brunswick suffered much less damage because it was not subject to flooding (it is too far from the coast), electricity was out for only a few days, and the center had a generator.

Location (e.g. birthplace) was also an important contributor to variation in ratings of ecological statements. The differences were not just U.S. born vs foreign-born, but the specific birthplace mattered. Respondents who were born in Europe rated all the ecological statements lower than did others, which may relate to overall inexperience with the ecological protection provided by dunes and salt marshes, and a general lack of belief in climate change (and thus in sea level rise). Respondents who were born in Mexico and Central American gave higher ratings to the statement “changing climate is due to human activity” than did others. And finally, respondents born in the U.S. and the Caribbean gave higher ratings to the statement that “damages were due to loss of dune”, which could relate to the higher percentage of coastal zones compared to interior lands. While the differences in these ratings were not great, it indicates the importance of considering cultural differences that derive from immigrant status (57% of the respondents were foreign-born). It appears that respondents born in the U.S. or in other countries bordering the Gulf of Mexico or Caribbean had higher ratings than those from South America or Europe where there are fewer coastal hurricanes. This suggests that experience with storms increases awareness of the effects of global warming and sea level rise. There is increasing interest in considering multiple social ecological approaches to understanding health and environmental inequities (Baron et al. 2014). By this, social scientists are not talking about ecology as ecologists do, but are referring to all the environmental and cultural factors that might affect inequities, such as geography (Gruebner et al. 2016), neighborhoods (Arcaya et al. 2014), social cohesion and social control (Heid et al. 2016), community factors (Lowe et al. 2015), and even housing density (Zoraster 2010), transportation availability (Lane et al. 2013) and

power outages (Lin et al. 2016), among others. Non-nativity is one factor that has been examined within a context of protecting health outcomes. Non-U.S. born Hispanics have better health than those born in the U.S. (Gallo et al. 2009), as well as attenuating the health benefit (the “Hispanic Paradox”, Franzini et al. 2001). Length of residence in the U.S. also influences environmental concerns (Caro and Ewert 1995). The present study indicates it is not just being foreign-born, but where people were born.

Management and policy implications

There is a clear need for an adaptive response to *Sandy* and other devastating disasters, including engagement and changes to policy (Wagner et al. 2014), as well as understanding increasingly diverse publics, and the way people perceive ecological resources and their role in coastal protection (Chase 2016). Research conducted four months after *Sandy* found that there was clear support for risk-reducing policies (half of respondents supported at least four of seven risk-reducing policies, Greenberg et al. 2014). Some people living in areas affected by the hurricane changed their support to politicians with “green” social policies after *Sandy* (Rudman et al. 2013). These studies suggest that the public has concerns, and that the recognition of the relationship between ecological structures and flooding, can be built upon and enhanced to enact public actions and policies to increase coastal resiliency. The present study also indicated strong support for the relationship between climate change, human activities, sea level rise, and damages.

Statements in the press were made immediately following *Sandy* about the role of sand dunes and salt marshes in protecting coastal communities, yet ratings for the importance of dunes and marshes were not as high as other concerns, such as health and possessions (Burger 2015). Ratings for damages being due to loss of salt marshes and dunes, however, were higher in the present study, indicating that time, additional flooding from other storms, and perhaps additional media attention have resulted in an increase in ratings for these two structures (Fig. 4). Soft infrastructure barriers (e.g. dunes, salt marshes) can serve as one component of coastal protection resiliency strategies, as well as hard engineered barriers. Both the present, and earlier study (Burger and Gochfeld 2014a, 2014b, 2015; Burger 2015) suggest that there is already some support for restoring dunes and marshes, and some recognition of the relationship between storm damages (and personal impacts) and the presence of dunes and marshes.

Both winds and tides combined to create surge flooding during both *Irene* and *Sandy*, suggesting that this relationship should be considered in coastal engineering, urban planning, and emergency management (Hsu 2013). The National Weather Service has models that can predict flood height with a 20% relative error (Forbes et al. 2014), suggesting that infrastructures and barriers can be built to withstand future severe hurricanes. Other models have also been developed to predict storm surges (Drews and Galarneau 2015; Wang et al. 2014). Thus, the science is available to provide height thresholds for dunes, and thresholds for the width of salt marshes that are protective. However, enhancing and building ecological barriers to protect coastal communities requires public will to support the initial investment and maintenance. Efforts by managers, public officials and others to continue discussing (and including) marshes and dunes as part of a coastal resiliency strategy will increase the

likelihood that funds and support will be available for beach and marsh restoration. Ecological barriers and storm surge models can be combined to develop resiliency strategies, which prevent (or reduce) flooding; the alternative may be retreating from the shore (Alexander et al. 2012). Each may be applicable to some regions, and both are underway in New Jersey. The importance of ecological barriers and storm surge models need to be incorporated into outreach programs at all education, economic, ethnic and cultural levels within communities, and must be incorporated into recovery and re-building strategies. If the public does not understand and appreciate the relationship between ecological barriers and flood damage, then they will not support continued maintenance of intact, well-vegetated sand dunes. Increased funds for beach-dune-marsh restoration rely on public support for restoration and amplification of healthy coastal ecosystems. In turn, support requires that the public understand the connections among healthy dunes, intact marshes, and decreased flooding.

Conclusions

This study indicated that respondents agreed with the experts that more frequent and stronger storms are due to climate change, storms will come more often, flooding was due to sea level change, and that changing climate is due to human activity and is not natural. There were no differences in ratings as a function of ethnicity and education, but location (center location, birthplace) and age were contributors to variation in the ecological statements. Although their ratings for damages from *Sandy* being due to loss of dunes and salt marshes were lower than their other ratings, they were higher than ratings given by a different New Jersey sample immediately after *Sandy* (Burger 2015) This information will aid in developing recovery and resiliency strategies for protecting ecological and human communities along coasts. Such strategies should include a well-balanced educational program that highlights the protective effect of dunes, beaches and marshes in preventing or reducing surge flooding, that is aimed at vulnerable populations that stand to gain the most from ecological barriers to flooding. The importance of interviewing this population in Spanish suggests that educational materials should be readily available in Spanish, particularly in the Federally Qualified Health Centers, as well as in other community centers.

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Fig 1.
Map showing the locations of the seven Federally Qualified Health Centers facilities where patients were interviewed three years after Hurricane *Sandy*

Fig 2.

Relative mean ($\pm$ standard error) ratings of respondents interviewed at Federally Qualified Health Centers in New Jersey three years after Hurricane *Sandy* with respect to ecological statements dealing with climate change, sea level rise, storms, and damages along the coast. All statements began with “Some experts say that”. 1 = strongly disagree and 5 = strongly agree. Different letters on the graph signify significant differences

Fig 3. Effect of gender on the mean ($\pm$ standard error) rating of ecological statements of respondents interviewed at Federally Qualified Health Centers in New Jersey three years after Hurricane *Sandy*. All statements began “Some experts say that”. 1 = strongly disagree and 5 = strongly agree. The star indicates that males and females differed significantly ($P < 0.05$)

Fig 4. Comparison of the mean rating ($\pm$ standard error) for protection and loss of salt marshes or dunes in protecting ecological and human communities from storms for coastal residents interviewed within 100 days of *Sandy* (after Burger 2015, Unpubl.) and respondents interviewed at the Federally Qualified Health Centers (FQHC) three years after *Sandy* (the present study)

Table 1

Multiple regression models explaining variations in agreement with ecological statements. Each statement started with - “Some experts say that...” and respondents answered 1 = strongly disagree to 5 = strongly agree. The models indicate whether a particular independent variable accounted for the variation in ratings for the 355 respondents

Model	More frequent and stronger storms are due to climate change	Storms like <i>Sandy</i> will come more often	Flooding from <i>Sandy</i> was mainly due to sea level rise	Changing climate is due to human activity and is not “natural”	Damage from <i>Sandy</i> along the Jersey shore was due to loss of sand dunes	Damage from <i>Sandy</i> along the Jersey shore was due to loss of natural salt marshes
F	2	1.1	1.5	1.9	1.1	1.1
Df	49	49	49	49	49	49
R ²	30	19	24	29	19	19
P	0.0003	NS	0.03	0.0007	NS	NS
Factors entering the best model						
Sex	3.2 (0.08)	NS	8.5 (0.004)	8.2 (0.005)	2.1 (0.14)	8.9 (0.003)
Age ^b	NS	NS	4.0 (0.05)	NS	NS	NS
Birthplace	1.7 (0.02)	NS	NS	1.5 (0.06)	NS	NS
Days electric out (# of days)	NS	NS	NS	NS	6.5 (0.01)	3.6 (0.06)
How soon did life return to normal? ^c	3.2 (0.08)	NS	NS	NS	3.6 (0.06)	NS
Sandy Impact Rating ^a	NS	1.7(0.13)	NS	2.5 (0.03)	NS	NS
Center Location	3.0 (0.007)	NS	2.0 (0.07)	NS	1.6 (0.14)	1.7(0.13)
Center visits/year	NS	NS	NS	NS	5.0 (0.03)	NS
Have you heard of Fracking?	3.9 (0.02)	2.1 (0.12)	NS	4.3 (0.01)	5.5 (0.005)	NS

^a *Sandy* Impact was a personal rating of impact from the storm ranging from 0 (no impact) to 5 (severely impacted)

^b Age entered as continuous variable

^c Days for life to return to ‘normal’

Relationship between rating of personal impact of *Sandy* and environmental issues. All questions started with “Some experts say”. Subjects gave a rating of 1 (strongly disagree) to 5 (strongly agree). There were no significant correlations with years of education or days without electricity. Given are Kendall tau values and the probabilities (in parentheses). NS = not significant

Table 2

	Age	Years in US	Personal Impact Rating	Days Before Life Returned to Normal	Center Visits/Year
Storms due to climate change	0.08 (0.05)	0.10(0.01)	NS	0.11 (0.01)	−0.10 (0.04)
Storms will come more often	NS	0.11 (0.006)	NS	NS	NS
Flooding due to sea level rise	0.16(0.0001)	0.12 (0.005)	NS	NS	NS
Changing climate due to human activity	NS	NS	−0.11 (0.01)	NS	NS
Sandy damage due to loss of sand dunes	0.07 (0.09)	0.11 (0.009)	NS	0.07 (0.09)	0.10 (0.03)
Sandy damage due to loss of salt marshes	0.13 (0.001)	NS	NS	NS	0.09 (0.05)

Table 3

Evaluation of relationships between storms, climate change, flooding, sea level rise and ecological features by ethnicity /race and sex. People were asked to rate their agreement with the statements listed below. Each statement started with “Some Experts Say”. Shown is the mean value ($\pm$ standard error), where 1 = strongly disagree to 5 = strongly agree. Comparisons are made with Kruskal-Wallis Chi Square test (p value). NS = not significant

	Overall		$\chi^2(p)$	Hispanic		$\chi^2(p)$	White		$\chi^2(p)$	Black		$\chi^2(p)$
	Female	Male		Female	Male		Female	Male		Female	Male	
Sample size (number interviewed)	231	125		133	60		47	32		48	31	
Percent evacuated	12.40%	12.40%	NS	11.7%	14.5%	NS	13.7%	17.7%	NS	11.8%	3.2%	NS
Percent without electricity	96.10%	93.30%	NS	97.7%	94.7%	NS	89.4%	87.1%	NS	98.0%	96.7%	NS
Ratings												
Some Experts say that....:												
Storms due to climate change	4.3 $\pm$ 0.1	4.5 $\pm$ 0.1	NS	4.3 $\pm$ 0.1	4.6 $\pm$ 0.1	2.9 (0.09)	4.3 $\pm$ 0.1	4.5 $\pm$ 0.2	NS	4.4 $\pm$ 0.1	4.5 $\pm$ 0.1	NS
Storms will come more often	4.0 $\pm$ 0.1	4.1 $\pm$ 0.1	NS	4.1 $\pm$ 0.1	4.1 $\pm$ 0.1	NS	4.1 $\pm$ 0.2	4.0 $\pm$ 0.2	NS	3.8 $\pm$ 0.2	4.3 $\pm$ 0.2	4.8 (0.03)
Flooding due to sea level rise	3.8 $\pm$ 0.1	4.3 $\pm$ 0.1	15.4 (<0.0001)	3.9 $\pm$ 0.1	4.3 $\pm$ 0.1	8.0 (0.005)	3.8 $\pm$ 0.2	4.1 $\pm$ 0.2	NS	3.7 $\pm$ 0.2	4.4 $\pm$ 0.2	7.7 (0.006)
Changing climate due to human activity	3.7 $\pm$ 0.1	4.2 $\pm$ 0.1	11.6(0.0004)	3.7 $\pm$ 0.1	4.3 $\pm$ 0.1	7.4 (0.007)	3.9 $\pm$ 0.2	4.2 $\pm$ 0.2	NS	3.4 $\pm$ 0.2	4.0 $\pm$ 0.2	3.1 (0.08)
<i>Sandy</i> Damage due to loss of sand dunes	3.4 $\pm$ 0.1	3.3 $\pm$ 0.1	NS	3.3 $\pm$ 0.1	3.2 $\pm$ 0.1	NS	3.7 $\pm$ 0.1	3.2 $\pm$ 0.2	3.9 (0.05)	3.4 $\pm$ 0.2	3.6 $\pm$ 0.2	NS
<i>Sandy</i> damage due to loss of salt marshes	3.2 $\pm$ 0.1	3.1 $\pm$ 0.1	NS	3.3 $\pm$ 0.1	3.2 $\pm$ 0.1	NS	3.2 $\pm$ 0.1	3.0 $\pm$ 0.2	NS	3.1 $\pm$ 0.2	2.9 $\pm$ 0.2	NS

Ratings (means $\pm$ standard error) of the subjects as a function of Health Center. All questions started with "Some experts say". Subjects gave a rating of 1 (strongly disagree) to 5 (strongly agree). Given are arithmetic means $\pm$ SE with Kruskal-Wallis Chi Square values *and* *p* values

Table 4

Statements	Ratings at each Center						Comparison among centers $\chi^2(p)$
	New Brunswick	Elizabeth	Jersey City	Lakewood	Long Branch	Plainfield	Toms River
Sample Size (number interviewed)	15	66	42	46	19	127	40
Storms due to climate change	3.7 $\pm$ 0.3	4.4 $\pm$ 0.1	4.3 $\pm$ 0.1	4.5 $\pm$ 0.1	4.2 $\pm$ 0.2	4.5 $\pm$ 0.1	4.4 $\pm$ 0.1 16.1 (0.01)
Storms will come more often	3.6 $\pm$ 0.3	4.0 $\pm$ 0.1	3.9 $\pm$ 0.2	4.0 $\pm$ 0.1	3.7 $\pm$ 0.2	4.2 $\pm$ 0.1	4.2 $\pm$ 0.2 12.6 (0.05)
Flooding due to sea level rise	4.1 $\pm$ 0.2	4.0 $\pm$ 0.1	3.5 $\pm$ 0.2	3.7 $\pm$ 0.2	3.8 $\pm$ 0.2	4.2 $\pm$ 0.1	4.2 $\pm$ 0.2 23.2 (0.0007)
Changing climate due to human activity	3.9 $\pm$ 0.4	3.9 $\pm$ 0.1	3.5 $\pm$ 0.2	4.2 $\pm$ 0.1	3.5 $\pm$ 0.3	3.8 $\pm$ 0.1	3.9 $\pm$ 0.2 NS
Sandy damage due to loss of sand dunes	3.4 $\pm$ 0.2	3.2 $\pm$ 0.1	3.1 $\pm$ 0.2	3.4 $\pm$ 0.1	3.3 $\pm$ 0.3	3.4 $\pm$ 0.1	3.8 $\pm$ 0.2 12.1 (0.06)
Sandy damage due to loss of salt marshes	3.2 $\pm$ 0.2	3.0 $\pm$ 0.1	3.0 $\pm$ 0.1	3.1 $\pm$ 0.1	3.2 $\pm$ 0.2	3.3 $\pm$ 0.1	3.0 $\pm$ 0.2 12.0 (0.06)
Hardest Hit Impact ^a	4	5	10	2	1	5	2
Household Hardship Rank ^a	36	5	2	15	19	63	8
Overall Personal Impact Rating for each center	3.1 $\pm$ 0.4	3.1 $\pm$ 0.2	3.4 $\pm$ 0.2	2.8 $\pm$ 0.2	3.2 $\pm$ 0.4	3.1 $\pm$ 0.1	3.0 $\pm$ 0.2 NS

^a After Halpin (2013) ranking of the municipality among 533 municipalities surveyed

Table 5

Ratings of agreement about 3 ecological statements by subjects interviewed at Federally Qualified Health Centers in New Jersey. 1 (strongly disagree) to 5 (strongly agree)

Birthplace of Respondent	% of the total Respondents	Ratings		
		Storms due to climate change	Changing climate due to human activity	Sandy Damage due to loss of dunes
New Jersey (US born)	43.5%	4.5 ± 0.1	3.9 ± 0.1	3.4 ± 0.1
Mexico	10.7%	4.4 ± 0.1	4.3 ± 0.1	3.3 ± 0.1
Central America	10.1%	4.4 ± 0.1	4.1 ± 0.2	3.3 ± 0.1
Caribbean	16.5%	4.3 ± 0.1	3.5 ± 0.2	3.5 ± 0.1
South America	16.2%	4.4 ± 0.1	3.7 ± 0.2	3.0 ± 0.1
Europe	2.9%	4.0 ± 0.3	3.0 ± 0.4	3.0 ± 0.3

Table 6

Ratings of the subjects as a function of self-identified personal impact. (0–1 = Low, 2–3 = Medium, 4–5 = High). Responses ranged from 1 = Strongly Disagree 5 = Strongly Agree, given are arithmetic means $\pm$ SE with Kruskal-Wallis Chi Square values and p values. NS = not significant

By sandy impact rating	Low	Medium	High	$\chi^2(p)$
Sample Size	42	179	132	
Storms due to climate change	4.4 $\pm$ 0.1	4.4 $\pm$ 0.1	4.4 $\pm$ 0.1	NS
Storms will come more often	3.7 $\pm$ 0.2	4.2 $\pm$ 0.1	4.0 $\pm$ 0.1	7.2 (0.03)
Flooding due to sea level rise	3.7 $\pm$ 0.2	4.0 $\pm$ 0.1	4.0 $\pm$ 0.1	4.8 (0.09)
Changing climate due to human activity	4.0 $\pm$ 0.2	4.0 $\pm$ 0.1	3.6 $\pm$ 0.1	NS
<i>Sandy</i> damage due to loss of sand dunes	3.3 $\pm$ 0.2	3.3 $\pm$ 0.1	3.4 $\pm$ 0.1	NS
<i>Sandy</i> damage due to loss of salt marshes	3.0 $\pm$ 0.1	3.1 $\pm$ 0.1	3.2 $\pm$ 0.1	NS

Table 7

Ratings for agreement with the ecological statements as a function of whether subjects had heard of fracking (yes) or not (no). Ratings for the ecological statements are on a scale of 1 (strongly disagree) to 5 (strongly agree). Twenty people did not answer

	<u>Heard of Fracking</u>		$\chi^2(p)$
	No	Yes	
Sample Size	65	270	
Storms due to climate change	4.3 $\pm$ 0.1	4.7 $\pm$ 0.1	10.2 (0.02)
Storms will come more often	4 $\pm$ 0.1	4.3 $\pm$ 0.1	7.7 (0.05)
Flooding due to sea level rise	3.9 $\pm$ 0.1	4.1 $\pm$ 0.1	9.4 (0.02)
Changing climate due to human activity	3.7 $\pm$ 0.1	4.2 $\pm$ 0.1	11.1 (0.01)
<i>Sandy</i> damage due to loss of sand dunes	3.2 $\pm$ 0.1	3.8 $\pm$ 0.1	26.0 (<0.0001)
<i>Sandy</i> damage due to loss of salt marshes	3.1 $\pm$ 0.1	3.2 $\pm$ 0.1	NS