The Demography of Disasters

Elizabeth Frankenberg
Duke University

Maria Laurito
Duke University

Duncan Thomas
Duke University

June 2014

Abstract

The frequency and magnitude of large-scale disasters in recent years has prompted increased interest in better understanding how major disruptive events alter key demographic processes. This article summarizes evidence establishing that disasters have significantly impacted mortality, health, fertility, and migration. While these processes are intimately inter-related, there have been relatively few integrative analyses that draw the evidence together, in large part because of inadequate data. Investment in population data collection systems to provide scientific evidence in the wake of disasters will broaden the depth and scope of disaster research, advance understanding of demographic changes, and inform policy interventions.

1. Introduction

The past decade has seen multiple large-scale natural disasters. These events, in combination with predictions that such events will increase in frequency as a result of global warming and rising population densities in vulnerable areas, have catalyzed interest in how affected populations respond to disasters, the effectiveness of emergency response programs and whether emergency or longer-term assistance programs alter the life course trajectories of those affected by disasters.

Both disasters and recovery efforts have the potential to affect many outcomes of interest to social and health scientists. Accordingly, a wide array of disciplines has contributed to the study of disasters. We thus begin with a brief review of definitions of disasters and approaches to their study. This chapter focuses on the relationship between disasters and demographic phenomena. We therefore focus on mortality, fertility, and migration. These are three key demographic outcomes that are affected not only by disasters themselves but also by policies and programs implemented both before and after disasters.

2. The Study of Disasters

Disciplinary Approaches

Efforts to define disasters and use these definitions to shed light on various social, health and demographic phenomena have a long history in the social sciences, particularly in sociology, geography and epidemiology. Early sociological work on disasters focused on understanding collective behavior under high-stress conditions, taking the approach of dispatching researchers to stricken communities to observe post-disaster dynamics as they unfolded (Fritz and Marks, 1954). Although areas of emphasis have varied over the years, understanding how disasters strain social systems has remained a focus of this research (Quarantelli, 1989; Dynes, Tierney, and Fritz, 1994; Klinenberg, 2002; Browning et al., 2006; Tierney 2007). Within geography, efforts have centered more on the vulnerability of human physical systems to hazards (Gray et al., 2014; NAS, 2006) and on how to increase resilience of human systems, most frequently by studying one or a small number of communities. Disaster epidemiology provides timely assessments of the short and long-term impact on health, broadly defined, and seeks to improve prevention and mitigation strategies (Guha-Sapir and Hoyois, 2012).

In many other disciplines, disasters are viewed through a broader lens. For example, in the economics literature, disasters are often treated as part of a more general class of "shocks," or unexpected changes. Shocks have been used to make inferences regarding the extent to which individuals are able to protect themselves, their families and their communities from unexpected events with potentially adverse consequences (Townsend, 1995). A related literature exists in demography, although the focus is on demographic outcomes, and larger-scale macro events with the potential to affect whole populations have received more attention (see for example, Heuveline's innovative reconstruction of the Cambodian population after the Khmer Rouge regime (Heuveline 1998, 2001, 2007). Economic and demographic analyses have tended to prioritize representativeness at the population level, and typically draw comparisons on a larger scale than geographic or purely sociological approaches. Finally, a large body of work in psychology and epidemiology examines the implications of disasters for various mental and in some cases physical health outcomes, most frequently through the analysis of survey data of varying degrees of representativeness (Armenian, Melkovian, and Hovanesian, 1998; Cao, McFarlane, and Klimidis, 2003; Norris et al., 2006).

Definitions of Disaster

Many definitions of disaster have been proffered over the years, generating a great deal of debate (Quarantelli, 1989, 2005). Most definitions recognize disasters as phenomena that arise from an unusually extreme precipitating event that is concentrated in time and space and that overwhelms local or, in some cases, larger-scale systems. Over time definitions have increasingly recognized the importance of social construction in whether an event is interpreted as a disaster.

From a perspective based in sociology, Kreps (2001) defines disasters as "non-routine events in societies that involve conjunctions of physical conditions with social definitions of human harm and social disruption" Several important elements of this definition warrant highlighting. First, according to this definition, disasters do not occur without people and the social systems they create. Second, chronic conditions, such as poverty, are not considered disasters. In some contexts, wars, genocides, famines, disease outbreaks and weather-related events like floods, hurricanes and tornadoes fit naturally into this definition. However, it is important to be precise about "non-routine". In some parts of the world, these types of events have become all too routine. In those cases, it is necessary to appeal to an argument that the

incidence may be routine but the precise timing or the severity of the event is not routine in order to apply this definition of a disaster. Alternatively, studies have treated the onset of such events as a disaster.

Disasters typically involve significant loss of resources and threats to - or actual loss of - life. The combination of these factors may result in a humanitarian crisis. Some studies have tried to classify precipitating events into various typologies, for example whether they arise from environmental phenomena such as geophysical forces or weather, or from technical or willful actions. Sociologists' emphasis on understanding shifting social processes caused by disasters, beyond studying the catastrophic event itself, has resulted in the evolution of the set of events that are included within the rubric of a disaster, in particular as new findings related to social impacts have emerged (Herring, 2013). It is widely recognized that the interaction of the physical events with characteristics of the affected societies, such as the nature of housing and patterns of land use, plays a fundamental role in how disasters unfold.

Other important and distinguishing features that vary across disasters are the magnitude, scope and duration of the event, the degree of advance warning available to the population at risk, and the precision with which the event can be predicted. As an example, the 2004 Indian Ocean tsunami that hit the island of Sumatra, Indonesia, and Hurricane Katrina (that affected the U.S. gulf coast) were very different with respect both to whether the event was (or could have been) predicted and the amount of time that those likely to be affected had to prepare for the onslaught of the water. The tsunami hit some coastlines of Indonesia within minutes of the earthquake, whereas, residents of New Orleans were warned about the approaching storm several days before Katrina made land fall (Munasinghe, 2007). Moreover, whereas hurricanes have been a part of the history of New Orleans since it was settled in the early 18th century, geological evidence indicates that there have been no tsunamis along the coast of Sumatra for over six centuries.

3. A Framework for Considering Disasters' Demographic Impacts

Demographers have examined disasters largely when their consequences occur at a scale with the potential to affect regional or national populations. Key parameters of interest are typically mortality, health, fertility, and migration, which in turn have implications for population size and composition.

The most dramatic link between disasters and demography is arises in those disasters that cause substantial numbers of deaths. The risk of death in a disaster may vary by age and sex, reflecting differences in vulnerability across these dimensions as a result of physical differences or likelihood of exposure. Socioeconomic status may also be associated with risks of exposure such as when the poorest live in particularly vulnerable areas (such as flood plains) or when damage caused by the disaster depends on the quality of housing (as might be the case for earthquakes or tornadoes). In addition to immediate deaths, disasters may have longer-term or indirect effects on mortality through their effects on health status or its drivers.

Disasters also have the potential to displace people, either because people move preemptively, or because the disaster affects their property or source of livelihood in ways that make remaining in the affected area unattractive or impossible. After disasters, displaced individuals may return, and others may move into the area, attracted by opportunities of various forms.

Though the mechanisms are less immediately obvious, disasters can also change fertility patterns. Disasters and the associated stress can affect coital frequency and potentially the ability to conceive a child or carry a pregnancy to term or they can change the demand for children. Disruption of services could also affect access to contraception. Disasters that result in large numbers of death may be followed by increased fertility. Finally, if the disaster changes the age and sex composition of the population as a result of mortality or migration, patterns of union formation may change in ways that alter fertility trends.

Several implications of the preceding discussion are worth drawing out in a little detail. First, although disasters typically begin with a precipitating event that can be pinpointed precisely in time, and often in space, temporal and spatial end points of disasters' impacts are not so cleanly delineated. Effects may be felt for a far longer time scale, and over a far greater geographic area than that within which the disaster causes physical damage. A corollary is that the longer-term effects of a disaster may well reach far beyond those who were directly. For example, a disaster that affects the local area population composition may also affect the labor and marriage markets on a wider scale. Furthermore, a disaster that is followed by in-migration from other areas clearly affects not only the affected population and the migrants but also the communities from which the migrants have moved.

Second, the demographic processes we have discussed above are connected in myriad ways. To provide just a few examples, decisions to move are likely to be affected by household structure and decision-making processes which are, themselves, directly altered by mortality. Loss of kin and migration can affect stress levels, health, the desire for children, and the ability to conceive and bear children. Relatively few analyses consider these inter-linkages, in part because few studies collect information on a broad set of potentially relevant behaviors and outcomes; fewer studies have successfully followed the trajectories of individual, families and communities affected by disasters over time.

Third, although we have emphasized the negative impacts of disasters, it is important to note that to the extent that disasters change opportunities, some of these changes may have positive consequences for individuals and communities. As disasters destroy land, housing or infrastructure in one area, the value of comparable land, housing or infrastructure is likely to increase. Disasters are often followed by reduced access to food and shelter: those who can provide food or shelter are potential beneficiaries of this misfortune. In many cases, these are provided by governments or non-government organizations as assistance. Indeed, assistance programs, themselves, may provide opportunities that change outcomes in positive ways as, for example, the programs buy food from local farmers. Other policy changes may affect longer-term outcomes and diminish the potential for known hazards to turn into large-scale disasters in the future. More generally the policy environment can affect demographic phenomenon associated with disasters in significant ways.

4. High Impact Disasters of the Last Decade

Before turning to evidence regarding demographic change in the context of disasters, we review the scope of disasters that have occurred over the last decade, based on two indicators of impact, the death toll and the estimated value of property damage.

The table below summarizes impacts for the five disasters that are estimated to have had the highest number of deaths over the past decade (Panel A) and the five disasters that are estimated to have had the greatest damage measured in financial terms (Panel B). Of course, financial estimates of damage are, at best, rough; the table is intended to provide an illustration of the magnitudes that are involved.

Table 1. Death and Property Destruction

Country	Year	Type of disaster	Deaths	Affected Population	Damage[1] (US$ Million)
A. Costliest for Lives					
South and Southeast Asia	2004	Earthquake/ Tsunami	225,841	2,273,723	7,791
Indonesia			*165,708*	*532,898*	*4,452*
Sri Lanka			*35,399*	*1,019,306*	*1,317*
India			*16,389*	*654,512*	*1,023*
Thailand			*8,345*	*67,007*	*1,000*
Haiti	2010	Earthquake	222,570	3,700,000	8,000
Myanmar	2008	Cyclone Nargys	138,366	2,420,000	4,000
China	2008	Earthquake	87,476	45,976,596	85,000
Pakistan	2005	Earthquake	73,338	5,128,309	5,200
B. Costliest for Property					
Japan	2011	Earthquake/Tsunami	19,846	368,820	210,000
United States	2005	Hurricane Katrina	1,833	500,000	125,000
China	2008	Earthquake	87,476	45,976,596	85,000
United States	2012	Hurricane Sandy	154	8,500,000[2]	65,000
Chile	2010	Earthquake	562	2,671,556	30,000

Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, University of Louvain, Brussels (Belgium). NOAA: "Billion-Dollar Weather/Climate Disasters" - www.ncdc.noaa.gov/billions/events

[1] The estimated damage is dollars of the year of occurrence.

[2] Estimate based on affected power consumers in the US, Tropical Cyclone report, Hurricane Sandy, National Hurricane Center, 2013 - http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf

With respect to mortality, the deadliest disaster was the 2004 Indian Ocean tsunami, which cost over 225,000 people their lives in Southeast and South Asia. The 2010 Haiti earthquake killed over 222,000, followed by Cyclone Nargis (138,366). Two other earthquakes, in China and Pakistan, caused tens of thousands of deaths as well.

With respect to property damage (measured in dollars of the year of the event), the earthquake and tsunami that hit Japan tops the list. Estimated property damages were approximately $US 210 billion, and Hurricane Katrina caused damages of $US 125 billion,according to data from the Center for Research on the Epidemiology of Disasters (CRED) at University of Louvain. The 2008 earthquake in China is the only disaster that appears in both panels, which points to an interesting feature of disasters: the deadliest are not necessarily the costliest in terms of property damage. Instead, the highest costs have accrued in high- or medium-income countries, and in three of those disasters the numbers of deaths were quite low.

How such a table will look in a decade is unknown. On the one hand, if the various hazards mitigations and emergency preparedness policies that have reduced death tolls in industrialized countries can be implemented in a greater number of developing countries, death tolls from disasters may diminish. On the other hand, the size and density of populations in areas vulnerable to extreme geophysical or meteorological events is growing, which increases the number of people at risk of exposure.

The table is based on estimates aggregated to the national level. While useful as summary evidence regarding scale, the numbers shed little light on the full demographic impact of these events, let alone processes and mechanisms linking disasters to demographic change over the longer term.

Indeed, a major barrier to studying the demography of disasters is the relative scarcity of appropriate data. Many studies are based on relatively small-scale unrepresentative samples of individuals clustered into camps or other highly-visible housing arrangements. Other studies use interviews of those who have remained behind in the affected areas. Typically, interviews are conducted once, shortly after the disaster. It is difficult to draw firm conclusions about the impact of the disaster on processes of population change with these types of data. The complexities of collecting population-representative data that characterize the periods both before and after the disaster, that span a continuum of destruction, and that follow movers to destinations other than camps, have severely limited the representativeness of study samples,

sample sizes, and follow up periods of available data (Sastry and Vanlandingham, 2009; Galea and Maxwell, 2009).

5. Demographic Processes and Outcomes

In this section we review the evidence for linkages between disasters and various demographic outcomes.

Mortality and Morbidity

As shown in Table 1, disasters can cause loss of life on a massive scale. The extent of mortality caused by disasters varies depending on factors such as type of disaster, location, and timing. Counts of the dead and missing may not be accurate and in some cases these rough estimates may not be finalized into an official death-toll. Whether deaths have a meaningful impact on population size depends, in part, of the extent to which mortality is spatially concentrated. Mortality rates can help clarify impact, but their calculation requires information on the number of individuals exposed as well as the number dead—information that is not always available.

Risk of mortality may vary by age and sex in ways that differ across disasters. Several studies provide evidence that the Indian Ocean tsunami was associated with higher mortality for women than for men, and for the young and old. For example, based on a survey representative of pre-tsunami population, Frankenberg et al. (2011) show that mortality was lowest among men aged 20 to 44 years. Mortality rates were significantly higher for same-aged women, and higher still for children and teenagers, and for older individuals. It is likely that these differences reflect differences in strength and ability to swim since exposure to the tsunami is unlikely to vary by demographic group. Similar results are also reported for Sri Lanka following the 2004 Indian Ocean tsunami, where women and children experienced higher mortality compared to adults aged 20 to 29 years (Nishikiori et al., 2006).

These mortality patterns are unusual. They are not observed for the tsunami in Japan, where mortality was lower for school-age children than for individuals of other ages, and there are no significant differences in tsunami-related mortality between men and women (Nakahara et al., 2013). Nor do they describe mortality in Haiti following the 2010 earthquake, where mortality was highest among those aged 18 and younger. In Haiti, about two-thirds of deaths were children younger than 12 years. Not only did children suffer higher mortality rates during the earthquake, they were also more likely to die from injuries and illness in the aftermath of the

disaster (Kolbe et al., 2010). In contrast, mortality rates associated with Hurricane Katrina were highest among older adults (those 75 years or older), mostly due to these people not leaving the affected areas prior to the hurricane and ultimately drowning in the water (Brukard et al., 2008).

Beyond mortality, disasters can affect health, with the nature of the impacts contingent on the characteristics of the event. Earthquakes often cause multiple injuries, including lacerations, fractures, contusions, chest and neurological problems, and potential cardiovascular issues (Bartels and VanRooyen, 2011). Health problems triggered by a disaster can continue in the long-term. Residents of Louisiana and Mississippi experienced an increases in headaches, nausea and digestive ailments, and respiratory and cardiac problems after Katrina (Adeola and Picou, 2012). Longer-term effects may be particularly important when the disaster creates additional health and environmental hazards, such as chemical, oil or radiation spills.

The psychological, physical and economic stresses associated with disasters can also affect birth outcomes for children born to women who are exposed while pregnant, and potentially these children's longer term health outcomes. Evidence from offspring of women pregnant during the Dutch Hunger Winter indicates that extremely low caloric intake during the pregnancy results in reduced weight at birth, shorter stature as an adult, elevated risk of cardio-vascular disease in mid life and premature mortality. These results have been interpreted as being driven by the impact of the *in utero* nutritional insults through plausible biological pathways and have also implicated the post-natal nutrition environment. (Stein 1975, Ravelli et al. 1998, Ravelli et al. 1999, Roseboom et al. 2001, Rooij et al. 2010).

Several studies have explored the impact of natural disasters such as droughts or floods that occur in utero or in early life and established these events can have effects that reach well into adulthood (Foster, 1995, Maccini and Yang, 2009). Other studies have investigated the impact of large-scale outbreaks of infectious diseases, most prominently, the 1918 influenza pandemic. Arguing the pandemic was unanticipated, Almond (2006) concludes that *in utero* exposure to the pandemic resulted in worse socio-economic outcomes in adulthood relative to those surrounding cohorts that were not exposed. However, Brown and Thomas (2014) establish that the parents of the cohorts exposed to the pandemic were also of lower socio-economic status relative to the parents of the surrounding cohorts which complicates interpretation of the evidence. This highlights the general issue of the centrality of establishing whether a disaster is anticipated when interpreting the evidence. If the disaster is anticipated (or anticipatable),

estimated effects likely reflect a combination of the impact of the disaster and potential behavioral responses in anticipation of the disaster.

Other studies have sought to investigate the relationship between stressful experiences during pregnancy and the physical health of offspring. These studies use quasi-experimental designs, drawing on some unexpected source of stress, such as acts of terror or war (Lauderdale 2006, Camacho 2008), an epidemic of crime (Brown 2014), earthquakes (Torche 2011) or hurricanes (Currie and Rossin-Slater, 2012). Using birth record data, they compare outcomes at birth of children *in utero* at the time of the event with outcomes of comparison children who were not exposed *in utero.* While the findings are consistent with the hypothesis that stress exposure affects birth outcomes, the estimated impacts are generally very small in magnitude and clinically unimportant. Moreover, many of the studies use large samples and the statistical significance of the estimated effects is not clear.

Morbidity after disaster extends beyond physical health. Studies in psychology and epidemiology have documented a number of systematic patterns of post-disaster mental health. Studies assess a variety of specific and non-specific psychological problems, but post-traumatic stress, depression, and anxiety are the most common ones regardless of the nature of the disaster (Norris et al., 2002; Norris and Elrod, 2006).

Relatively few studies are able to examine changes in psychological symptoms over time, but among those that do, most find that symptoms improve (Norris et al., 2002; Pietrzak et al., 2012). Data from the Galveston Bay Recovery Study (GBRS) shows that individuals exposed to Hurricane Ike had symptoms consistent with PTSD, anxiety, and panic but that prevalence of these symptoms declined with time (depression remained stable across waves) (Pietrzak et al., 2012). Similar evidence has been reported for Indonesians affected by the Indian Ocean tsunami (Frankenberg et al., 2014).

Migration and Relocation

Migration, whether voluntary or impelled, is a potentially strong factor in reshaping populations after a disaster. In the context of disasters, population movements encompass temporary and permanent migration, both out of and into disaster-affected areas. Destinations can include unaffected areas (where the displaced may or may not have family or friends) as well as locations relatively nearby the impacted area where formal and informal camps may be established. But residents may also choose to stay where they were living at the time of the

disaster, even if the area was badly affected, and new groups may move in, particularly if they perceive opportunities (most likely work-related) associated with relocating.

Migration decisions are affected by damage to the built and natural environment, among other things. Massive destruction displaces victims from their homes, potentially for extended periods of time. The 2010 earthquake in Haiti destroyed an estimated 24.4 percent of homes, and damaged 41.5 percent. About 1.24 million Haitians were relocated to temporary settlements (Kolbe et al., 2010). Overall, it is estimated that Port-au-Prince lost 23 percent of its permanent residents.

Using an unusual methodology that relies of mobile phone data to study migration patters in Haiti following the earthquake, Lu et al. (2012) analyze movements of 1.9 million phone users for up to one year after the earthquake. They show that shifts in location were more predictable than originally anticipated. Movements were closely related to patterns that predated the earthquake and were associated with location of social support networks.

Hurricane Katrina is another disaster that caused an almost unprecedented level of relocation of people in the United States, with some 1.5 million people emigrating from affected areas (Groen and Polivka, 2010). For residents of heavily damaged and low-income communities, opportunities to return to New Orleans were highly constrained by resource availability and the degree of destruction to their homes. Using a representative sample of pre-Katrina residents of New Orleans, Fussell et al. (2010) show that black residents experienced higher rates of housing damage, which often delayed their return to the city and contributed to reshape demographic characteristics post-disaster. Relying on data from the Current Population Survey, Groen and Polivka (2010) show that age, family income, and magnitude of damage at the county level significantly conditioned return of displaced populations even a year after the hurricane.

As discussed briefly above, some outcomes linked to disasters may have unexpected positive elements. Hurricanes Katrina and Rita caused massive migrations of students from low performing to higher quality schools. After initial drop in median test scores, performance quickly recovered and by 2009 median tests scores for movers had rose by 0.18 standard deviations (Sacerdote, 2012).

Overall, Hurricane Katrina served to accelerate an ongoing reduction of the population of New Orleans (Zaninetti and Colten, 2012). In some cases, however, disasters do not result in significant population shifts. Using data collected from 291 tornado victims in Bangladesh, Paul

shows that for the most part victims of this event decided to remain in affected areas, where they were likely to receive recovery assistance—an example of how post-disaster programs can generate their own demographic impacts (Paul, 2005).

Gray et al. (2014) compare mobility strategies among individuals living in small local areas that sustained different degrees of damage caused by the 2004 Indian Ocean Tsunami in Indonesia. Those analyses call into question several common assumptions in the literature. For one thing, many individuals from heavily damaged areas did not move to IDP camps. More than half of the population either relocated to private homes or stayed in their community weathering adverse living conditions. Outside the heavily damaged zone, there was movement among individuals from areas relatively untouched by the tsunami , and regardless of origin area, mobility was higher for the better educated. These data underscore the likely value-added of studies that are designed to be population representative and capture both immediate impacts of disasters as well as responses to disasters over time.

Disasters can also attract new residents to damaged areas, especially if reconstruction efforts create employment opportunities. Given data limitations it can be difficult to differentiate between returning and new migrants. Analyses of population structure of New Orleans after hurricane Katrina show an increase in the percentage of Hispanic residents compared to pre-disaster levels (Groen and Polivka, 2010). Using census data from 2000 and 2010, Zaninetti and Colten (2013) estimate the Hispanic share of the population in New Orleans increased by 57 percent while the hurricane accelerated the decline of the black populationLatino immigrants took advantage of high demand of construction labor in the aftermath of Hurricane Katrina to relocate to New Orleans. Using a sample collected within 5 and 7 months after Katrina, Fussell (2009) shows that Hispanic immigrants moving to the area were younger and had weaker social networks, and were often of Brazilian and Mexican origin.

Fertility, Reproductive Health, and Family Change

Disasters have the potential to affect fertility, reproductive health, and family change through a variety of mechanisms. Most proximately, high mortality disasters may change family composition. Adult deaths can leave young children without parents and create widows and widowers, who may or may not remarry. The 1958-61 famine in China is an example of an event that had significant consequences for family demography. During the famine period, fertility and marriage rates declined, while divorce rates and family division increased (Zhao and Reimondos,

2012). It is not clear that the entire three year famine can be treated as unanticipated which complicates interpretation of the results.

However, the Indian Ocean tsunami caused similar disruption to families. Using a population-based survey for Indonesia, Frankenberg et al. (2011) estimate that about 10 percent of children lost a parent, and 10 percent of survivors lost a spouse. Deaths of children may leave parents with fewer offspring than they planned for and desire. On the other hand, when disasters cause high mortality, they are also likely to destroy assets and livelihoods, which may leave unmarried adults feeling less prepared to enter a union and couples feeling less prepared to provide for another child.

Even when disasters do not result in substantial mortality, they may prompt family change. Using a theoretical framework guided by work in psychology on stress and attachment, Cohan and Cole (2002) analyze rates of marriage, birth, and divorce before and after Hurricane Hugo, in affected and unaffected South Carolina counties. In counties declared disaster areas, rates for each of these outcomes rise and then fall. These changes do not occur in other counties, leading the authors to suggest that exposure to a life-threatening event prompted significant actions and measurable changes with respect to close relationships.

Potential changes to fertility can also be considered through a proximate determinants framework. Stress-affected populations may experience changes in coital frequency, rates of conception, miscarriages, and stillbirths. With respect to pregnancy outcomes, the Chinese famine resulted in a significant increase in stillbirths and miscarriages. By the end of the famine period, only 92 percent of pregnancies resulted in live births, down from more than 95 percent in 1958 (Zhao and Reimondos, 2012). Deterioration of physical health in the case of the famine also contributed to delays in reproductive development of young girls, and reduced rates of breastfeeding (Zhao and Reimondos, 2012). Evidence from the 2004 Indian Ocean tsunami suggests that in the months following the disasters, rates of miscarriage rose for women from badly damaged areas (Hamoudi et al., 2012).

On the other hand, destruction of facilities and services may reduce access to contraception, leading to unintended births. Just as disasters destroy homes, shocks caused by disasters can create significant disruptions in infrastructure and complicate access to contraceptive supplies. Following the 2004 Indian Ocean Tsunami there were significant issues with health infrastructure (public and private health centers and midwifery). Frankenberg et al. (2014) show that for many communities disruptions in health facilities extended for at least a

month and their reopening did not necessarily imply resumption in contraceptive supply. Midwifery services also suffered interruptions, in particular in communities where midwifes were among tsunami casualties.

Literature exploring empirical links between contraceptive availability after disasters and behaviors is limited. Some evidence shows disasters may result in the substitution from more- to less-effective family planning alternatives, with a resulting increase in unplanned births. In a retrospective study of 450 women in the aftermath of the 2006 earthquake in Yogyakarta, Indonesia, Hapsari et al. (2013) uncovered evidence of increased usage of less effective contraceptive methods, which was accompanied by a subsequent rise in unplanned pregnancies in the year following the earthquake. Because the earthquake caused damage to over 200 health facilities, the authors conclude that shortage in access likely explains substitution of contraceptive methods. This evidence is consistent with studies that document increased fertility as a response to disruptions (availability, price) in contraceptive supply (Salas, 2013; Potter et al., 2013; White et al., 2012). In the case of service disruptions in Indonesia following the tsunami, Frankenberg et al. (2014) show lower uptake and higher discontinuation of family planning services among married women in heavily damaged areas. Changes in contraceptive usage were also predominant among women who desired more children; however, the authors do not find conclusive evidence of an increase in unintended fertility triggered by issues in supply of contraception.

Change in contraceptive use after a disaster may reflect changes in demand rather than supply. Loss of resources at the community and individual level may discourage couples from pregnancy and childbirth under precarious conditions (Carballo, 2005). On the other hand, child deaths may encourage parents to increase fertility, which in turn would reduce demand for family planning options (Preston, 1978; Zhu et al., 2013; Nobles et al., 2014).

In terms of linkages between demographic processes prompted by a disaster, the evidence base in the demography literature does not fully characterize fertility responses to large-scale mortality caused by disasters (Hill, 2004). Some of the best evidence comes not from disasters, but from wars and conflict. Decreases in fertility, either overall or for more- relative to less-affected subgroups, during conflicts accompanied by major social upheaval have emerged in a number of studies (Lindstrom and Berhanu 1999; Caldwell 2004; Agadjanian and Prata 2002; Blanc 2004; Heuveline and Poch 2007). In some instances the end of the conflict is accompanied by a fertility increase. Famines are characterized by a similar temporal fertility pattern, as

evidenced by studies from the Netherlands, China, and Bangladesh (Stein and Susser 1975; Ashton et al. 1984; Watkins and Menken 1985).

Relying on retrospective birth histories Heuveline and Poch (2007) show a significant decrease in fertility during the years of Khmer Rouge regime (1975-1978), a sharp increase afterwards (1978-1980), and a subsequent decline. Based on this fertility pattern the authors conclude that the significant increase in fertility was a direct response to heightened mortality during the conflict.

Isolating proximate mechanisms and disentangling whether fertility increases represent fundamental shifts in fertility desires or simply the realization of deferred reproduction are complicated when the precipitating events occur over multiple years and involve shifting spatial boundaries.

Nobles et al (2014) document similar behavior following the 2004 Indian Ocean Tsunami in Indonesia. Using data from a population representative longitudinal study that includes observations before and after the 2004 Indian Ocean Tsunami in Indonesia, they provide evidence of an increase in fertility between 2006 and 2009 in areas affected by the tsunami relative to unaffected areas. Two other studies explore fertility in the aftermath of high-mortality disasters. Finlay (2009), using cross-sectional surveys, considers fertility for three earthquakes, each with death tolls of 15,000 or more. Comparing fertility before and after the earthquake for residents of areas affected by the earthquake with fertility of residents of areas that were not affected reveals greater post-disaster increases in fertility in affected areas. The same approach is adopted, with census data, to examine the impact of the 2003 Bam earthquake in Iran. The authors document a fertility decline in 2004, followed by a rise in 2005-2007 (Hosseini-Chavoshi and Abassi-Shavazi 2013).

6. Discussion

As discussed in the preceding sections, disasters have implications for the demographic processes of mortality, migration, and fertility, as well as for the linkages among them. The potential for feedback mechanisms among these processes is clear from a theoretical perspective, but relatively little empirical work has attempted to examine the inter-connections and thereby test hypotheses about and provide a better understanding of the complex behaviors that underlie demographic processes. An exception is Heuveline's work on mortality and fertility in Cambodia during and after the decade marked by war and genocide (Heuveline 1998, 2001; Heuveline and

Poch 2007). These investigations require data on multiple domains and behaviors of individuals, their families and, in many instances, communities that are collected over a time frame that is sufficiently long after the disaster for the behaviors to be revealed.

Unfortunately, such data are rarely available. Moreover, in the ideal world, the data would also be collected prior to the disaster although, as we have emphasized, disasters are in general unanticipated. However, creative investment in data infrastructure that exploits recent technological advances is likely to have a substantial payoff for science and policy. With the availability of high quality satellite imagery, extensive administrative data sources, and population-representative longitudinal surveys being conducted on a regular basis across the globe, much of the key information needed to evaluate is already in place. In the case of the 2004 Indian Ocean tsunami, our international team of collaborators worked closely with Statistics Indonesia and followed up people who had been interviewed as part of the annual socio-economic survey, SUSENAS, conducted about 10 months before the tsunami in all the districts along the west coast of Aceh and North Sumatra on the island of Sumatra. The 2004 SUSENAS served as the baseline for the Study of the Tsunami Afermath and Recovery which followed the respondents annually for five years after the tsunami and then re-interviewed them again 10 years after the tsunami.

The demographic outcomes we have considered, as well as their interconnections, can be affected by policies and programs related to disaster preparedness and response. The development and enforcement of building codes, the creation of warning systems, evacuation plans, and temporary shelters, and well-trained first responders can alter the immediate consequences of disasters for mortality, health and migration. Emergency assistance and longer-term recovery efforts can shape how outcomes unfold in a disaster's aftermath. The intersection of these policy and planning efforts with demographic phenomena has received relatively little attention in the literature to date. The questions are important, however, given the continued occurrence of major disasters, and projected increase of people exposed to risk as a function of climate change.

References

Adeola, F.O., Picou, J.S., 2012. Race, social capital, and the health impacts of Katrina: evidence from the Louisiana and Mississippi gulf coast. Human Ecology Review. 19(1), 10-24.

Agadjanian, V., Prata. N., 2002. War, peace, and fertility in Angola. Demography. 39(2), 215-231.

Almond, D., 2006. Is the 1918 Influenza Pandemic Over? Long-term Effects of In Utero Influenze Exposure in the Post-1940 U.S. Population. Journal of Political Economy. 114.4.

Armenian, H., Melkonian, A.K., Hovanesian, A.P., 1998. Long term mortality and morbidity related to degree of damage following the 1998 earthquake in Armenia. American Journal of Epidemiology. 148, 1077-1084.

Bartels, S., VanRooyen, M.J., 2011. Medical complications associated with earthquakes. The Lancet. S0140-6736(11), 60887-8.

Blanc, 2004. The role of conflict in the rapid fertility decline in Eritrea and prospects for the future. Studies in Family Planning. 35(4), 236-245.

Brown, R., (2014). The Intergenerational Impact of Terror: Does the 9/11 Tragedy Reverberate into the Outcomes of the Next Generation? April 2014. Working Paper.

Brown, R., and Thomas, D. (2014). On the long term effects of the 1918 Influenza Pandemic. Mimeo.

Browning, C.R., Feinberg, S.L., Wallace, D., Cagney, K.A., 2006. Neighborhood social processes, physical conditions, and disaster-related mortality: the case of the 1995 Chicago heat wave. American Sociological Review: 71(4), 661-678.

Brunkard, J., Namulanda, G., Ratard, R., 2008. Hurricane Katrina Deaths, Louisiana, 2005. Disaster Medicine and Public Health Preparedness: 2(4), 215-223.

Caldwell, 2004. Social upheaval and fertility decline. Journal of Family History. 29(4), 382-406.

Camacho, A. 2008. Stress and Birth Weight: Evidence from Terror Attacks. American Economic Review, Papers and Proceedings, 98.2:511-5.

Cao, H., McFarlane, A.C., Klimidis, S., 2003. Prevalence of psychiatric disorder following the 1988 Yun Nan (China) earthquake-The first 5-month period. Social Psychiatry and Psychiatric Epidemiology. 38, 204-212.

Carballo, M., Hernandez, M., Scheider, K., Welle, E., 2005. Impact of the tsunami on reproductive health. Journal of the Royal Society of Medicine. 98, 400-403.

Cohan, C.L., Cole, S.W., 2002. Life course transitions and natural disaster: marriage, birth, and divorce following Hurricane Hugo. Journal of Family Psychology. 16(1), 14-23.

Committee on Increasing National Resilience to Hazards and Disasters; Committee on Science, Engineering, and Public Policy; The National Academies, 2012. Disaster Resilience: A National Imperative. http://www.nap.edu/catalog.php?record_id=13457 (accessed 14.06.18)

Currie, J., Rossin-Slater, M., 2012. Weathering the Storm: Hurricanes and Birth Outcomes. NBER Working Paper 18070.

Dynes, R., Tierney, K., Fritz, C., 1994. Foreword: the emergence and importance of social organization: the contributions of E.L. Quarantelli, in: Dynes, R., Tierney, K. (Eds.), Disasters, Collective Behavior, and Social Organization. University of Delaware Press, Newark.

EM-DAT: The International Disaster Database, Center for Research on the Epidemiology of Disasters www.emdat.be/database

Finlay, 2009. Fertility response to natural disasters: the case of three high mortality earthquakes. Policy Research Working Paper #4338. World Bank.

Foster, A., 1995. Prices, Credit Constraints and Child Growth in Rural Bangladesh, Economic Journal, 105.430:551-70.

Frankenberg, E., Nobles, J., Thomas, D., 2014. Contraception in the aftermath of natural disaster. Population Association of America Meetings.

Frankenberg, E., Gillespie, T., Preston, S., Sikoki, B., Thomas, D., 2011. Mortality, the family and the Indian Ocean tsunami. The Economics Journal. 221(554), F162-182.

Fritz, C.E., Marks, E.S., 1954. The NORC studies of human behavior in disaster. Journal of Social Issues. 10(3), 26-41.

Fusell, 2009. Post-Katrina New Orleans as a New Migrant Destination. Organization & Environment. 22(4), 458–469.

Fussell, E., Sastry, N., VanLandingham, M., 2010. Race, socioeconomic status, and return migration to New Orleans after Hurricane Katrina. Popul. Environ. 31, 20-42.

Galea, S., Maxwell, A. R., 2009. Methodological Challenges in Studying the Mental Health Consequences of Disasters, in: Neria, Y., Galea, S., Norris, F. (Eds.), Mental Health and Disasters. Cambridge University Press, New York.

Gray, C., Frankenberg, E., Gillespie, T., Sumantri, C., Thomas, D., 2014. Studying displacement after a disaster using large scale survey methods: Sumatra after the 2004 tsunami. Annals of the Association of American Geographers. 104(3), 594-612.

Groen, J.A., Polivka, A.E., 2010. Going home after Hurricane Katrina: Determinants of Return Migration and Changes in Affected Areas. Demography. 47(4), 821-844.

Guha-Sapir, D., Hoyois, P., 2012. *Measuring the Human and Economic Impact of Disasters*, Brussels: Government Office for Science.

Hamoudi, A., Frankenberg, E., Sumantri, C., Thomas, D., 2012. Impact of the December 2004 tsunami on birth outcomes in Aceh, Indonesia.

Hapsari, E.D., Widyawati, Nisman, W.A., Lusmilasari, L., Siswishanto, R., and Matsuo, H., 2009. Change in contraceptive methods following the Yogyakarta earthquake and its association with the prevalence of unplanned pregnancy. Contraception. 79(4), 316-322.

Herring, 2013. Sociology of Disasters, in: Bobrowsky, P.T, (Ed.), *Encyclopedia of Natural Hazards*. Springer, Netherlands, pp. 926-935.

Heuveline, P., Poch, B., 2007. The phoenix population: demographic crisis and rebound in Cambodia. Demography. 44(2), 405-426.

Heuveline, P. 2001. The demographic analysis of mortality crises: the case of Cambodia, 1970-1979. In *Forced Migration and Mortality*. Washington DC: NAP. 2001. Pp. 102-129.

Heuveline, P. 1998. 'Between one and three million': towards a demographic reconstruction of a decade of Cambodian history (1970-79). Population Studies, 52(1998), 49-65.

Hill, 2004. War, Humanitarian Crises, Population Displacement, and Fertility: A Review of Evidence. National Resource Council, Washington, DC.

Hosseini-Chavoshi, M., Abbasi-Shavazi.M.J., 2013. Demographic consequences of the 2003 Bam earthquake. International Conference on the Demography of Disasters. Australian National University.

Kamel, 2012. Social marginalization, federal assistance and repopulation patterns in the New Orleans metropolitan area following Hurricane Katrina. Urban Studies. 49(14), 3211-3231.

Klinenberg, 2002. Heat Wave: A Social Autopsy of a Disaster, first ed. University of Chicago Press, Illinois.

Kolbe, A.R., Hutson, R.A., Shannon, H., Trzcinski, A., Miles, B., Levitz, N., Puccio, M., James, L., Noel, J.R., Muggah, R., 2010. Mortality, crime and access to basic needs before and after the Haiti earthquake: a random survey of Port-au-Prince households. Medicine, Conflict and Survival. 26(4), 281-297.

Kreps, 2001. Sociology of Disasters, in: Smelser, N.J., Baltes, P.B. (Eds.), International Encyclopedia of the Social & Behavioral Sciences, fist edition. Elservier, Ltd, Oxford, pp. 3718-3721.

Lauderdale, D. 2006. "Birth outcomes for Arabic-named women before and after September 11." *Demography*. 43(1): 185-201.

Lindstrom, D. P., Kiros, G-E., 2007. The impact of infant and child death on subsequent fertility in Ethiopia. Population Research and Policy Review. 26, 31-49.

Lu, X., Bengtsson, L., Holme, P., 2012. Predictability of population displacement after the 2010 Haiti earthquake. 109(29), 11576–11581.

Maccini, S., and Yang, D., 2009. Under the weather: Health, schooling and economic consequences of early-life rainfall. American Economic Review, 99.3:1006-26.

Munasinghe, 2007. The importance of social capital: Comparing the impacts of the 2004 Asian Tsunami on Sri Lanka, and Hurricane Katrina 2005 on New Orleans. Ecological Economics. 64, 9-11.

Nakahara, S., Ichikawa, M., 2013. Mortality in the 2011 tsunami in Japan. J Epidemiol. 23(1), 70-73.

National Hurricane Center, 2013. Tropical Cyclone report: Hurricane Sandy http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf (accessed 14.06.24).

Nishikiori, N., Abe, T., Cost, D.G.M., Dharmaratne, S. D., Kunii, O., Moji, K., 2006. Who dies as a result of the tsunami? – Risk factors of mortality among internally displaced persons in Sri Lanka: a retrospective cohort analysis. BMC Public Health. 73(6), 1-8.

NOAA: Billion-Dollar Weather/Climate Disasters www.ncdc.noaa.gov/billions/events

Nobles, J., Frankenberg, E., Thomas, D., 2014. The effects of mortality on fertility: population dynamics after a natural disaster. Forthcoming.

Norris, F.H., Elrod, C.L., 2006. Psychosocial consequences of disaster. A review of past research, in: Norris, F.H., Galea, S., Friedman, MJ., Watson, PJ. (Eds), Methods for Disaster Mental Health Research. The Guildford Press, London, pp. 20–42.

Norris. F.H., Friedman, M.J., Watson, P.J., Byrne, C.M., Diaz, E., Kaniasty, K., 2002. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981–2001. Psychiatry. 65(3), 207–39.

Paul, B.K., 2005. Evidence against disaster-induced migration: the 2004 tornado in north-central Bangladesh. Disasters. 29(4), 370-385.

Paul, S.K., Paul, B.K., Routray, J.K., 2012. Post-cyclone Sydr nutritional status of women and children in coastal Bangladesh: an empirical study. Nat Hazards. 64, 19-36.

Pietrzak, R., Tracy, M., Galea, S., Kilpatrick, D.G., Ruggiero, K.J., Hamblen, J.L., Southwick, S.M., Norris, F.H., 2012. Resilience in the face of disaster: prevalence and longitudinal course of mental disorders following Hurricane Ike. PLoS ONE. 7(6), e389664.

Potter, J.E., Hopkins, K., White, K., Grossman, D., 2013. Evaluating the impact of abortion restrictions and drastic budget cuts for family planning in Texas. Working paper, IUSSP.

Preston, 1978. The Effects of Infant and Child Mortality on Fertility. Academic Press, New York.

Quarantelli, 1989. Preliminary paper No.136, the NORC research on the Arkansas tornado: a fountainhead study. Disaster Research Center University of Delaware. 1-20.

Quarantelli, 2005. A Social Science Research Agenda for the Disasters of The 21st Century: Theoretical, Methodological And Empirical Issues And Their Professional Implementation." Chapter 20 in *What is a Disaster? New Answers to Old Questions*. International Research Committee on Disasters. (eds: Perry, R., E.L. Quarantelli). Pp. 325-395.

Ravelli, A.C.J., van der Meulen, Jan H.P., Michels, R.P.J., Osmond, C., Barker, D., Hales, C.N. and Bleker, O.P. (1998) "Glucose tolerance in adults after prenatal exposure to famine", *Lancet*, 351:173-177.

Ravelli, A.C.J., van der Meulen, Jan H.P., Osmond, C., Barker, D. and Bleker, O.P. (1999) "Obesity at the age of 50 years in men and women exposed to famine prenatally", *American Journal of Clinical Nutrition*, 70:811-816.

Rooij WH, Yonker JE, Painter RC, Roseboom TJ. 2010. Prenatal under-nutrition and cognitive function in late adulthood. Proceedings of the National Academy of Sciences 107:16881-86.

Roseboom, Tessa J., van der Meulen, Jan H.P., Osmond, Clive, Barker, David J. and Blecker, Otto P. (2001) "Adult survival after prenatal exposure to the Dutch famine 1944-1945," *Paedeatric and Perinatal Epidemiology*, 15:220-225.

Sacerdote, 2012. When the saints go marching out: long-term outcomes for student evacuees from Hurricanes Katrina and Rita. American Economic Journal: Applied Economics. 4(1), 109-135.

Salas, 2013. Consequences of withdrawal: free condoms and birth rates in the Philippines. Working paper.

Sastry, N., VanLandingham, M., 2009. Prevalence of and disparities in mental illness among pre-Katrina residents of New Orleans one year after Hurricane Katrina. American Journal of Public Health. 99(S3), 725-731.

Stein, Z., Susser, M., Saenger, G. and Marolla, F. (1975) *Famine and human development: The Dutch hunger winter of 1944-45*, Oxford: Oxford University Press.

Tierney, 2007. From the margins to the mainstream? Disaster research at the crossroads. Annual Review of Sociology. 33, 503-525.

Torche, F. 2011. "The effect of maternal stress on birth outcomes: exploiting a natural experiment." *Demography* 48: 1473-1491.

Townsend, 1994. Risk and insurance in village India. Econometrica. 62(3), 539-591.

Wang, Y., Chen, H., Li, J., 2012. Factors affecting earthquake recovery: the Yao'an earthquake of China. Nat Hazards. 64, 37-53.

White, K., Grossman, D., Hopkins, K., Potter, J.E., 2012. Cutting family planning in Texas. New England Journal of Medicine. 367, 1179-1181.

Zaninetti, JM., Colten, C.E., 2012. Shrinking New Orleans: post-Katrina population adjustments. Urban Geography. 33(5), 675-699.

Zhao, Z., Reimondos, A., 2012. The demography of China's 1958-61 famine: a closer examination. Population-E. 67(2), 281-308.

Zhu H., Lei, H., Huang, W., Fu, J., Wang, Q., Shen, L., Wang, Q., Ruan, J., Liu, D., Song, H., Hu, L., 2013. Fertility in older women following removal of long-term intrauterine devices in the wake of a natural disaster. Contraception. 87(4), 416-20.