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LETTER

# Assessing the environmental justice consequences of flood risk: a case study in Miami, Florida

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## Abstract

Recent environmental justice (EJ) research has emphasized the need to analyze social inequities in the distribution of natural hazards such as hurricanes and floods, and examine intra-ethnic diversity in patterns of EJ. This study contributes to the emerging EJ scholarship on exposure to flooding and ethnic heterogeneity by analyzing the racial/ethnic and socioeconomic characteristics of the population residing within coastal and inland flood risk zones in the Miami Metropolitan Statistical Area (MSA), Florida—one of the most ethnically diverse MSAs in the U.S. and one of the most hurricane-prone areas in the world. We examine coastal and inland flood zones separately because of differences in amenities such as water views and beach access. Instead of treating the Hispanic population as a homogenous group, we disaggregate the Hispanic category into relevant country-of-origin subgroups. Inequities in flood risk exposure are statistically analyzed using socio-demographic variables derived from the 2010 U.S. Census and 2007–2011 American Community Survey estimates, and 100-year flood risk zones from the Federal Emergency Management Agency (FEMA). Social vulnerability is represented with two neighborhood deprivation indices called economic insecurity and instability. We also analyze the presence of seasonal/vacation homes and proximity to public beach access sites as water-related amenity variables. Logistic regression modeling is utilized to estimate the odds of neighborhood-level exposure to coastal and inland 100-year flood risks. Results indicate that neighborhoods with greater percentages of non-Hispanic Blacks, Hispanics, and Hispanic subgroups of Colombians and Puerto Ricans are exposed to inland flood risks in areas without water-related amenities, while Mexicans are inequitably exposed to coastal flood risks. Our findings demonstrate the importance of treating coastal and inland flood risks separately while controlling for water-related amenities, and recognizing intra-ethnic diversity within the Hispanic category to obtain a more comprehensive assessment of the social distribution of flood risks.

## Introduction

Floods continue to be a major social concern as they cause deaths, injuries, adverse health effects, property damage, and disruptions in the functions of entire urban and rural systems (Walker 2012). Furthermore, the adverse impacts of floods are unevenly distributed across people and places. Environmental justice (EJ) is broadly defined as equitable environmental quality for all social groups, with particular consideration that socially vulnerable groups are not disproportionately exposed to environmental hazards. Social vulnerability is defined by Wisner *et al* (2004, p 11) as 'the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard.' Risk is a product of the hazard and the vulnerability of those exposed to the hazard (Turner *et al* 2003, Wisner *et al* 2004); thus understanding social vulnerability is essential to the effective management and mitigation of risks imposed by natural hazards (Tate 2012, Oulahen *et al* 2015). EJ research on flooding focuses on identifying whether socially vulnerable groups such as racial/ethnic minorities and individuals of lower socioeconomic status are inequitably exposed to flood risk and ensuring equitable management of flood hazards.

Although EJ research in the U.S. began in the 1980s, most case studies have examined social inequities associated with anthropogenic hazards such as air pollution and toxic waste instead of natural hazards (Bullard 1990, Brown 1995, Brulle and Pellow 2006, Mohai *et al* 2009). However, the disproportionate impacts of Hurricane Katrina in 2005 on African-American and low-income residents of New Orleans, Louisiana, led to an expansion of the EJ framework to include natural disasters and initiated empirical investigations on the EJ implications of flooding (Morse 2008, Maantay and Maroko 2009, Walker and Burningham 2011, Walker 2012, Montgomery and Chakraborty 2013, Chakraborty *et al* 2014, Grineski *et al* 2015).

A limitation of most prior EJ studies on floods is that all flood-prone areas have been treated as one aggregate zone and thus assumed to pose equal risk. This approach is problematic because it fails to consider social disparities between those exposed to coastal and inland flood risk, as well as different amenities that are associated with flood hazards. Recent research on exposure to flood risks in the U.K. suggests that residents of lower social classes were disproportionately exposed to flooding, but this inequity was pronounced within coastal flood zones while exposure to inland flood risk was generally equitable (Fielding 2007, Walker and Burningham 2011, Walker 2012). Research on flood hazards in the U.S. state of Florida indicates that coastal areas are populated primarily by non-Hispanic White and economically affluent residents, while racial/ethnic minorities are overrepresented in inland flood zones (Ueland and Warf 2006, Montgomery and Chakraborty 2013, Chakraborty *et al* 2014). Water-related amenities such as beach access and water views are indivisible from coastal flood hazards because the amenities and hazards are innate features of the location, and amenities must be consumed *in situ* (Kates 1971, Grineski *et al* 2015). Conversely, urban and suburban development and associated impervious surfaces increase likelihood of floods in inland areas which may lack the amenities of proximity to open water. The indivisible nature of water-related amenities associated with certain flood risks, and differences in socioeconomic status between those residing in coastal and inland flood zones warrant separate assessments of exposure to coastal and inland flood risks.

Recent EJ research has also emphasized the need to acknowledge diversity and heterogeneity within various socio-demographic groups. Collins *et al* (2011) found that racial/ethnic status combined with other dimensions of social inequality in complex ways to shape divergent intra-group relationships with cancer risks from air pollutants for Hispanics in El Paso County, Texas, as compared to non-Hispanic Whites. The only previous EJ study to examine Hispanic heterogeneity based on country-of-origin (Grineski *et al* 2013) found Cuban and Colombian neighborhoods to be exposed to significantly higher cancer risk from vehicular air pollutants than Mexican neighborhoods in the Miami Metropolitan Statistical Area (MSA), Florida. These two studies demonstrate that treatment of Hispanics as a monolithic category obscures environmental inequities among diverse Hispanic subgroups, particularly in urban areas with a large Hispanic population.

This letter contributes to the EJ research literature on flood risks and ethnic heterogeneity through a case study of the Miami MSA, Florida. Our study has two primary research objectives. The first objective is to evaluate spatial and social inequities in the distribution of both coastal and inland flood risks in the Miami MSA, while controlling for indivisible water-related amenities. The second objective is to examine how the EJ consequences of exposure to these flood risks differ when: (a) treating the large and diverse Hispanic population of this MSA as a single ethnic group, compared to (b) disaggregating the Hispanic population into contextually-relevant subgroups (i.e., Colombians, Cubans, Mexicans, and Puerto Ricans) based on their country-of-origin. Our statistical analyses are based on logistic regression models that use neighborhood-level data on racial/ethnic composition, social vulnerability, and water-related amenities in the Miami MSA to estimate the likelihood of residing within coastal and inland flood risk zones.

## Study area

The Miami MSA is particularly suitable for this research since it is a coastal and flood-prone urban area with a large and diverse Hispanic population. This MSA, shown in figure 1, encompasses three counties in the state of Florida: Miami-Dade, Broward, and Palm Beach. With about 5.6 million residents according to the 2010 U.S. Census, this tri-county area is the most populous MSA in Florida, and the eighth largest MSA in the U.S. Located between the Gulf of Mexico and Atlantic Ocean, the Miami MSA is highly vulnerable to hurricane and tropical storm impacts. The south Florida region has been hit by 29 Category 3 or higher hurricanes since 1888 (Nijman 2011). Hurricane Andrew hit the Miami area in 1992, and it was the most costly hurricane to strike the U.S. at that time (Nijman 2011). Broward, Miami-Dade, and Palm Beach Counties were ranked first, second, and third, respectively, for flood-induced property damage in Florida from 1997 to 2001 (Brody *et al* 2007).

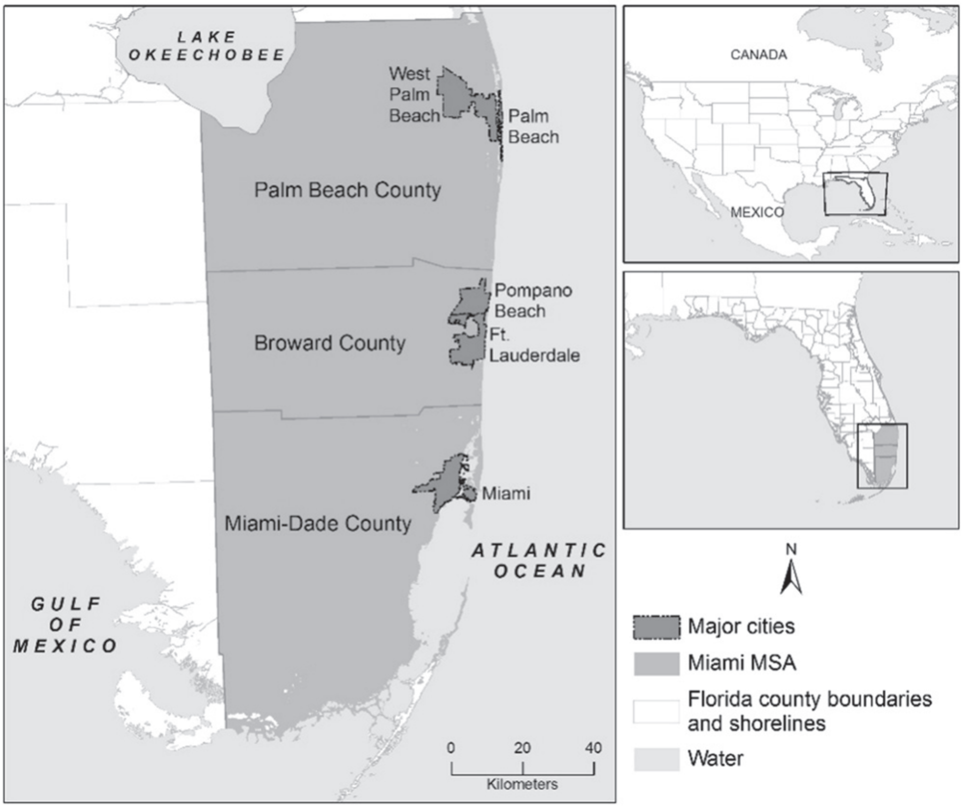


**Figure 1.** Study area: Miami Metropolitan Statistical Area (MSA), Florida, USA.

The Miami MSA 2010 population comprises 41% Hispanic, 36% non-Hispanic White, and 20% non-Hispanic Black residents. Cubans are the largest portion of Hispanics, at 17.4% of the total Miami MSA 2010 population. In addition to Cuba, the Hispanics of the Miami MSA also originate from Puerto Rico (3.8%), Colombia (3.7%), Mexico (2.4%), and several other Central and South American countries (U.S. Census Bureau 2010, Nijman 2011).

Treating Hispanic residents in the Miami MSA as a monolithic category is particularly problematic because of variations in socioeconomic status and migration histories within this group. Miami has Latinized intensely in the last 40 years, and Cubans are the largest Hispanic immigrant group (Grineski *et al* 2013). The first wave of Cuban immigration happened in 1959–1961, and brought immigrants who were mostly White, educated, and upper middle class individuals. The second wave of Cuban migrants (e.g., Freedom Flights from 1965 to 1973) belonged to the working and middle class. The third wave were those from the Mariel boatlift in 1980, who were mostly low-income with low levels of education (Nijman 2011). Colombians in the U.S. are more economically affluent; their socioeconomic profile in the U.S. and Miami closely resembles that of the overall U.S. population (MPI 2014). Puerto Ricans are generally more educated than the U.S. Hispanic population, but have higher poverty rates than the general U.S. and U.S. Hispanic populations (Brown and Patten 2013). Mexicans mostly reside at the urban fringes of Miami MSA instead of highly urbanized areas because they are largely employed in agricultural labor (Nijman 2011, Grineski *et al* 2013). Almost 50% of all migrant/seasonal/farm workers in south Florida are Mexican, and at least one-third of Mexicans in south Florida are undocumented, with a median educational attainment level of sixth grade (Nijman 2011). Mexicans may thus be the most socially vulnerable Hispanic origin subgroup of those examined herein in the Miami MSA.

## Data and methods

The 100-year floodplain is used to delineate flood risks in this research, since this designation is used in the U. S. by the Federal Emergency Management Agency (FEMA) to regulate the purchase of flood insurance and floodplain management activities enacted by federal, state, and local entities (Maantay and Maroko 2009, Brody *et al* 2013, Chakraborty *et al* 2014). Previous research on flood hazards in the U.S. have also utilized 100-year flood zones to examine social vulnerability to floods (Maantay and Maroko 2009, Brody *et al* 2013, Chakraborty *et al* 2014). The 100-year flood hazard zones are defined as areas that have a 1% chance of flooding every year and they are spatially delineated using FEMA's National Flood Hazard Layer (NFHL) (FEMA 2015a).

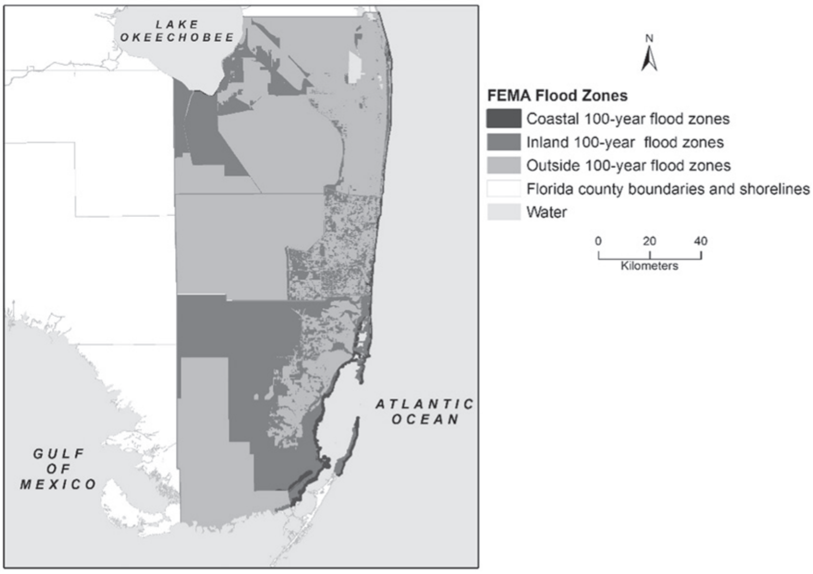


**Figure 2.** Federal Emergency Management Agency (FEMA) flood hazard zones in the Miami MSA.

Flood risks were categorized into coastal and inland 100-year flood zones, based on the NFHL data. All V and VE flood zones in the NFHL were aggregated to represent coastal 100-year flood risk zones. V and VE zones correspond to areas with three feet or more of wave action hazards on top of 100-year flood elevations (FEMA 2015c). Although the FEMA definition of V and VE zones is not necessarily restricted to open ocean coasts, three feet of wave action is usually associated with open ocean coasts and previous research has employed V and VE zones to represent coastal flood risk (Montgomery and Chakraborty 2013, Chakraborty *et al* 2014). Inland 100-year flood zones include all A, AE, and AH zones in the NFHL, which are areas of 100-year flood risk with less than three feet of wave action hazards on top of 100-year flood elevations (FEMA 2015c). Figure 2 depicts flood risks in the Miami MSA according to the NFHL data categorized into coastal and inland 100-year flood zones, and areas outside 100-year flood zones.

Social inequities in flood risk exposure are assessed with logistic regression modeling and socio-demographic data that originate from the 2010 U.S. Census and 2007–2011 American Community Survey (ACS) 5-year estimates (U.S. Census Bureau 2015). The 2010 census tracts were used as the units of analysis because they represent the smallest census areal units with the widest range of socio-demographic data available. Out of 1219 tracts in the tri-county Miami MSA, our analysis uses 1177 tracts with at least 500 residents and no missing ACS data. We utilize tract-level percentages of non-Hispanic Blacks and Hispanics to assess equity in exposure to flood risks for these minority groups. While most U.S. based EJ studies have analyzed environmental risks associated with non-Hispanic Blacks, previous research on Hurricane Andrew in Miami also indicates that Black neighborhoods suffered significantly greater property damage and received disproportionately insufficient funds for recovery (Morrow and Peacock 1997, Peacock and Girard 1997). Additionally, we used four Hispanic subgroup variables representing the percentage of each tract's total population that was Colombian, Cuban, Mexican, and Puerto Rican in origin. In the ACS, the country of origin is based on self-reported Hispanic origin. Although the ACS estimates of Hispanic origin subgroups have high margins of error, the estimates implicitly account for unauthorized immigrants and they are the most reliable data source for disaggregating the Hispanic population of the Miami MSA (U.S. Census Bureau 2013).

We develop and use two neighborhood deprivation indices called economic insecurity and instability to represent social vulnerability (Messer *et al* 2006, Grineski *et al* 2015). Indices such as economic insecurity and instability provide more comprehensive and detailed assessments of social vulnerability than singular variables such as household income or poverty status (Cutter *et al* 2003, Oulahen *et al* 2015). Additionally, indices such as neighborhood deprivation may become increasingly important for reliability, since variables from ACS estimates have high margins of error (Grineski *et al* 2015). Principal components analysis was employed to calculate economic insecurity and instability using IBM SPSS Statistics 22 software and several variables from the 2007–2011 ACS 5-year estimates used in prior research (Messer *et al* 2006, Grineski *et al* 2015). The variables and component loadings matrix for economic insecurity and instability are listed in Supplementary Materials 1.

To control for water-related amenities associated with flood hazard zones, tract-level percentages of

**Table 1.** Descriptive statistics for Miami MSA 2010 census tracts with at least 500 residents.

| Variables | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Coastal 100-year flood risk | 0.00 | 1.00 | 0.08 | 0.28 |
| Inland 100-year flood risk | 0.00 | 1.00 | 0.82 | 0.38 |
| Percent non-Hispanic Black | 0.00 | 97.00 | 19.02 | 24.98 |
| Percent Hispanic | 0.80 | 97.70 | 38.49 | 29.56 |
| Percent Colombian | 0.00 | 23.20 | 3.44 | 3.25 |
| Percent Cuban | 0.00 | 82.60 | 15.84 | 21.33 |
| Percent Mexican | 0.00 | 42.00 | 2.21 | 3.80 |
| Percent Puerto Rican | 0.00 | 13.70 | 3.50 | 2.14 |
| Economic insecurity | −2.54 | 4.70 | 0.00 | 1.00 |
| Instability | −2.08 | 4.23 | 0.00 | 1.00 |
| Percent seasonal homes | 0.00 | 55.90 | 5.22 | 9.01 |
| Proximity to beach sites | 0.01 | 4.32 | 0.24 | 0.43 |

Note: $N = 1177$ tracts.

seasonal homes and proximity to public beach access sites are used in regression models. Seasonal homes, also referred to as vacation homes, are expected to be concentrated in coastal areas due to attractiveness of the beaches and the importance of beach tourism in the Miami MSA (Chakraborty *et al* 2014). Proximity to public beach access sites is the inverse of tract-level population-weighted distances (PWD) to public beach access sites (Montgomery *et al* 2015), estimated on the basis of a methodology adapted from park accessibility research (Zhang *et al* 2011, Wen *et al* 2013) and explained in supplementary materials 2. The PWD method of modeling proximity to public beach sites was chosen because it accounts for probability of visitation based on population density and vehicle parking capacity, and it employs a distance decay parameter informed by empirical research (Da Silva 2002, Giles-Corti and Donovan 2002, Zhang *et al* 2011, Montgomery *et al* 2015). Summary statistics for all variables used in this study are presented in table 1.

To classify census tracts as exposed to coastal or inland flood risk, spatial selections were implemented using ArcGIS 10.1 software. We originally intended to estimate exposure to flood risks with ordinary least squares regression models and dependent variables that represent the proportion of tracts' area coincident with coastal and inland flood zones. However, these dependent variables (areas within flood zones) exhibited a bimodal distribution with values clustered near zero and 100%, which suggests that most tracts were either not intersected by flood zones or completely contained by them. Binary logistic regression was thus the more appropriate method of analysis. Dichotomous dependent variables indicating exposure to coastal and inland flood risk were created for each tract, using a mutually exclusive classification scheme. First, all tracts that intersected coastal 100-year flood zones were classified at risk to coastal flooding and assigned a value of 1 for the coastal flood risk dependent variable. Second, tracts that intersected inland 100-year flood zones that were not already classified at risk to coastal flooding were assigned a value of 1 for the inland flood risk dependent variable. The binary dependent variables for our analysis are thus coded as 1 if the tract intersected the flood zone of interest and as 0 if it did not intersect it. Figure 3 shows the Miami MSA tracts used in our analyses classified according to flood risk.

Logistic regression analysis was used estimate the odds of a census tract in the Miami MSA being exposed to flood risk based on race, ethnicity, social deprivation, and water-related amenities, both with and without disaggregating Hispanics by national origin. We estimated two sets of logistic regression models using IBM SPSS Statistics 22 software to assess the EJ consequences of flood risk exposure. One set of models (C) estimates the odds of exposure to coastal flood risk, and the other set (L) estimates odds of exposure to inland flood risk. Standardized regression coefficients are provided so that relative contributions of each independent variable can be compared. Since most of our variables were not normally distributed, non-parametric bivariate correlation coefficients (Spearman's rho) were calculated prior to logistic regression modeling to examine relationships between dependent and independent variables and assess relative social vulnerability of racial/ethnic groups based on the neighborhood deprivation indices.

## Results

The results of bivariate analysis, based on non-parametric coefficients, are listed in table 2. These correlation coefficients indicate that higher tract-level neighborhood instability, percentages of seasonal homes, and proximity to public beach access sites are significantly ($p < .05$) and positively correlated with coastal flood risk. Higher tract-level percentages of non-Hispanic Blacks, Hispanics, Colombians, Cubans, Mexicans, Puerto Ricans, and economic insecurity are significantly ($p < .01$) and positively correlated with inland flood risk. The percentages of

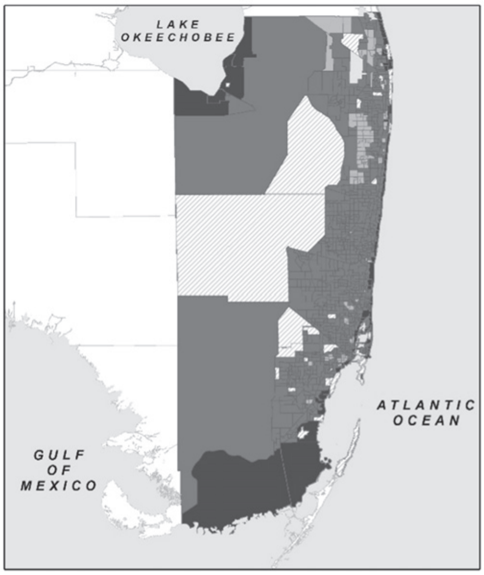


**Figure 3.** Census tracts with at least 500 residents and no missing neighborhood deprivation index values classified by flood risk: coastal ($n = 99$), inland ($n = 967$), and tracts outside flood zones ($n = 111$).

non-Hispanic Blacks, Hispanics, and Hispanic subgroups of Cubans and Puerto Ricans are significantly ($p < .01$) and positively correlated with neighborhood economic insecurity. The Colombian percentage is significantly and negatively correlated with economic insecurity. The percentages of non-Hispanic Blacks, Hispanics, and Hispanic subgroups of Mexicans and Puerto Ricans indicate a significantly positive ($p < .01$) correlation with instability. Correlations between seasonal homes and proximity to public beach access sites and flood risks indicate that these two water-related amenities are significantly and positively associated with coastal flood risk, but significantly and negatively associated with inland flood risk.

The results for logistic regression analysis of coastal flood risk are summarized in table 3. Non-Hispanic Blacks, Hispanics, and economic insecurity have a significantly negative relationship with the odds of coastal flooding in model C1A, but these relationships become non-significant when water-related amenity variables of percent seasonal homes and proximity to public beach access sites are incorporated in model C1B. Non-Hispanic Blacks, Cubans, and Puerto Ricans also indicate significantly negative associations with the odds of coastal flooding in model C2A. However, percentages of Cubans and Puerto Ricans lose significance and percent non-Hispanic Black takes on a significantly positive relationship with the odds of coastal flood risk when water-related amenity variables are included in model C2B. Economic insecurity has a significant and negative relationship with the odds of coastal flood risk in all models, except C1B in which it is non-significant ($p > .05$). Instability is positively associated with the odds of coastal flood risk and significant ($p < .01$) in models C1A and C2A, but it loses significance in models C1B and C2B that include water-related amenities. The consistencies among the coastal flood risk models indicate that the Mexican percentage, seasonal homes, and proximity to public beach access sites are positively and significantly ($p < .01$) related to the odds of coastal flood risk.

Table 4 presents the logistic regression models for inland flood risk. Greater tract-level percentages of non-Hispanic Blacks and Hispanics significantly increase the odds of inland flood risk in models L1A and L1B. Percent Mexican has a significantly negative association and percent Puerto Rican has a significantly positive relationship with odds of inland flood risk in models L2A and L2B. Cubans and Colombians are both positively associated with odds of inland flood risk, although the significance of these associations varies among models L2A and L2B. Economic insecurity does not have a significant association with odds of inland flood risk in any model. However, instability is negative and significant in models L1A and L2A, which do not include the water-related amenity variables. The water-related amenity variables are both significantly and negatively related with odds of inland flood risk (models L1B and L2B), indicating their relative absences in these flood zones.

## Discussion

This study extends previous research on the EJ consequences of coastal and inland flood risks (Ueland and Warf 2006, Fielding 2007, Walker 2012, Montgomery and Chakraborty 2013, Chakraborty *et al* 2014) by including assessments of Hispanic origin subgroups of Colombians, Cubans, Mexicans, and Puerto Ricans in the Miami MSA, and using variables

**Table 2.** Spearman's rho non-parametric bivariate correlation coefficients for tract-level dependent variables (flood risk types) and independent variables.

| | Coastal flood risk | Inland flood risk | % Non-Hispanic Black | % Hispanic | % Colombian | % Cuban | % Mexican | % Puerto Rican | Econ. Insecurity | Instability | % Seasonal homes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inland flood risk | −.650$^{***}$ | | | | | | | | | | |
| % Non-Hispanic Black | −.177$^{***}$ | .183$^{***}$ | | | | | | | | | |
| % Hispanic | −.073$^{**}$ | .195$^{***}$ | −.345$^{***}$ | | | | | | | | |
| % Colombian | −.009 | .176$^{***}$ | −.233$^{***}$ | .615$^{***}$ | | | | | | | |
| % Cuban | −.048 | .182$^{***}$ | −.394$^{***}$ | .921$^{***}$ | .539$^{***}$ | | | | | | |
| % Mexican | .016 | .062$^{**}$ | .123$^{***}$ | .291$^{***}$ | .215$^{***}$ | .114$^{***}$ | | | | | |
| % Puerto Rican | −.181$^{***}$ | .280$^{***}$ | .353$^{***}$ | .439$^{***}$ | .562$^{***}$ | .341$^{***}$ | .428$^{***}$ | | | | |
| Econ. insecurity | −.261$^{***}$ | .203$^{***}$ | .420$^{***}$ | .224$^{***}$ | −.248$^{***}$ | .160$^{***}$ | .025 | .171$^{***}$ | | | |
| Instability | .109$^{***}$ | −.002 | .146$^{***}$ | .139$^{***}$ | .010 | .031 | .269$^{***}$ | .116$^{***}$ | −.016 | | |
| % Seasonal homes | .335$^{***}$ | −.311$^{***}$ | −.195$^{***}$ | −.458$^{***}$ | −.021 | −.480$^{***}$ | .053 | −.236$^{***}$ | −.576$^{***}$ | .036 | |
| Proximity to beach sites | .367$^{***}$ | −.321$^{***}$ | −.039 | −.283$^{***}$ | −.313$^{***}$ | −.279$^{***}$ | .098$^{***}$ | −.301$^{***}$ | −.191$^{***}$ | −.397$^{***}$ | .423$^{***}$ |

Note: significance codes: $^{***}p < .01$; $^{**}p < .05$ (2-tailed).

**Table 3.** Coastal 100-year flood risk: logistic regression model results for Miami MSA.

| Standardized variables | Model C1A | Model C1B | Model C2A | Model C2B |
|---|---|---|---|---|
| (Intercept) | −2.924*** | −3.113*** | −3.170*** | −3.339*** |
| % Non-Hispanic Black | −0.819*** | 0.377 | −0.422* | 0.660** |
| % Hispanic | −0.513*** | 0.339 | | |
| % Colombian | | | 0.239* | 0.072 |
| % Cuban | | | −0.373** | 0.334 |
| % Mexican | | | 0.507*** | 0.709*** |
| % Puerto Rican | | | −1.053*** | −0.039 |
| Econ. insecurity | −0.500** | −0.314 | −0.623*** | −0.796*** |
| Instability | 0.577*** | 0.064 | 0.528*** | −0.082 |
| % Seasonal homes | | 0.843*** | | 0.805*** |
| Proximity to beach sites | | 0.873*** | | 0.995*** |
| *AIC* | 595.77 | 410.93 | 553.39 | 384.92 |
| *Nagelkerke R-squared* | 0.175 | 0.487 | 0.259 | 0.535 |

Note: *** $p < .01$; **$p < .05$; *$p < .10$. C stands for coastal flood risk. Models C1A and C1B include percent Hispanic. Models C2A and C2B include percentages of Hispanic origin subgroups. Models C1A and C2A exclude the two amenity variables of percent seasonal homes and proximity to public beach access sites that are included in models C1B and C2B.

**Table 4.** Inland 100-year flood risk: logistic regression model results for Miami MSA.

| Standardized variables | Model L1A | Model L1B | Model L2A | Model L2B |
|---|---|---|---|---|
| (Intercept) | 1.690*** | 1.731*** | 1.855*** | 1.855*** |
| % Non-Hispanic Black | 0.673*** | 0.251* | 0.459*** | 0.152 |
| % Hispanic | 0.741*** | 0.357*** | | |
| % Colombian | | | 0.146 | 0.346*** |
| % Cuban | | | 0.420*** | 0.100 |
| % Mexican | | | −0.188** | −0.240*** |
| % Puerto Rican | | | 0.897*** | 0.469*** |
| Econ. insecurity | −0.072 | −0.163 | 0.066 | 0.042 |
| Instability | −0.274*** | 0.058 | −0.235*** | 0.066 |
| % Seasonal homes | | −0.486*** | | −0.420*** |
| Proximity to beach sites | | −0.574*** | | −0.565*** |
| *AIC* | 1033.80 | 919.50 | 971.19 | 885.64 |
| *Nagelkerke R-squared* | 0.108 | 0.255 | 0.195 | 0.301 |

Note: *** $p < .01$; **$p < .05$; *$p < .10$. L stands for land (as in inland flood risk). Models L1A and L1B include percent Hispanic. Models L2A and L2B include percentages of Hispanic origin subgroups. Models L1A and L2A exclude the two amenity variables of percent seasonal homes and proximity to public beach access sites that are included in models L1B and L2B.

that represent the presence of water-related amenities typically associated with coastal flood risk zones.

Our findings indicate that water-related amenities of percent seasonal homes and proximity to public beach access sites are present in areas of coastal flood risk, but relatively absent in areas of inland flood risk. Controlling for these two indivisible water-related amenities in areas of coastal flood risk (in models C1B and C2B) had significant impacts on the EJ consequences, relative to models C1A and C2A that excluded these amenities. Neighborhoods with greater non-Hispanic Blacks, Hispanics, and economic insecurity significantly exhibit decreased odds of coastal flood risk before we controlled for water-related amenities. After accounting for water-related amenities, all of these variables indicated positive although non-significant associations with coastal flood risk. Neighborhoods with more Colombians, Mexicans, and neighborhood instability show increased odds of coastal flood risk when we did not control for water-related amenities. When controlling for water-related amenities, neighborhoods with higher percentages of non-Hispanic Blacks and Mexicans indicated significantly greater risk to coastal flooding. Higher exposure to coastal flood risk for neighborhoods with a larger Mexican population can be explained, in part, by their residence proximate to agricultural employment opportunities within tracts that coincide with V zones at the Atlantic Ocean coast in the southern section of the study area and Lake Okeechobee in the northern section (figure 3). Nevertheless, inequitable exposure to coastal flood risk for neighborhoods with higher proportions of non-Hispanic Blacks and Mexicans is an EJ concern because of their greater economic insecurity and instability (table 2), which reduces their ability to cope with or recover from flood events.

Pertaining to inland flood risk, our results show that neighborhoods with greater percentages of non-

Hispanic Blacks and Hispanics are disproportionately exposed to inland flooding, even when controlling for water-related amenities. These results are consistent with those reported in a recent study of the Miami MSA (Chakraborty *et al* 2014) which found neighborhoods with greater percentages of non-Hispanic Blacks and Hispanics to be inequitably exposed to inland flood risk when controlling for median housing values and vacation homes. Neighborhoods with lower percentages of Mexicans and greater percentages Colombians and Puerto Ricans are exposed to inland flood risk when controlling for water-related amenities. The disproportionate exposure of neighborhoods with greater percentages of non-Hispanic Blacks, Hispanics, and the Hispanic subgroup of Puerto Ricans to inland flood risk is an important concern because of their higher economic deprivation levels (table 2), which hinders the ability of these residents to mitigate inland flood risks. Alternatively, neighborhoods with more Colombians exhibit lower social vulnerability based on their negative association with economic insecurity and thus possess resources to mitigate inland flood risks.

## Conclusion

This study contributes to the emerging literature on the EJ consequences of flood risks by making an analytical distinction between coastal and inland flood risks (Fielding 2007, Montgomery and Chakraborty 2013, Chakraborty *et al* 2014), and recognizing the heterogeneity of the large Hispanic immigrant population in the Miami MSA (Grineski *et al* 2013). Our results show that inequities in exposure to coastal and inland flood risks are more a function of racial/ethnic minority status than social vulnerability as captured by our neighborhood deprivation indices, based on the values and the statistical significance of these variable coefficients in our regression models. Furthermore, the inequitable exposure of neighborhoods with greater percentages of non-Hispanic Blacks, Hispanics as a whole, and the Hispanic subgroup of Puerto Ricans to inland flooding suggests that these socially vulnerable residents are residing in flood zones that lack indivisible water-related amenities. Amenities associated with coastal flood zones must outweigh the hazards if individuals of lower social vulnerability, such as non-Hispanic Whites and those with lower neighborhood deprivation, reside there. Conversely, racial/ethnic minority and low-income residents are often constrained in their choices for housing location and thus relegated to neighborhoods exposed to inland flood risk that lack water-related amenities.

This study also demonstrated the importance of disaggregating the Hispanic category in the Miami MSA into contextually-relevant origin subgroups of Colombians, Cubans, Mexicans and Puerto Ricans. Our analyses resulted in varied EJ consequences of flood risk exposure for these four Hispanic subgroups and provided empirical insights that cannot be obtained by treating Hispanics as a single homogenous category. For example, we observed that Mexicans are inequitably exposed to coastal flood risk while Colombians and Puerto Ricans are disproportionately at risk of inland flooding. Differences in educational attainment, economic affluence, and neighborhood composition for these four Hispanic subgroups arise from historical immigration patterns, which are affected by racism and homophily. Neighborhoods of the Miami MSA are highly segregated based on income and racial/ethnic characteristics (Frey and Myers 2005, Fry and Taylor 2012). Historical white flight, especially after Hurricane Andrew, and residential red-lining by real estate agents have contributed to the segregation of Miami neighborhoods (Peacock and Girard 1997, Nijman 2011).

It is also important to consider the policy implications of this research for the National Flood Insurance Program (NFIP), which is a U.S. government program managed by FEMA that provides affordable flood insurance to homeowners. The NFIP has been criticized for charging premiums that are lower than actuarial risk-based rates (U.S. CBO 2009, U.S. GAO 2010) and there are currently ongoing efforts to address both financial insolvency and affordability in the NFIP (Kousky and Kunreuther 2014). Our findings indicate that risk-based premiums may be equitable for property owners within coastal flood zones in the Miami MSA, but inequitable for those who reside in inland flood zones. Residents in desirable coastal flood zones in Florida are economically affluent (Montgomery and Chakraborty 2013, Chakraborty *et al* 2014) and are thus able to afford higher flood insurance premiums. Our findings demonstrate the need for more research on the social equity implications of flood insurance reform. As FEMA publishes new coastal and inland 100-year flood zones for communities in the NFIP, more research is necessary to assess the social vulnerability of residents that may be faced with greater flood risks and flood insurance premiums. EJ should be an explicit policy goal in planning for a more equitable NFIP so that reforms will not result in unjust consequences for racial/ethnic minorities and individuals of lower socioeconomic status exposed to flood risks.

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