Published in final edited form as:

Reg Environ Change. 2018 February ; 18(2): 311–323. doi:10.1007/s10113-017-1121-9.

Environmental injustice and flood risk: A conceptual model and case comparison of metropolitan Miami and Houston, USA

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Abstract

This article outlines a conceptual model and comparatively applies it to results from environmental justice (EJ) studies of flood risk in the Miami, Florida, and Houston, Texas, metropolitan areas. In contrast to most EJ studies of air pollution, which have found that socially-vulnerable groups experience disproportionate risk, distributive EJ studies of flooding reveal inconsistent findings regarding the relationship between social vulnerability and flood exposure. Counterintuitively (from a conventional EJ perspective), some pre-flood EJ studies have found that socially-advantaged people experience the highest residential exposure to flood risks. To integrate those anomalous findings within an EJ perspective, our conceptual model focuses on (1) the differential capacities of social groups to deploy/access protective resources for reducing the threat of loss, even while they reside amid flood-prone environments, and (2) both flood hazards and water-based benefits. Application of this model in Miami reveals that environmental injustices materialize as socially-privileged groups expose themselves to residential flood risks by seeking coastal amenities, as the costs of mitigating risks are conveyed to the broader public; in the process, socially-vulnerable residents are relegated to areas with air pollution and/or inland flood risks, where they experience constrained access to protective resources and coastal amenities. Findings from Houston better align with conventional EJ expectations—with flood zones disproportionately inhabited by socially-vulnerable people—because many coastal lands there are used by petrochemical industries, which produce major residential-environmental *disamenities*. Results underscore the need to consider protective resources and locational benefits in future empirical research on the EJ implications of flood hazards.

Keywords

Flood hazard; Flood risk; Floodplain; Environmental justice; Social vulnerability; Miami

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Introduction

In recent decades, distributive justice issues have become increasingly important in risk assessment of environmental hazards. Recognition of social inequalities in the distribution of toxic pollution hazards—first in the U.S. and then globally—has informed a social movement, policy debates, and a large body of research. Under the rubric of environmental justice (EJ) analysis, numerous quantitative spatial studies have focused on examining the extent to which racial/ethnic minority, lower socioeconomic class, or other oppressed communities are disproportionately exposed to toxic pollution hazards and related health risks. Various statistical and spatial analytic techniques have been employed in a variety of contexts worldwide. The majority of studies indicate that racial/ethnic minorities, people of low socioeconomic status, and other socially marginalized groups experience disproportionate residential exposure to technological hazards such as air pollution, hazardous waste, and chemical releases from industrial facilities (Chakraborty et al. 2011; Walker 2012). The impacts of and governmental failures to adequately respond to Hurricane Katrina catalyzed academic inquiry on the social injustices associated with events such as hurricanes and floods. Specifically, concerns regarding the uneven impacts of Katrina on African-American, elderly, and low-income residents of New Orleans led to an expansion of the empirical EJ research framework to include the unjust implications of flooding (Bullard and Wright 2009; Colten 2007; Ueland and Warf 2006; Walker and Burningham 2011).

While distributive EJ research has produced important knowledge regarding injustices associated with various technological hazards, this body of work is characterized by specific limitations that constrain empirical understandings of the social justice implications of flood hazards. This article first highlights the complex findings emerging from relatively recent EJ-related studies of flood hazards, and clarifies some key limitations of conventional distributive EJ research. Second, it introduces a conceptual model with corresponding propositions for enhancing understanding of the complex distributive dimensions of environmental injustices associated with flood hazards. It then comparatively applies the model to recent EJ-related studies of flood hazards in the Miami, Florida and Houston, Texas metropolitan areas.

Environmental justice, social vulnerability and flood hazards

Findings from empirical studies

EJ-related studies of floods have yielded ambiguous findings regarding relationships between indicators of social vulnerability and exposure to flood risks. Divergent relationships between indicators of social vulnerability and risks associated with flood hazards have been found for empirical studies focused on disproportionality in pre-flood hazard exposure compared to those that examine disproportionality associated with actual flood events.

One approach to examining EJ implications of flooding is to clarify which people live at greatest risk of flooding, or the social characteristics of those residing in locations within or proximate to floodable zones. Such distributive EJ-type studies have not consistently found associations between indicators of social vulnerability and pre-flood hazard exposure. More

than a few quantitative spatial analyses have found, counterintuitively (from a conventional EJ perspective which assumes that socially-disadvantaged populations will be exposed to greater risks), that socially-advantaged people (i.e., those of low social vulnerability) experience the highest pre-event exposure to flood hazards in particular contexts (Chakraborty et al. 2014a; Fielding and Burningham 2005; Grineski et al. 2013; Montgomery and Chakraborty 2013; Ueland and Warf 2006). Of the pre-flood exposure studies focused in the U.S., we know of only one reporting a consistent pattern of areas characterized by high social vulnerability experiencing disproportionately high pre-flood hazard exposure (Burton and Cutter 2008). Notably, this study is based on a measure of spatial flood risks associated with failure-susceptible levees, a variable that integrates (a lack of) flood hazard mitigation (Burton and Cutter 2008), and which points towards issues of process/procedural injustice in the context of flooding (Johnson et al. 2007). Results from other U.S.-based studies have not revealed clear patterns of disproportionate exposure for socially vulnerable groups (e.g., Mantaay and Maroko 2009), including one focused on spatial associations between neighborhood socioeconomic composition and flood exposure in New Orleans (Masozera et al. 2007). In the U.K., research reveals that flood risks in inland areas are not equitably distributed, but that coastal flood risks are born disproportionately within lower social class areas subject to economic decline via port-based deindustrialization (Fielding 2007; Walker and Burningham 2011; Walker 2012).

On the other hand, far more numerous and methodologically broader ranging studies of flood impacts, response, and post-event recovery have typically documented disproportionate impacts for socially-disadvantaged communities. Most such work has been conducted using a social vulnerability to hazards/disasters lens (Rufat et al. 2015). The last three decades have marked the emergence of a social vulnerability perspective on hazards and disasters, which emphasizes the influence of social inequalities on differential risks (Cutter 1996; Wisner et al. 2004). Studies of disaster events associated with flood hazards, as well as a range of hazard types reveal that disadvantaged social groups are at increased risk to experiencing debilitating damage, uncompensated loss, and long-term suffering. Key characteristics explaining variations in natural disaster impacts are context-dependent, but often include social class, race, ethnicity, gender, age, disability and health status, and immigration and citizenship status – some of the axes of social inequality that EJ research focuses on (Cutter et al. 2003; Wisner et al. 2004).

Vulnerability studies reveal that socially marginalized people have reduced capacities for self-protection in terms of mitigating flood hazards at home sites pre-event, evacuating in response to flooding, returning home or to employment following flood-induced livelihood disruption; and accessing social protection resources to reduce the impacts of flooding such as flood insurance, pre-flood hazard mitigation infrastructure, emergency response information, and post-disaster assistance (Collins 2009, 2010; Elliott and Pais 2006; Maldonado et al. 2016a; Mustafa 2005; Pelling 1999). Additionally, such studies indicate that socially vulnerable groups experience the more adverse consequences of flood disasters in terms of morbidity and mortality (Collins et al. 2013; Jimenez et al. 2013; Zahran et al. 2008), which may reflect both their increased exposure to flooding during actual flood events and their reduced access to protective resources.

To summarize, in contrast to the focus of pre-flood studies on the *distributive* dimension of injustice in terms of the spatial correspondence between traditional EJ communities and flood risks, studies of social vulnerability to floods typically emphasize the role of *process-based* inequities in shaping disproportionate risks for socially vulnerable people. Thus, from an EJ perspective, the anomalous and divergent findings from distributive and process-based studies of flood hazards are difficult to reconcile. To better integrate these findings within an EJ perspective, the next sections identify limitations of the distributive EJ approach and propose a conceptual framework with specific considerations that analysts should make when examining the EJ implications of flood hazards via future studies.

Key limitations of prior research

To expand knowledge of the EJ implications of flooding, we must begin from the premise that research on the EJ dimensions of flooding (and the broader quantitative distributive EJ literature) has several limitations. We focus on two specific limitations that are most relevant to conceptualizing EJ in the context of flood hazards. The distributive EJ literature is founded on (1) an incomplete conception of risk as high hazard exposure, which neglects people's capacities to reduce risks; and (2) an underlying assumption that people seek to avoid hazards when selecting home locations, which neglects other factors influencing residential decision-making such as locational benefits.

With reference to limitation (1), in order to broaden the EJ conception of risk, it is useful to engage concepts from studies of social vulnerability to hazards/disasters. The social vulnerability to hazards/disasters and EJ research fields are topically related, yet conceptually distinct. A theoretical premise of vulnerability studies is that *risk* is determined partly by human exposure to a *hazard* and partly by people's *social vulnerability*. While there is debate about the meaning and measurement of social vulnerability, the following definition is useful: "*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*" (Wisner et al. 2004:11). The recognition that risk is shaped in part by social vulnerability factors that condition people's capacities to mitigate risks is an important advance upon the conception of *risk as high hazard exposure* reflected in the distributive EJ literature (Collins 2010). The EJ conception of risk supports the expectation that the most disadvantaged groups in society inhabit the most hazardous environments. While findings from most EJ studies of *technological* hazards meet that expectation, results from spatial analyses of social patterns of *natural* hazard exposure most often do not (Kates and Haarman 1992; Mantaay and Maroko 2009; Masozera et al. 2007). We argue that the conception of risk from vulnerability studies facilitates understanding of complex socio-spatial patterns of exposure to various hazard types—patterns that would be viewed as anomalous from an EJ perspective (e.g. the residence of socially elite people in high hazard zones)—because it illuminates capacities that enable people to mitigate risks associated with living in hazardous environments. A strength of the vulnerability perspective is the acknowledgment that people have varying capacities to deploy resources (e.g., from their own reserves or through access to social protections) to enhance security and reduce risks, even under conditions of high hazard exposure.

With regard to limitation (2), distributive EJ research has been limited by its one-dimensional treatment of the environment as hazard. EJ scholars have focused their attention primarily on the distribution of negative environmental attributes. The EJ expectation that vulnerable people inhabit the most hazardous locations, for example, is rooted in the assumption that environments present only hazards and not benefits to people (Collins 2008, 2009, 2010). Although a bevy of EJ studies over the decade have examined distributional injustices associated with positive environmental attributes such as tree canopy cover, parks, and green space (Heynen et al. 2006; Landry and Chakraborty 2009; Wolch et al. 2014), this research has also treated the environment in a one-dimensional manner. Few distributive EJ or social vulnerability analysts, however, have examined the role of locational benefits in the distribution of risks across social groups. A handful of EJ studies suggest that employment opportunities—a type of locational benefit that stems from residence near industrial zones—may influence residential patterns of air pollution exposures (Boone 2002; Oakes et al. 1996). Likewise, a few vulnerability analysts have described how exposure to hazards is influenced by associated locational benefits like production and livelihood opportunities, accessibility, and amenities (e.g., Pelling 1999; Wisner et al. 2004). However, the influence of locational benefits on exposure to risks has also been a tangential emphasis of the literature on social vulnerability to hazards.

Locational benefits associated with hazards have been a more central focus of scholarship emanating from the disciplines of psychology and economics than they have from the fields most central to EJ scholarship (e.g., sociology, geography, and public health). The psychology-based risk perception literature reveals that, in the process of making decisions about a place to live, people are influenced by multiple interacting factors, with an important one being the trade-off between the perceived risks and benefits of a location (Slovic 2000). Hazards to which people voluntarily expose themselves (assuming they have some agency) are associated with benefits; otherwise, people would generally avoid risky locations. To the extent that the benefits are perceived as exceeding the risks of high hazard exposure, people may choose to remain at risk (technically-speaking). Technical risk assessments generally find that people tend to accept higher levels of hazard exposure in locations where the associated benefits are high (Slovic et al. 1980). Scenic views and a sense of exclusivity, for example, entice people to live on highly combustible and geologically unstable slopes in Malibu, California (Davis 1998). In contrast to technical risk assessments, people's perceptions of benefits and hazards tend to be negatively correlated; residents typically underestimate hazards in environments where associated benefits are perceived to be greater, which may lead them, even those with relatively low social vulnerability, to accept higher levels of hazard exposure (Alhakami and Slovic 1994, Siegrist and Cvetkovich 2000, Slovic 1987).

Economists have explored spatial relationships between high hazard exposure, environmental benefits, and land values. Along the coastline, flood risk is often associated with environmental amenities such as ocean views and proximity to beaches. Research shows that proximity to shoreline in the U.S. is highly desirable in residential land markets (Earnhart 2001). Bin and Kruse (2006) found that properties located within the 100-year flood zone (with a 1% or greater chance of flooding per year) had significantly higher cash values than comparable properties outside of the 100-year flood zone. They hypothesized

that this counter-intuitive result derives from the close relationship between risk and amenity value in coastal settings. In a subsequent study, Bin et al. (2008) statistically isolated the effects of amenity value and flood risk on property values, providing support for that hypothesis.

In summary, a more detailed analytical consideration of risk mitigation and locational benefits is needed to expand our understanding of the EJ implications of flood hazards. Next, extending from the literatures on EJ and social vulnerability to hazards/disasters, we present an integrated conceptual framework designed to address these two limitations and advance knowledge of socio-spatial influences on exposure to flood hazards, which may be applicable to other types of hazards as well.

EJ implications of flooding: a conceptual model

The conceptual model presented in Figure 1 was developed to make sense of the anomalous relationship found in prior studies between high hazard and low social vulnerability (i.e. high social status or social privilege) in the case of environmental hazards associated with high locational benefits. The conceptual model aims to integrate understanding of such anomalous findings within an expanded conception of distributive environmental justice, which accounts for the roles of locational benefits and mitigation capacities in structuring complex society-hazard relationships. *Divisibility* refers to the ability to separate (geographically speaking) the risks and benefits associated with a hazard (Kates 1971). Theoretically, divisibility plays a pivotal role in spatial relationships between social vulnerability and high hazard exposure. In particular, fundamental differences in *divisibility* may generate divergent social distributions of exposure to flood vs. air pollution hazards. However, divisibility has not been conceptually well integrated in either EJ or vulnerability studies. This relates to the aforementioned lack of consideration of both negative and positive environmental attributes in these two fields. Theoretically, differences in divisibility exist between “natural” (e.g., flood) and “technological” (e.g., sources of toxic air pollution) hazards. The benefits associated with many natural hazards must be consumed in place (i.e., they are not geographically separable), whereas the risks/benefits associated with technological hazards are separable by design. Thus, risks/benefits may typically be less divisible for many types of natural hazards and more divisible for many types of technological hazards.

To conceptualize how divisibility plays a pivotal role in distributive aspects of EJ, it is useful to draw a comparison between air pollution—the most extensively studied hazard in the EJ literature—and flooding. Path (a) in Figure 1 depicts the traditional EJ conception of the relationship between social vulnerability and high residential hazard exposure, in which there is assumed to be relationship between high social vulnerability and high hazard exposure. This model does not account for the divisibility of risks/benefits associated with hazards or people’s (differential) capacities to mitigate hazards, and is based largely on EJ scholars’ empirical analyses of distributive injustices associated with residential exposure to air pollution and other toxic pollution hazards.

Path (b) in Figure 1 depicts our conception of the relationship between social vulnerability and high hazard exposure when the risks and benefits are divisible, as they are in the case of residential exposure to major stationary sources of pollutants like manufacturing facilities. In the case of an industrial manufacturing facility, commodities are produced and distributed for profit and pollution is released into surrounding areas. Nearby residents may be at risk and not benefiting from their proximity to polluting factories, especially when the factories do not provide them with employment. This is an example of how stationary sources of air pollution like manufacturing facilities are characterized by a high degree of divisibility. With respect to environmental hazards in which risks/benefits are highly divisible, proximate locations tend to be less desirable for residential uses and have relatively low land values, which may influence the in-migration of socially vulnerable residents due to the relatively low cost of housing (Been 1994; Oakes et al. 1996; Hernandez et al. 2015). At the same time, socially vulnerable residents typically lack political power and have reduced capacities to mitigate risks of high hazard exposure and, through time, lower value lands near their homes may be continually targeted for development by industries that emit toxic air pollution (Bolin et al. 2005; Cole and Foster 2001; Pulido 2000).

Path (c) in Figure 1 depicts our conception of the relationship between social vulnerability and high hazard exposure when the risks are not divisible from the benefits, as with coastal flood risk. In the case of coastal hazards in particular, risks and benefits are largely indivisible. To optimize beach access and ocean views from the home, a household must live at risk to flooding. With respect to hazard types in which risks and benefits are highly indivisible, socioeconomic factors may influence high hazard exposure indirectly through the capitalization of amenities in land markets. Socially elite groups may reside in locations characterized by high levels of hazard exposure as they are able to garner/implement structural and nonstructural forms of mitigation to minimize risks and protect values (Collins 2008, 2009, 2010; Davis 1998).

Applying the model: comparing the Miami and Houston cases

Recent collaborative work by the authors and their students has focused on the Miami, Florida and Houston, Texas metropolitan areas and illustrates the applicability of our conceptual model to the case of environmental injustice in the context of flood risk. Figures 2 and 3 respectively depict flood the Miami and Houston study areas. This work stems from a U.S. National Science Foundation-funded project on social vulnerability to air pollution and flood risks in the Miami and Houston metropolitan areas. The project took a comparative approach and included the analysis of close-ended survey, in-depth interview and secondary data. We focus specifically on the following EJ-related studies of flood hazards in metro Miami and Houston: Chakraborty et al. (2014a), Grineski et al. (2015), Grineski et al. (2016), Maldonado et al. (2016a), Maldonado et al. (2016b), Montgomery and Chakraborty (2015), and Montgomery et al. (2015). In what follows, we also reference applicable project-related papers focused on air pollution risks in Miami and Houston.

The approximately 6 million people who live in the Miami-Fort Lauderdale-West Palm Beach metropolitan area (Miami) are ethnically diverse, with non-Hispanic White residents accounting for only 32% of the total population, and Hispanics and non-Hispanic Blacks,

respectively, accounting for 43% and 20% of the population (based on American Community Survey 2014 1-year estimates). Miami is also highly residentially segregated along ethnic lines and characterized by some of the highest levels of income inequality in the U.S. In terms of flood risks, metro Miami is one of the most hurricane-prone urban areas in the world. A study of coastal flood risk ranked Miami as first in asset exposure and fourth in population exposure for cities worldwide (Nicholls et al. 2009). The three counties of metro Miami (Broward, Miami-Dade, and Palm Beach) have been ranked first, second, and third, respectively, for flood-induced property damage in Florida (Brody et al. 2007).

With a total population of just under 6.5 million residents, the Houston-Sugarland-Baytown metro area (Houston) is the sixth largest in the US. According to the American Community Survey 2014 1-year estimates, non-Hispanic Whites comprise 38% of the Houston MSA population, followed by Hispanics (36%), and non-Hispanic Blacks (17%). Flooding has posed serious and recurring problems in Houston. Major flood events in Houston were associated with Tropical Storm Allison (2001), Hurricane Rita (2005), and Hurricane Ike (2008). As recently as 2015 and 2016, metro Houston experienced severe flooding that resulted in a loss of human lives, destroyed or damaged thousands of homes, and caused several billion dollars in damage (Yan and Lavandera 2016; BBC 2015). Miami and Houston are thus particularly suitable locales for analyzing the EJ implications of flood hazards. Figures 2 and 3 depict federally-designated flood risk zones within the Miami and Houston metro areas.

Table 1 summarizes the research questions and relevant results from each of the EJ studies related to flood hazards in metro Miami and Houston (additional details are provided in Online Resource 1). In alignment with the conceptual model presented in Figure 1 (path (a)), the EJ studies regarding flood hazards in metro Miami summarized in Table 1 reveal that distributive relationships between social vulnerability indicators (e.g., lower socioeconomic status, racial/ethnic minority status) and flood risk tend to be opposite from the relationships between social vulnerability indicators and air pollution exposure. That is, greater social vulnerability is typically *negatively* associated with residential exposure to flood risk (Chakraborty et al. 2014a; Grineski et al. 2015; Maldonado et al. 2016b; Grineski et al. 2016), while it is generally positively associated with exposure to air pollution (see Chakraborty et al. 2016; Collins et al. 2015a; Grineski et al. 2013; Grineski et al. 2015). Evidence suggests that the divergence in social profiles of risk for residential exposure to flood risk vis-à-vis air pollution is due, in part, to the low divisibility of locational benefits within coastal landscapes from the risks of residential flood exposures (as opposed to the relatively higher divisibility of benefits from risks in the case of air pollution). In Miami, floodable landscapes along the coast are amenity rich and urbanization has been largely structured by the value of coastal access. Indicators of coastal amenity value (e.g., housing cash value, prevalence of seasonal/recreation homes, proximity to public beach access) exhibit robust positive relationships with coastal flood risk (Chakraborty et al. 2014a; Montgomery and Chakraborty 2015), and a pattern of environmental injustice exists whereby socially vulnerable groups experience constrained access to coastal amenities, such as public beaches (Montgomery et al. 2015). When 100-year flood zones in Miami are disaggregated based on inland or coastal zonation, social vulnerability indicators are generally positively associated with inland flood zones and negatively associated with

coastal flood zones (Chakraborty et al. 2014a). These results provide further evidence that the counterintuitive social patterning of exposure to coastal flood risk in Miami is partly contingent upon the indivisibility of amenity values from high risk landscapes. In contrast, inland flood zones—which typically lack the water-based amenities of coastal zones—are characterized by a risk pattern that aligns with traditional EJ expectations.

To fully comprehend the EJ implications of the aforementioned distributive patterns, it is necessary to apply a process-based perspective. While metro Miami is generally at very high risk to flood exposure, the fact that the most socially advantaged residents are concentrated in areas at the greatest risk to coastal flooding suggests that amenity values outweigh the costs of flood risks. In this context, socially privileged residents (e.g., highly affluent non-Hispanic Whites) are able to externalize risks of coastal living to all U.S. taxpayers through insurance coverage offered by the National Flood Insurance Program (NFIP), which provides highly subsidized premiums to residents in high risk coastal flood zones (U.S. Congressional Budget Office 2007). Socially privileged residents of metro Miami typically choose to reside in or near coastal locations because coastal flood risks are mitigated through a variety of public investments (e.g., flood insurance, engineered flood control structures, “beach nourishment” programs, etc.). Thus, the risks of dwelling within coastal zones are offset by institutionally-mediated access to mitigation resources, including flood insurance policies with premiums that are lower than the actuarial costs of flood risks. Additionally, some of Miami’s affluent coastal residents live in high-rise condominiums, which offer vertical protection from ground-level flood impacts.

Indeed, Chakraborty et al.’s (2014a) results align with our conceptual model, in that they suggest that flood insurance subsidization through the NFIP in particular may inflate property values and facilitate residential risk-taking, especially for socially privileged households, because it enables them to externalize risks in their pursuit of coastal amenities. Recent efforts in the U.S. Congress to systematically increase flood insurance premiums to match actuarial rates has generated resistance from representatives of flood-prone coastal districts as well as home construction and real estate industry groups, who argue that planned rate increases will depress real estate markets in areas where flood insurance is currently heavily subsidized by the NFIP. Although increases in flood insurance premiums would likely affect real estate markets in such locations, this reality underscores the fact that NFIP subsidization has indeed facilitated land speculation, housing development, and residential risk-taking in flood-prone coastal locations.

Our research conducted in metro Houston (Grineski et al. 2015; Maldonado et al. 2016a, Maldonado et al. 2016b), provides a comparative basis for assessing the generalizability of our conceptual model. Results from analyses of flood risk in Houston correspond more with expectations based on the EJ literature (Fig. 1, paths (a) and (b)), while results for metro Miami contradict those expectations and align with the conception depicted in Figure 1, path (c). Our EJ research regarding flood hazards in Houston summarized in Table 1 reveals that distributive relationships for social vulnerability indicators with flood risk exhibit similarities to relationships with air pollution exposure; i.e. in Houston, greater social vulnerability tends to be positively associated with residential exposure to both flood risk

(Maldonado et al. 2016a; Maldonado et al. 2016b) and air pollution (see Chakraborty et al. 2014b; Collins et al. 2015b; Grineski et al. 2015; Hernandez et al. 2015).

The best explanation for the divergent findings between Miami and Houston lies in dramatic difference in the role of water-based amenities in structuring patterns of settlement between the two metro areas. In contrast to Miami, residential settlement across Houston is far less structured by water-based amenities, despite that metro area being adjacent to the coast. The main economic activities taking place along the coast bounding metro Houston are associated with the petrochemical industrial complex, which is among the largest in the world and a major source of environmental pollution (Chakraborty et al. 2014b). Such water-based economic activities represent major residential *disamenities*. This implies that many landscapes at high risk to flooding in metro Houston have relatively low water-based amenity value for residents. Those areas consequently tend to be inhabited by more socially vulnerable people, who are placed at high risk not only to flooding, but also health-harming toxics in the forms of chronic emissions and acute releases from nearby petrochemical industrial sources. We hypothesize that the notable disjuncture between water-based residential amenities and flood risk across many metro Houston landscapes is perhaps the reason why our findings there align with traditional EJ expectations. In any case, our somewhat divergent results regarding the EJ implications of flood risk between Miami and Houston suggest that distributive human-flood hazard relationships have been structured differently between the two locales, in part due to the contrasting role that water-based amenities have played in urbanization within the two study areas.

From a process-based perspective, similarities are exhibited in EJ dimensions of flood risk between metro Miami and Houston. As is the case with Houston, some socially vulnerable residents of metro Miami experience high exposure to flood risks, especially within inland flood zones (Chakraborty et al. 2014a), which is of serious concern owing to their generally reduced capacities to prepare for, respond to, and recover from flood events (Maldonado et al. 2016a). Miami is one of the most economically unequal metropolitan areas of the U.S. and also perhaps the most flood-prone. Flood exposure similar to that experienced in New Orleans during Hurricane Katrina would generate highly disparate adverse impacts based on prevailing racial/ethnic and economic inequalities. The presence of socially-disadvantaged groups at risk to flooding in Miami and Houston creates the potential for very high magnitude disasters. Beyond the NFIP, which targets the recovery needs of property owners in particular, protective resources for socially vulnerable groups at risk to flooding in Miami and Houston alike are minimally available, and some highly vulnerable groups (e.g., undocumented immigrant renter-occupants) are fortunate if they are able to access any resources to partially meet their recovery needs (Maldonado et al. 2016a). Without the implementation of genuine need-based programs to ameliorate vulnerability among socially marginal residents of flood-prone areas, the risks of a flood disasters of monumental proportions in both Miami and Houston will remain alarmingly high.

In summary, environmental injustices in metro Miami appear to be (re)produced as socially privileged groups seek to monopolize access to coastal amenities while the added costs of flood risk mitigation are treated as an externality conveyed to the broader public; meanwhile, socially vulnerable groups have been relegated to areas with inland flood hazards and other

environmental health risks (e.g., mosquito-borne diseases). In metro Houston, floodable areas tend to be characterized not by water-based amenities but instead by toxic petrochemical industrial disamenities; as a result, through processes of marginalization, socially vulnerable residents have been concentrated in residential zones with high flood risks. In both metro areas, socially vulnerable residents have largely confined to living in the most polluted zones, where they are less able to access protective resources or enjoy coastal amenities.

Future research should adopt comparative approaches focused on multiple study sites, as different geographic contexts may be characterized by varied types and levels of water-based amenities that select particular social groups to live in areas exposed to flood hazards. While different contexts may be characterized by divergent social patterns of exposure to flood risks, we believe that the conceptual model introduced here provides a valuable heuristic for understanding the EJ implications of flood hazards across a range of contexts.

Conclusions

We conclude by first returning to the two limitations in current EJ scholarship outlined at the beginning: the incomplete conception of risk as high hazard exposure and the underlying assumption that people seek to avoid hazards. Future research on the EJ implications of flood hazards should focus on addressing these limitations. To do so, a process-based EJ perspective focused on unequal power relations and differential capacities to mitigate hazards should be integrated within distributive EJ analysis in order to foster a more comprehensive understanding of flood risk. Distributive EJ analysts should consider the differential capacities of individuals and social groups to mitigate flood risks by deploying or appropriating resources (e.g., from their own reserves or through access to social-protections made available through institutions), in order to enhance their security and reduce the threat of loss, even while residing in flood-prone environments. While socially elite residents may voluntarily expose themselves to flood hazards in their pursuit of environmental amenities, they are often able to externalize risks by harnessing a disproportionate share of the flood mitigation resources redistributed by state and market institutions to support flood preparedness, response, recovery and reconstruction (Collins 2010). It would be erroneous to infer that such social elites suffer environmental injustices even though some may experience acute flood impacts. In fact, one should arrive at precisely the opposite inference, i.e. that social elites living in scenic, flood-prone environments are beneficiaries of environmentally unjust processes (Collins 2010). Such situations highlight limitations to the one-dimensional conception of the *environment as hazard* (or, alternatively, as *amenity*), which is employed (often tacitly) in EJ research.

Second, the reality that flood-prone environments typically reflect both positive and negative attributes necessitates that researchers examine the EJ implications of both flood hazards *and* water-based benefits, when making inferences regarding distributive (in)justices. Expanding upon the conceptual model introduced in Figure 1c, landscapes are often simultaneously environmentally attractive and biophysically dynamic, and, the risks instantiate an obstacle to accumulation for elite social groups (i.e., those of the lowest social vulnerability). Increasing the exchange value of private property and consuming the use values of coastal

environments while averting flood risks necessitates the enlistment of state and market institutions to redirect the appropriated social surplus toward mitigating flood risks. Thus, analysts of the EJ implications of flood risks should direct their attention to the multidimensional character of flood-prone environments, with recognition that counterintuitive socio-spatial patterns of exposure to flood hazards may result from processes founded on highly uneven power relations.

In addressing these two limitations, EJ analysts should also integrate distributive and procedural approaches with a focus on pattern-process linkages in order to more fully comprehend environmental injustices in the context of flood hazards, as well as other unevenly distributed environmental risks and resources. The fact that seemingly contradictory social patterns of exposure to hazards can flow from environmentally unjust processes supports the point that pattern-process linkages merit closer attention in EJ research. Multiscalar, mixed methods, and comparative research approaches should be integrated in empirical studies of distributive and procedural EJ. In addition to quantitative analyses of aggregated socio-demographic data for census-designated areal units, there is a need to focus on people's decision-making regarding costs and benefits associated with flood-prone residential locations, including their subjectivities and differential material constraints, in order to characterize the environmental injustices they experience. Such micro-scale research demands the inclusion of qualitative methods, which are best suited to uncovering complex, situational and subjective factors that influence experiences of injustice in the context of flood hazards, and have been underutilized (Hernandez et al. 2015). Qualitative approaches hold the potential to more fully explain patterns that have been identified in quantitative distributive EJ studies and provide more detailed insights on the EJ implications of flooding. Analysts must also recognize that contemporary patterns of risk exposure across social groups articulate with macro-scale historical-geographical processes. An explicitly multiscalar perspective on environmental injustice, has not been widely adopted or implemented by EJ scholars. Given the complex EJ implications of flooding, there is a growing need for EJ scholars to embrace a multiscalar perspective that fosters insights into how distributional injustices are actively (re)produced through the articulation of constraining and enabling forces.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors recognize Marilyn Montgomery, Alejandra Maldonado, Maricarmen Hernandez, Jose Castañeda, Sofia De Anda, and Dorian Payan for their work on various facets of the project from which this article extends. The authors acknowledge U.S. National Science Foundation (NSF) grants CMMI-1129984 and CMMI-1536113 for funding this work. The content is solely the responsibility of the authors and does not necessarily reflect the views of the NSF.

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Figure 1.

Conceptual model of the relationship between social vulnerability and high hazard exposure:
 (a) traditional EJ, (b) air pollution exposure, and (c) coastal flood risk

Figure 2.
The metropolitan Miami study area

Figure 3.
The metropolitan Houston study area

EJ studies related to flood hazards in metro Miami and Houston: research questions and results

Table 1

Study	Research Question(s)	Significant Results (related to flood hazards)
Chakraborty et al. (2014a)	<ul style="list-style-type: none"> Is flood risk distributed inequitably with respect to race/ethnicity and socioeconomic status? Are relationships between flood risk and race/ethnicity and socioeconomic status influenced by type (inland vs. coastal) of flood risk zone? 	<p><u>Miami</u></p> <ul style="list-style-type: none"> 100-year and inland flood risk are associated with higher percentages of black and Hispanic residents 100-year flood risk is associated with higher median housing value (an indicator of amenity value) Inland flood risk is associated with lower median housing value and a reduced prevalence of vacation homes (both indicators of amenity value) Coastal flood risk is associated with <i>lower</i> percentages of black and Hispanic residents, and <i>higher</i> median household income; however, when adjusting for the strong positive effects of amenity values (housing value and vacation homes), coastal flood risk is associated with <i>higher</i> percentages of black and Hispanic residents, <i>lower</i> household income, and higher poverty rates
Grineski et al. (2015)	<ul style="list-style-type: none"> Are there patterns of environmental injustice with respect to economic deprivation (insecurity and instability), race and ethnicity for 100-year flood risk and chronic cancer risk from air toxics? 	<p><u>Miami</u></p> <ul style="list-style-type: none"> 100-year flood risk is associated with less economic insecurity and lower percentage of black residents <p><u>Houston</u></p> <ul style="list-style-type: none"> 100-year flood risk is associated with lower percentages of black and Hispanic residents
Maldonado et al. (2016a)	<ul style="list-style-type: none"> What differences exist in self-protective actions and perceptions of risk between Hispanic immigrants, US-born Hispanics, and US-born white residents who live at high risk to flooding? Why do differences in self-protective actions and perceptions of risk exist between the three groups? 	<p><u>Miami and Houston</u></p> <ul style="list-style-type: none"> Hispanic immigrants exhibit lower levels of self-protection from flooding and higher perceptions of flood risk Lower levels of self-protection among foreign-born Hispanics are influenced by high rates of renter-occupancy, constrained access to resources (due to disadvantaged socioeconomic and immigration status), and a deficit in hazard-specific knowledge (due to linguistic isolation and inadequate information dissemination) Higher flood risk perceptions among Hispanic immigrants are influenced by their amplified vulnerability, as reflected in their precarious positionality (in terms of socioeconomic status, immigration status, and housing-tenure arrangements) and the barriers they face in self-protection
Maldonado et al. (2016b)	<ul style="list-style-type: none"> Are Hispanic immigrants disproportionately exposed to flood risks, adjusting for other race/ethnicity categories, housing tenure, socioeconomic status, flood self-protection, flood risk perception, and the desire to live near water-based amenities? 	<p><u>Miami</u></p> <ul style="list-style-type: none"> 100-year flood risk is associated with being non-Hispanic White (as compared to being Hispanic immigrant), having higher socioeconomic status, and having flood insurance <p><u>Houston</u></p>

Study	Research Question(s)	Significant Results (related to flood hazards)
		<ul style="list-style-type: none"> 100-year flood risk is associated with being Hispanic immigrant (as compared to being US- born Hispanic, non-Hispanic black, and non-Hispanic white), having less property-level flood hazard mitigation, and having lower perceptions of flood risk
Montgomery & Chakraborty (2015)	<ul style="list-style-type: none"> Are there social inequities in the distribution of coastal and inland flood risks, adjusting for water-related amenities? Do distributive inequities in exposure to coastal and inland flood risks differ when treating the Hispanic population as a single ethnic group vs. disaggregating the Hispanic population into relevant subgroups? 	<p><u>Miami</u></p> <ul style="list-style-type: none"> Inland flood risk is associated with higher percentages of Hispanic (especially Colombian and Puerto Rican) and black residents, lower prevalence of vacation homes, and less proximity to beach sites Coastal flood risk is associated less economic insecurity, higher prevalence of vacation homes, and greater proximity to beach sites
Montgomery et al. (2015)	<ul style="list-style-type: none"> Are there social inequities in access to public beaches? 	<p><u>Miami</u></p> <ul style="list-style-type: none"> Greater public beach access is associated with a higher percentage of white residents, lower percentages of black and especially Hispanic residents, and less economic insecurity
Grineski et al. (2016)	How do hazard characteristics (i.e., suddenness of onset, frequency/magnitude, and divisibility) influence relationships between socially vulnerability and hazard exposure?	<p><u>Miami</u></p> <ul style="list-style-type: none"> Greater flood exposure is associated with higher socioeconomic status.