Population Displacement and Mobility in Sumatra after the Tsunami

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Abstract

The Indian Ocean tsunami of December, 2004 was one of the most severe natural disasters in human history and resulted in extensive relocation by people living in damaged areas. We describe post-tsunami geographic mobility in the provinces of Aceh and North Sumatra in Indonesia, the area worst-affected by the tsunami. Data from a unique longitudinal survey of 10,000 households who were interviewed both before and after the tsunami are used to quantify and map various dimensions of mobility and to provide insights into the individual, household and contextual factors that influence mobility. Levels of mobility increased dramatically with the extent of tsunami damage. Displacement from heavily damaged areas occurred primarily beyond the community of origin. Results from multivariate statistical models indicate that in damaged areas individuals were displaced similarly across demographic and socioeconomic lines, and that semi-voluntary decisions about mobility were influenced by household assets and prior livelihood strategies.

Keywords: tsunami, disaster, displacement, migration, Indonesia.

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Introduction

On December 26, 2004 one of the largest earthquakes ever recorded occurred in the Indian Ocean and generated a massive tsunami that devastated 4,500 kilometers of coastline, claiming over 200 thousand lives in ten countries, and displacing an estimated 1.7 million people from their homes (Rofi et al. 2006; Doocy et al. 2007). Indonesia, adjacent to the earthquake epicenter, was the worst affected country with an estimated 130 thousand dead and 500 thousand displaced (World Bank 2008).

While the combined scale and severity of the tsunami make it unique in recorded human history, it is only one of several large-scale natural disasters[1] to strike Asia in the past five years. These include the 2005 earthquake in Kashmir, Pakistan; the 2008 earthquake in Sichuan, China; the 2008 floods in Bihar, India; and the effects of Cyclone Nargis in Burma in 2008. In combination, these disasters are thought to have caused over three hundred thousand deaths (EMDAT 2009).

Disasters and natural hazards can also cause significant population movement. Meeting the needs of the displaced is a key policy challenge, but evidence on the magnitude and nature of post-disaster population displacements is usually scant. Even the number of displaced people is typically estimated with great uncertainty (Reed et al. 1998). Studies of the displaced are often restricted to those in refugee camps or other temporary settlements (Grais et al. 2006; van Griensven et al. 2006). These studies ignore displaced people who settle elsewhere as well as people who do not move, two groups that likely differ in important ways from individuals in camps. Much work on hazard-induced human displacement in developing countries has focused on documenting the number and living conditions of the displaced. These studies have described the needs of displaced populations (e.g., Noji 1997), and drawn attention to the potentially large number of “environmental refugees” worldwide (Hugo 1997). However, little is known about the characteristics of those who are displaced or specifically why they move. This is an important gap in knowledge if policies to reduce hazard-related displacement are to be successful (UNHCR 2006). The fundamental problem is one of data limitations: few studies of natural disasters or hazards-induced mobility are based on representative samples of the affected population with information available both before and after the precipitating event (Quarantelli 2001; Jacobsen and Landau 2003; Stallings 2006).

To address these issues we investigate mobility after the tsunami using extremely rich longitudinal data designed for this analysis. The Study of the Tsunami Aftermath and Recovery in Sumatra, Indonesia (STAR) includes a large-scale baseline survey of individuals in Indonesia that was collected about nine months prior to the tsunami and is representative of the population living in districts along the affected coastline of Aceh and North Sumatra at that time. We followed up the same respondents after the tsunami. Some of the respondents were directly affected by the tsunami. Others were living inland or in coastal areas that were up to several hundred kilometers away from where the tsunami came ashore, and so were not directly affected. These individuals provide a valuable comparison group to the population in the most heavily damaged areas. We have combined these survey data with remote-sensed satellite imagery to construct location-specific measures of damage due to the tsunami. The data shed new light on the impact of this major, unanticipated natural disaster on multiple dimensions of well-being, as well as on coping strategies in the tsunami’s aftermath.

We focus on population mobility, defined as a change in residence (independent of duration or distance) in the four months after the tsunami. For some individuals the change in residence was forced by inundation, erosion, and submersion of the land on which they were living. For others, the change represents a choice of coping strategy after the disaster. For those who were living in "comparison" communities in which the tsunami had no direct impact, we assume that residential moves were driven primarily by factors other than the tsunami and draw contrasts between these people and those displaced from damaged areas.[2] Our approach is guided by related literatures on livelihoods, vulnerability, and migration, which suggest hypotheses about characteristics that should affect mobility (these are discussed in more detail below).

We find very high levels of residential mobility after the tsunami: change in location is clearly a key post-disaster coping strategy for many. Almost two-thirds of people who were living in areas that were heavily damaged moved within four months of the tsunami. Given the high levels of damage to the natural and built environment in these communities, it is logical to view these moves as displacement because of the disaster. Most of these people moved outside the community and stayed in a camp for the displaced. On average, the population of the heavily damaged communities was cut by more than half through the processes of death and displacement. For those who, before the tsunami, were living in areas that were damaged, the decision of whether to move is predicted by asset ownership and other features of pre-tsunami livelihood strategies. We find no evidence that the most vulnerable – such as women, older adults and people with limited resources – are the most likely to be displaced. However, among those displaced from damaged areas, the less educated and those with fewer resources are more likely to move to a camp or temporary settlement rather than a private home.

Study Context

The areas of Indonesia that were directly affected by the tsunami include the coast of Aceh and the islands of Nias and Simeulue. While the affected areas are predominantly rural, there are several urban areas, including the provincial capital Banda Aceh with approximately 150 thousand people. Rural population densities are relatively high in the lowlands that skirt the coast, where key livelihood strategies include wet-rice agriculture, fishing, coconut cultivation and aquaculture. The lowland population is predominantly Acehnese but also includes populations descended from Javanese, Minangkabau and Chinese immigrants.

On the morning of December 24, 2004, a strong earthquake preceded the tsunami. The ocean retreated from the shore, but this signal of an impending tsunami was not widely recognized except on the island of Simeulue. On mainland Aceh, the most recent previous tsunami occurred in medieval times (Monecke et al. 2008) whereas the island of Simelue was hit by a tsunami in 1907. That population, which is culturally distinct from the mainland population, retained a collective memory of that tsunami and nearly everyone survived the 2004 tsunami (Gaillard et al. 2008).

The tsunami wave reached Aceh approximately thirty minutes after the earthquake and engulfed communities along 800 kilometers of coastline. The height and inland reach of water from the tsunami on shore was a complicated function of slope, wave type, water depth, vegetation and coastal topography (Ramakrishnan et al. 2005). Field surveys conducted within a week or two of the event indicate that in the city of Banda Aceh water flowed three to four kilometers inland. At the beachfront in Banda Aceh, water depths were approximately 9 meters, but further inland typically did not exceed the second story of buildings (Borrero 2005). Along parts of the west coast of Aceh, the water removed bark from trees as high as 13 meters (Borrero

2005). In areas of cliffs, the water reached as high as 35 meters (Tsuji et al. 2005; McAdoo et al. 2007). Where rivers emptied into the ocean, the water moved inland as much as six to nine kilometers (Kohl et al. 2005; Umitsu et al. 2007).

The worst-affected areas were low-lying communities within a few kilometers from the coast, and these were largely destroyed. Almost all structures were torn completely apart, most of the vegetation was swept away, and over a third of the population died. Further inland, uphill and in topographically sheltered areas, flooding damaged many structures and deposited enormous quantities of debris. In these areas a larger proportion of the population survived. In the mountainous interior, communities sustained earthquake damage but were unscathed by the tsunami.

When the water receded, an estimated 100 thousand housing units had been destroyed, about 130 thousand people had been killed, and up to a third of critical infrastructure had been damaged along coastal Aceh (KDP 2007; World Bank 2008). Poor, middle-class and wealthy households all experienced deaths and damage (Frankenberg et al. 2009a). The natural resources that supported rice, fishing, and aquaculture (key sources of income for many households) were also damaged or destroyed, as were houses and lands along with other assets such as boats, equipment, and livestock (Budidarsono et al. 2007).

Estimates of population movement after the tsunami suggest that between 350 and 550 thousand Indonesians left their damaged communities (USAID 2005; Robinson 2006; KDP 2007). Many took shelter with family and friends. Others relocated to public buildings, tents, or makeshift shelters, before moving to large communal temporary housing (where much of the disaster assistance was distributed) or returning to their original sites of residence. Still others remained behind in heavily damaged areas, and some individuals from nearby undamaged areas moved to temporary settlements because of damage to infrastructure such as roads and the loss of their livelihoods.

Buoyed by an unprecedented US$7.5 billion reconstruction effort, the macroeconomic effects of the tsunami on Aceh have been short lived. Poverty and unemployment are estimated to have risen in 2005, but they declined significantly in 2006 (World Bank 2008). The reconstruction effort was also given a significant boost by a peace agreement ending the conflict between the Free Aceh Movement and the Indonesian government (Aspinall 2005).

Theoretical Models of Migration, Mobility, and Displacement

Migration, on a permanent or temporary basis, is one of the key survival strategies adopted by people in the wake of a disaster (Hugo 2008). Studies of livelihoods in the developing world have highlighted the strategies that households adopt both to protect themselves from anticipated hazards and in response to hazardous events (Dercon 2002; Wisner et al. 2003; Yang 2008). In these models, households faced with the risk of natural hazards make choices to mitigate the consequences of a hazard or disaster. These include asset accumulation, livelihood diversification, and participation in risk-reduction activities and in risk-sharing networks (Rosenzweig and Stark 1989; Ellis 2000). After a disaster, individuals, their households and their families attempt to blunt its impact by borrowing or spending down assets, changing their spending patterns, re-allocating time across work and leisure, and drawing on social networks and public programs for assistance (Udry 1994; Frankenberg et al. 2003; Skoufias 2003).

One key response to a disaster is relocation out of the affected area, motivated by needs for shelter or assistance, to search of employment elsewhere, or to reduce demands on household and family members who stay behind (see, for example, Hunter 2005, and Paul 2005 for a counterexample). The livelihoods model suggests that people are more likely to migrate from damaged areas if they have invested (before the disaster) in strategies that support subsequent migration. These strategies include accumulation of human capital (such as education) and social capital (such as contacts and networks that will support resettlement elsewhere).

In contrast, the accumulation of financial capital has a theoretically ambiguous influence on displacement in this model. On the one hand, greater wealth enables a household to weather the storm by drawing on prior savings. This effect will likely be weaker if assets are illiquid (land and housing, for example), particularly if property rights are insecure. On the other hand, spending down wealth may enable a move to a more desirable location. Among movers, those with more financial and human resources are probably the least likely to move to camps where new opportunities are likely to be limited. Destruction of some assets is likely to result in greater displacement when alternative opportunities to re-establish one's livelihood exist elsewhere. As an example, people who own a home or a farm are less likely to move away. If the home or land is destroyed by the event, they will no longer impede out-migration.

Several theories of migration make qualitatively the same predictions about the role that these economic, social and family resources play in decisions about human mobility[3] (Sjaastad 1962; Stark 1991; Massey and Durand 2005). An important advantage of our research design is that we will compare mobility in areas that were damaged by the tsunami with mobility in areas that were far from this damage. Migration from the latter areas can be interpreted as indicative of mobility in the absence of the tsunami. These comparisons will provide insights into the extent of displacement due to the tsunami and thereby highlight the characteristics of those who were displaced by the tsunami relative to those who would probably have moved even if the tsunami had not occurred.

Studies of vulnerability have investigated the biophysical and social dimensions of vulnerability to natural hazards, including the spatial pattern of hazards and the roles of social, political and economic exclusion in explaining exposure to risk (Wisner et al. 2003; Neumayer and Plumber 2007). This approach has revealed that the occurrence of hazards is highly uneven over space at various scales (Gillespie et al. 2007). It has also revealed that marginalized populations often live in poor-quality housing in risky areas and have limited scope for preparing for hazards in advance, thus they suffer disproportionately when hazardous events take place (Cutter 1996). Poorer, less educated individuals, those who were isolated from social networks, and women, children and older adults may all be disproportionately affected: they are both more likely to be displaced and more likely to be displaced to less desirable destinations such as camps (Fothergill et al. 1999). We will test these hypotheses for the case of the Indian Ocean tsunami.

Empirical Evidence on Hazards-induced Mobility

Studies of hazards-induced mobility have employed various methodological approaches. Macro-scale studies have drawn on published statistics about displacement (Hugo 1996) and on aggregate measures of migration and natural disasters (Myers et al. 2008; Saldaña-Zorrilla and Sandberg 2009). This approach has revealed that the scope of hazards-induced mobility is potentially large, with more than 1 billion people estimated to have been displaced by natural disasters in Asia from 1976-1994 (Hugo 1996). However, aggregate statistics on displacement are not thought to be very reliable (Reed et al. 1998), and this approach provides little insight into decision-making by individuals and households.

The majority of micro-level studies have been conducted in refugee camps or other settlements of the displaced (e.g., Grais et al. 2006). Particularly relevant for this study, in February 2005 Rofi et al. (2006) interviewed a sample of nearly 400 Indonesian households displaced by the Indian Ocean tsunami to sixteen camps and surrounding communities in two districts in Aceh. The authors restrict attention to people who stayed in the same *kecamatan* (sub-district) and highlight the differences between people who were in camps and those who had re-located to private homes. Bivariate comparisons indicate that those who were in camps had less education, were more likely to be married or widowed, were less likely to come from a female-headed household, and had more household members that died in the tsunami. While the study provides an important early assessment of tsunami-induced displacement, it has several important limitations. First, because the study covers only those who were displaced, it is not possible to compare them with people who did not move or who were not directly affected by the tsunami. Second, people who were displaced to areas far from camps are not included in the study. Both of these limitations result in a sample selected on characteristics that are closely related to the outcome of interest, reducing the generalizability of inferences. Third, the study relies on retrospective information about individuals' and households' pre-disaster characteristics which limits the range of characteristics that can be explored without raising concerns about recall error.

A small number of studies have addressed the first concern using cross-sectional surveys of displaced and non-displaced individuals to investigate hurricane evacuation in the United States as well as environmentally-induced and conflict-induced migration in the developing world. Studies of hurricane evacuation have commonly collected data through post-hurricane telephone interviews in the affected region (e.g., Smith and McCarty 1996; Bateman and

Edwards 2002; Zhang et al 2004; Elliot and Pais 2006). For example, 2004 was the most active year for hurricanes in Florida's history. Using telephone interviews Smith and McCarty (2009) found that 25 percent of state residents evacuated one or more times. Multivariate analyses reveal that evacuation was more common among women and mobile home inhabitants, increased with hurricane strength, and that these factors also influenced whether evacuees stayed with friends or family, in a public shelter, or in a hotel. Groen and Polivka (2008) extend this approach using data from multiple cross-sections from the Current Population Survey to investigate displacement after Hurricane Katrina on the US Gulf Coast. They show that 1.5 million adults were displaced, rates of evacuation were similar across demographic groups, and within one year 65 percent of the displaced had returned to their previous residence.

Results from cross-sectional and retrospective studies of environmental influences on migration in developing countries are mixed (Munshi 2003; Henry et al. 2004; Gray 2009), suggesting that clear cases of environmentally-induced migration may be less common than previously thought. Studies of armed conflict, in contrast, have consistently found significant positive effects of violence on displacement (Morrison and May 1994; Berhanu and White 2000; Czaika and Kis-Katos 2009). Of particular interest, Engel & Ibáñez (2007) investigated conflict-related displacement in Colombia and found that land ownership and access to social services had less influence on mobility for households exposed to violence, whereas education had more influence, indicating that the process of conflict-induced mobility was distinct from other moves.

These examples indicate that cross-sectional surveys can provide insights into displacement dynamics, but there are several important limitations to this approach. In general, selection of a sample that is representative of the pre-disaster population of the study area is not possible, making it difficult to draw generalizable conclusions. It is especially difficult to collect information about people who died and to interview movers, particularly when entire households move. These challenges are greatest precisely where the damage is most extensive. Additionally, information about individuals' and households' pre-disaster characteristics and contexts must be obtained retrospectively.

In principle, these limitations can be addressed with data from panel surveys, which collect information from a representative sample of respondents at baseline and then re-interview the same respondents in follow-ups after the disaster. Insightful work by Yang (2008) uses the 2000 and 2002 rounds of the El Salvador Rural Household Survey to investigate the effects on internal and international migration of two earthquakes that occurred in 2001. In the absence of information on individuals who move after the earthquake, migration is measured by whether a sample household has a close relative who lives outside the study community. This measure limits what can be learnt about who is displaced by a disaster. Yang finds that distance from the epicenters of the earthquakes is not related to a change in the probability a household has a migrant relative. However, among the 40 percent of households that had a migrant in 2000, the fraction that also had a migrant in 2002 was reduced by about half in areas that were closer to the earthquake epicenters indicating that migrants from these areas returned to the origin location. The magnitudes of these effects are larger when the models account for variation at the department level, suggesting that distance from the epicenter also captures unobserved spatial variation in migration propensities. Controlling for distance to the epicenters, households that had experienced modest damage were the least likely to have a close relative living away. Yang suggests that those households needed the labor of migrants whereas households that had experienced considerable damage from the earthquake benefited more from the remittances of migrants. As Yang notes, it is not possible to distinguish distance from the epicenter from other, unobserved characteristics of the study sites and so it may be that the differences in responses to the earthquake reflects the influence of these unobserved differences across the areas. We will directly address this concern in our analysis of the tsunami.

Data Collected on Displacement and the Indian Ocean Tsunami

Our investigation of displacement of individuals in response to the tsunami uses data from a rich panel survey that we designed and implemented to explore the impact of an unanticipated disaster on well-being. The study design addresses some of the constraints that have confronted prior research in this area. We use a large-scale survey that is representative of the pre-tsunami population as the baseline. It was collected in February and March 2004, about nine months prior to the tsunami as part of the annual National Socioeconomic Survey (SUSENAS) which is conducted annually by Statistics Indonesia. SUSENAS is a broad-purpose survey that covers over 200,000 households across the whole of Indonesia and is representative of the population at the *kabupaten* (district) level in each province.

We turned this baseline into a panel survey. Collaborating with Statistics Indonesia, we followed up respondents from that survey, selecting all respondents who were living in every *kabupaten* that had a coastline along the north and west coasts of Aceh and North Sumatra as well as the islands off those coasts. Some 39,500 respondents living in these 11 *kabupaten* make up the STAR sample. They are drawn from 585 enumeration areas in 525 *desas* (villages, the lowest administrative unit in Indonesia) and represent a pre-tsunami population of about 4.3 million.

The study areas were selected to include people who were living in areas that were directly affected by the tsunami and people who were living nearby but not directly affected (because of the physical features of the coast or an interior location). The sample also includes people who were living up to several hundred kilometers away from tsunami-damaged areas along the west coast of Aceh and North Sumatra. They provide "controls" against which to compare those affected by the tsunami. The study sites are displayed in Figure 1 along with the areas that were damaged by the tsunami.

STAR respondents have been followed annually since the tsunami. In this paper, we combine the baseline data from before the tsunami with data from the first post-tsunami re-survey which was conducted between May 2005 and May 2006. Our measures of mobility draw on information provided by each respondent about changes of residence immediately after the tsunami and during the subsequent four months. We mounted an extensive effort to identify all the people who had died and paid special attention to following people who moved, interviewing them in their new location. We restrict attention in this paper to respondents age 15 and older at the time of the follow-up survey.

Of 27,500 age-eligible respondents, we determined survival status for 96 percent. Of these, just under 2,000 (7 percent) were confirmed to be dead at the time of the first follow-up. Among known survivors, about 93 percent were from pre-tsunami households in which at least one person was interviewed after the tsunami. Ultimately we were able to conduct face to face individual-level interviews with 22,390 of the age-eligible respondents known to have survived. Among those that we failed to interview, most had moved and were not relocated despite extensive tracking efforts (less than 1 percent refused).

The interviews consisted of a face-to-face meeting during which a trained enumerator conducted a structured interview to obtain information on a wide range of topics. Among other things respondents were asked about their location at the time of the tsunami and any changes in residence between the tsunami and the interview. These individual-specific reports of mobility are used to measure displacement in this study. In addition, each respondent was asked about socio-demographic characteristics, social networks, economic status, health, well-being, and exposure to the tsunami. Questions about mobility recorded the place of residence at the time of the tsunami as well as the date and destination of each subsequent change of residence, with no restriction on the minimum duration or distance of each move. Destinations were recorded and coded at the *desa* level, but within *desa* moves were also recorded.

Measurement of Mobility, Displacement and Tsunami Damage

Our first measure of mobility is each respondent's report of whether he or she moved after the date of the tsunami but before the end of April 2005 (the month that precedes the beginning of the resurvey in May 2005). We refine this indicator by taking distance into account and distinguish people who stayed within their pre-tsunami community (as measured by *desa*) from those who moved outside the *desa*. About two-thirds of the people who moved relocated outside the *desa.* The third measure considers the type of residence to which individuals moved, distinguishing individuals who moved only to private homes from those moved at least once to a camp, barracks, mosque or other temporary settlement for displaced people. About half the people who moved stayed in a camp or temporary settlement.[4]

Perhaps the most natural starting point is to determine whether patterns of mobility vary by degree of tsunami damage. Categorizing the study sites by degree of damage is not straightforward. We draw on data from multiple sources to construct a robust classification in each of the 585 study sites of the extent of damage due to the earthquake and tsunami. We use several biophysical measures derived from satellite imagery, drawing on Global Positioning

System (GPS) measurements that we conducted in the field during the follow-up survey in each of the 585 study sites. One measure was constructed by comparing satellite imagery from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) for December 17, 2004, a week before the tsunami, to imagery for December 29, 2004, three days after the tsunami. The proportion of land cover that was changed by the tsunami to bare earth (through scouring or sediment deposition) was manually assessed for a 0.6 km^2 area centered around each GPS point. These estimates were supplemented with estimates of damaged areas derived from remotely sensed imagery and prepared by the USGS, USAID, the Dartmouth Flood Observatory, and the German Aerospace Center (Gillespie et al., 2009). Second, in each community we conducted interviews with local leaders who provided their own assessments of the extent of destruction to the built and natural environment due to the tsunami and earthquake. Third, our survey supervisors completed a questionnaire in each community that detailed damage due to the tsunami and earthquake based on their own direct observation.

These sources of information are used to construct a four-category indicator of damage to the enumeration area. 16 percent of enumeration areas were classified as severely damaged, 17 percent of areas were classified as moderately damaged, 26 percent of areas were classified as lightly damaged, indicating peripheral flooding or earthquake damage only, and an additional 41 percent were classified as undamaged. We refer to enumeration areas that were severely, moderately or lightly damaged as tsunami-damaged areas. This indicator is a strong and significant predictor of many tsunami-related outcomes derived from the household data including mortality, injuries, posttraumatic stress disorders, extent of damage to houses and land (Frankenberg et al. 2008, 2009a). The indicator is a better discriminant of damage than alternative measures derived from these data or from publicly available damage maps. We link the measure to individuals based on their place of residence at the time of the pre-tsunami baseline[5]. Individual and household-level indicators of damage to assets and livelihoods that are recorded in the face-to-face interviews allow us to also account for variation in the degree of damage sustained by individuals and households from the same community.

Mobility, Displacement and Extent of Tsunami Damage: A First Look

Patterns of mobility, overall and by damage zone, are presented in Table 1.[6] Overall, about one in five respondents changed residences in the four months after the tsunami. This statistic masks tremendous variation in rates of mobility across damage zones. In severely damaged areas, nearly two out of three adults (age $\geq$15) changed residences, in the moderately damaged zones over one in four did so, and about one in eight moved in the lightly damaged areas.

An advantage of our study design is that we interviewed people in areas that were not damaged. In those areas, only about one in sixteen respondents age 15 and older moved during the study window. The mobility rate in severely damaged areas is ten times higher than in undamaged areas and this gap is an estimate of the extent of displacement in those areas due to the tsunami. It will be an underestimate if some people in areas that were not damaged moved because of the tsunami – perhaps because of damage to roads and infrastructure or possibly because they took advantage of new opportunities that arose because of the tsunami.

The spatial distribution of mobility, and its association with the extent of damage, is illustrated in Figure 1 which displays, for each *desa,* the fraction of adults who changed residences along with an indicator of damage due to the tsunami developed by the US Agency for International Development (buffered to 10 km for visibility; Gillespie et al. 2009). High-mobility communities (greater than 75 percent changing residences) are primarily located along the most-impacted stretch of coastline between Banda Aceh and Meulaboh. Mobility rates were also high on the island of Simeulue (Gaillard et al. 2008), on the island of Nias (which was struck by another severe earthquake in March 2005; Briggs et al. 2006) and for some communities on the southern coast of North Sumatra, reflecting lighter tsunami damage that is not captured by the USAID map but is captured by our survey data. The rates of displacement in damaged areas are comparable to rates estimated for hurricanes in the United States, where the population is much more mobile in the absence of a natural disaster (Smith and McCarty 1996; Smith and McCarty 2009).

If we assume that the difference in mobility among people who were living prior to the tsunami in undamaged areas and those who were living in areas that were damaged provides an estimate of displacement due to the tsunami, about half a million people were displaced and, of those, 300,000 were living in areas that were heavily damaged. These are consistent with estimates in the literature (see, for example, KDP 2007).

The remaining rows of Table 1 focus on the destination of moves. About two-thirds of people who moved away from their home also crossed a *desa* boundary and thus moved to a different community. About half the people who moved stayed at a camp or shelter at some point while the other half only stayed in private homes.

Among adults who were living in communities that were severely damaged, eight out of ten movers left the community so that over half the surviving adults moved out of these communities. Nearly 60 percent of these movers spent some time in a camp. In moderately damaged areas, four out of ten movers left the community and, as in the heavily damaged areas, among those who moved, over 60 percent were in a camp at some point. In contrast, most of the movers from areas that were lightly damaged left the community but were much less likely to have lived in a camp. This variation across damage zones likely reflects, at least in part, the fact that camps were located where there were large numbers of displaced people with few housing options: the areas that were heavily and moderately damaged (as measured by our index).

Figure 2 adds a temporal dimension to the analysis and displays the month of a move. The upper panel displays the timing of the first move after the tsunami. In January 2005 more than half the adults living in the heavily damaged zone changed residences, whereas around 10 percent of those in areas of light and moderate damage moved, and less than 5 percent of those from undamaged areas moved. Differentials by damage zone are almost non-existent in February and April, although in March movement was greater for those from heavily and moderately damaged areas. The reason for the spike in March is clear in the lower panel of the figure. It displays the percentage of people who moved to a camp for the first time by month. In January, around half the moves made by people from damaged areas were to camps. The spike in moves in March is almost entirely made up of people who moved to a camp for the first time in that month when, presumably, space became available.

Table 1 and Figure 2 clearly document the high rates of mobility among people who were living in areas that were heavily damaged. Although a large number of people were displaced in these areas, it is important to note that one-third of adults in the areas did not move. Residential change was not a universal coping strategy, even in areas that were substantially damaged. We turn next to multivariate analyses which provide insights into the characteristics of the people who moved in the tsunami's aftermath, relative to those who did not.[7]

Multivariate Methods to Test Hypotheses

We use multivariate regression models to identify the characteristics of people who are most likely to have moved after the tsunami. Among movers, additional models identify those who are more likely to move outside their communities rather than remain close to their homes as well as those who are likely to move to camps or shelters rather than stay in private homes. Drawing on the richness of the information collected in STAR, we include a large set of covariates motivated by the hypotheses described above regarding livelihoods, migration and vulnerability. The covariates along with their means are listed in Table 2.

The first set of covariates are measured prior to the tsunami and so do not reflect the impact of the tsunami. They include age, gender, marital status, and education, which have all been shown to be strong predictors of migration in many non-disaster contexts. The migration literature has established that typically young, male and better educated people are more likely to move. In the aftermath of a disaster, however, the vulnerability literature suggests that it is older, female and less educated people and those from female-headed households who are most likely to be displaced and to end up in camps.

Covariates are chosen to provide insights into the influence on mobility of livelihoods, socio-economic status and wealth, all measured prior to the tsunami. First, we use pre-tsunami household expenditure as a marker of resources available to the household and include the logarithm of per capita expenditure in the models. Second, controls for whether the household owned a home, a farm enterprise or a non-farm enterprise and whether the household owned other non-liquid assets (primarily land) and liquid assets (such as cash) are included. Third, because resource availability is intimately linked to household composition, the models control for the number of male and female adults ($age \geq 15$) and number of children ($age<15$) living in the household. Access to other social networks prior to the tsunami is indicated by whether the household head had access to a family member or a friend who could provide financial support.[8] The models also control whether each study site prior to the tsunami was urban.

The regression models control for our index of damage which is included as an indicator variable for each of the three damage zones with undamaged areas as the excluded category. As noted above, interpretation of estimates of the impact of damage on displacement in the literature is complicated by the fact that it is difficult to separate the impact of damage in an area (as measured by distance to the epicenter of an earthquake, for example) from other, unobserved economic, biophysical and social characteristics of that area. This is important because tsunami damage was greatest in Banda Aceh and along the coast where, prior to the tsunami, socio-economic status was generally higher and where economic infrastructure and communication systems were more developed.[9] To address this concern, we exploit the fact that tsunami damage was highly localized and compare mobility of people in the same *kecamatan* (sub-district) some of whom were living in communities directly affected by the tsunami and others were not. By including an indicator variable for each *kecamatan*, the models take into account all pre-existing differences between *kecamatans* at the time of the tsunami as long as those factors affect mobility in a linear and additive way.

Extended models that capture the tsunami's impact also include respondent reports of the trauma and loss they experienced. These models are restricted to respondents who were living in areas that were damaged (according to our index). The additional covariates are whether the individual was injured in the tsunami, whether at least one household member died because of the tsunami, whether the home was damaged, whether liquid or non-liquid assets were destroyed, and whether members of the household social networks were affected by the tsunami. The social network variables distinguish non-co-resident family and friends.

We use logistic regression to model each mobility outcome. These statistical models have been used to model both voluntary migration (e.g., Massey and Espinosa 1997) and forced migration and displacement (e.g., Engel and Ibáñez 2007). The model takes the following form:

$$\ln\left(\frac{\Pr(y_i=1)}{\Pr(y_i=0)}\right)=\beta_0+\beta_1 T_a+\beta_2 X_{iha}+\beta_3 X_{ha}+\beta_4 X_a+\alpha_s+e_{is}$$

where $\Pr(y_i = 1)$ is the probability of moving as defined in Table 1, $\Pr(y_i = 0)$ is the probability of not moving and the βs are vectors of coefficients to be estimated. T_a is a set of three indicator variables, one for each level of damage that occurred at the time of the tsunami to the enumeration area. X_{iha} is vector of individual characteristics and X_{ha} is a vector of household characteristics, all measured prior to the tsunami. X_a is an indicator for whether the enumeration area was urban prior to the tsunami and α_s is a vector of sub-district level fixed effects which absorb all observed and unobserved characteristics that affect mobility in a linear and additive way. Unobserved heterogeneity, e_{is}, is assumed to be uncorrelated with the covariates but allowed to be correlated within communities. In the first set of models, all of the individual and household characteristics are measured prior to the tsunami. In the second set of models, we extend these covariates to include individual- and household-specific indicators of damage caused by the tsunami itself. Relying on the fact that the tsunami was not anticipated, we assume none of the covariates reflect choices made in preparation for the tsunami and so treat the covariates as uncorrelated with unobserved heterogeneity.

Multivariate Evidence on Mobility, Displacement and Tsunami Damage

Table 3 presents results from these logistic regressions. Estimates are reported as odds ratios which can be interpreted as the multiplicative effect of a unit increase in the predictor on the odds of that form of displacement relative to no displacement. The significance level for the test that each odds ratio is equal to one is noted next to the coefficient. Wald tests for the joint significance of groups of covariates are reported at the foot of the table. Variance-covariance matrices estimates take into account clustering at the enumeration area level and are robust to arbitrary forms of heteroskedasticity (Huber, 1981).

The model in the first column of Table 3 includes only the indicators of the severity of tsunami damage in each community. The odds ratios are transformations of the percentages of people who move reported in the first row of Table 1.[10] Relative to undamaged areas, the odds of displacement were 26 times higher in severely damaged areas, 6 times higher in moderately damaged areas, and over twice as high in lightly damaged areas. All of these effects are significantly different from unity.

Pre-tsunami characteristics and sub-district fixed effects are included in the model in the second column. Wald χ^2 tests at the foot of the table indicate that overall, the individual and household characteristics are significant predictors of mobility as are the sub-district effects. Inclusion of these controls reduces the size of the effects of tsunami damage, particularly in the heavily damaged areas. However, the effects remain large and significant, indicating that displacement increased dramatically with the level of damage in each community and that observed differences in pre-tsunami characteristics as well as pre-tsunami local contextual factors can only partially explain variation in mobility of across the damage zones.[11] Controlling all of these factors, the odds of moving out of severely damaged areas were nearly 12 times higher than in undamaged areas, 5 times higher in moderately damaged areas, and about twice as likely in lightly damaged areas.

Whereas, overall, individual and household characteristics are significant predictors of mobility (as indicated by the Wald test), the probability of moving is not related to gender, marital status, household structure or composition. Mobility is related to age.[12] The probability rises with age among teenagers (age 15-20) and then declines slowly. Household resources (as indicated by per capita expenditure) are not associated with migration but respondents are more likely to move if they live in households with liquid assets, have a non-farm business or do not have a farm business.

The patterns in column 2 mask important differences between undamaged and damaged areas. Results from models estimated separately for respondents from each of these areas are in the third and fourth columns of Table 3. The size and significance of differences between these estimates are reported in the fifth column.[13]

The association between age and mobility noted above is apparent only among respondents in undamaged areas whereas people of all ages were at equal risk of being displaced in areas that were damaged. As column 5 indicates, this difference is significant. (This has been confirmed in models that allow the relationship between age and mobility to be more flexible.) In areas that were not damaged, married people are far less likely to move than single people. In contrast, in damaged areas, marital status is not associated with displacement and this difference is also significant. Higher levels of household resources, as indicated by per capita expenditure, are associated with higher rates of migration out of areas that were not damaged but in damaged areas displacement is less likely as per capita expenditure increases. However, it is not the poor who were displaced. Home owners, who are likely to be better off and who have presumably set down roots in the community, are less likely to move in areas that were not damaged but more likely to move from areas that were damaged. Both of these differences are significant.

People who had a farm business prior to the tsunami were less likely to move – from both damaged and undamaged areas. But, people in areas that were damaged who had a non-farm business were more likely to move. This may be because the skills associated with non-farm businesses – such as trading – are not as location-specific as farming and, with the destruction in the damaged areas, people were moving to other markets or where new markets developed. People who owned some liquid assets prior to the tsunami were also more likely to move from damaged areas.

Being younger, unmarried, from a household with more resources or without a home have all been shown in the literature to be important predictors of migration in non-disaster contexts. This suggests that those who moved from undamaged areas after the tsunami were not primarily driven by the tsunami but rather were striking out in search of better lives. In sharp contrast, these traditional predictors of migration are not associated with moving out of damaged areas. Moreover, taken together, the factors that influence mobility in damaged and undamaged areas are significantly different as indicated by the Wald test in column 5. We interpret these differences as indicating that movers from damaged areas were displaced by the tsunami and their decisions were not driven by the same strategies as movers from undamaged areas. Further, indicators of potential vulnerability such as gender, education and access to social networks, do not appear to play a role in post-tsunami displacement in damaged areas. Thus the patterns observed in previous studies of migration (e.g., that young unmarried adults are most likely to move) and previous studies of vulnerability (e.g., that females, the elderly, and the poorly educated are more likely to be affected by natural hazards) do not appear to hold in general for the case of post-tsunami displacement in Indonesia.

The sixth column of Table 3 presents results for the sub-sample of respondents who were living in damaged areas and extends the model to include individual- and household-level indicators of tsunami-related damage. All of these indicators are associated with a higher probability of displacement. A respondent who was injured by the tsunami was almost 5 times more likely to move than a respondent who was not injured. Having family members or friends to whom one would normally look for help who themselves suffered losses in the tsunami is also associated with a higher likelihood of mobility. This suggests that the loss of social networks may contribute to displacement.

Recall from above, in areas that were damaged owning a home and having more liquid assets was associated with greater mobility. This extended model sheds light on why. Displacement is more likely among people whose home was damaged by the tsunami and especially among people who lost liquid assets because of the tsunami. After taking into account these indicators of damage, home owners and those who owned liquid assets are no more likely to be displaced than those who did not own these assets prior to the tsunami.

The inclusion of the individual- and household-level indicators of damage due to the tsunami reduces but does not eliminate differences in displacement across the community-based measures of damage. Those who were living in areas that were heavily damaged are over three times more likely to move than those who were living in areas that were lightly damaged (the excluded category).[14]

The final two models place the spotlight on the destinations of those who moved from damaged areas. First, we examine whether movers stay in or move out of the community in which they were living at the time of the tsunami and treat crossing a *desa* boundary as moving out of the community. Second, we examine whether the respondent stayed in a camp after the tsunami or stayed in a private home[15] .

Moving out of the *desa* is not significantly associated with the extent of damage to the community, controlling all other characteristics, but is much more likely among those who were living in urban areas prior to the tsunami (where *desas* are closer and transport systems are more developed). People who had liquid assets prior to the tsunami are more likely to leave the *desa* – presumably drawing on those resources to cover the costs of moving. The death of a household member and loss of non-liquid assets (such as farm land or a boat) are also associated with moving further away. However, people whose friends suffered loss in the tsunami tended to stay closer to home.

Relative to those who move to a private home, people who are more likely to move to a camp tend to be disadvantaged: they are less educated and have lower levels of household per capita expenditure. A person is more likely to move to a camp if he/she was injured by the tsunami or if a household member died in the tsunami. Farmers were also more likely to spend time in a camp. Broadly speaking, people who moved after the tsunami but stayed in private homes are more similar to the people who moved from areas that were not damaged than the people who stayed in a camp. Neither women nor older people are more likely to move to a camp.

The differences in displacement probabilities between people from areas that were more or less damaged by the tsunami are relatively small, after controlling all the covariates in the models. The decision to move out of the desa is not related to our measure of damage at the community level. People from more damaged areas are about twice as likely to move to a camp than people from areas that were lightly damaged but this difference is not statistically significant.

Conclusions

This study uses population-representative longitudinal survey data on individuals and households from coastal areas of Aceh and North Sumatra in Indonesia to provide scientific evidence on the process of displacement in the immediate aftermath of the Indian Ocean tsunami. The fraction of the population that was displaced increased with the level of tsunami damage and, in the areas most affected by the tsunami, nearly two-thirds of the population moved after the tsunami. Damage from the tsunami took a number of forms, many of which influenced displacement: injuries, death of household members, loss of or damage to assets and housing, loss of social networks, and damage to community infrastructure all emerge as important factors that influence post-tsunami mobility. In the most severely damaged areas people moved predominantly to areas outside of their original community and over half moved to camps or other temporary settlements. Nonetheless, it is important to note that even in these areas many individuals remained in their original residence or community of origin and many were able to stay with friend and family in private homes.

The results have important implications for theory, research methods, and future disaster relief efforts. Regarding theory, the analytical results support the importance of livelihood characteristics in post-disaster displacement. The extent to which attributes traditionally associated with migration and with vulnerability emerge as important contributors to displacement varies across outcomes. Consistent with the livelihoods framework, the results indicate that post-tsunami mobility can be best understood as a coping mechanism that is, at least in part, voluntary. Individuals did not flee to the nearest safe haven and remain there, but instead drew on all of their resources and moved to a preferred destination or chose to remain in their home. This process was distinct from mobility in undamaged areas and differs from mobility as described by previous studies of migration in non-disaster contexts. In that literature, gender, age, marital status and education are all powerful predictors of mobility. None of these factors predicts displacement of people who were living in an area that was damaged. While potentially vulnerable populations such as the less educated and those with fewer resources were not more likely be displaced, they were more likely to be displaced to camps and other temporary settlements. However, neither gender nor age is predictive of either being displaced or the destination of those who are displaced. Thus, there is, at best, only partial support for predictions of the vulnerability model of displacement.

An important advantage of our study design is that the tsunami was completely unexpected and that households of all classes were affected. In many contexts, it is difficult to determine whether the most vulnerable are affected by a natural disaster because they live in areas that are vulnerable or because the better off were able to leave the area before the disaster struck. Hurricane Katrina provides a good example.

Regarding research methods, this study represents a significant methodological advance over previous studies of hazards-induced displacement by drawing on data from a large-scale population-representative longitudinal survey. Key elements of the design of STAR include the foundation of a pre-disaster baseline that is representative of the population at that time, extensive tracking of migrants no matter where they went, collection of data at multiple levels and the analysis of remotely-sensed imagery to develop indicators of damage. While the approach is complex, it provides important analytical advantages over smaller-scale approaches, including the ability to estimate causal effects and to generalize to the broader population. Survey and statistical approaches such as the one described here are broadly applicable to a large number of unresolved questions in natural hazards research and human-environment geography, and can be feasibly and productively integrated with qualitative and ethnographic approaches (Axinn and Pearce 2006). Studies drawing on these and related methods have already significantly advanced understandings of environmentally-induced migration (e.g., Massey et al. 2007), tropical deforestation (e.g., Pan et al. 2007), forest product collection (e.g., Pattanayak and Sills 2001), common property management (e.g., Jagger et al. 2005), and agrobiodiversity (e.g., Van Dusen and Taylor 2005), and ideally future studies will extend these approaches to investigate other human-environment issues.

Finally, the results have important implications for future disaster relief efforts. Disaster relief has traditionally targeted the population living in camps or other temporary settlements (e.g., UNHCR 2006), though for the case of the Indian Ocean tsunami disaster in Indonesia some assistance also reached those displaced to private homes and those who were not displaced (Robinson 2006). Given the relative lack of economic opportunities and social support networks in temporary settlements, relief agencies are clearly justified in prioritizing the needs of this population in the immediate aftermath of a disaster. Nonetheless, our results indicate that in the areas that were heavily damaged by the tsunami, about a third of individuals displaced from tsunami-damaged communities found shelter exclusively in private homes and did not reside in camps or other temporary settlements in the four months after the tsunami. Moreover, about one-third of the people living in the most heavily damaged areas were not displaced. These people who did not move were not unaffected by the tsunami: half of those who owned a home lost it to the tsunami, one-third lost other assets and a household member died in the tsunami for one in twelve of these people. The implication for future relief projects is that it is likely to be worth investing resources to reach individuals who were displaced to private homes, as well as those, who despite suffering damage, did not move away. Together these people represent more than half the population that was living in areas that were severely damaged by the tsunami.

Notes

[1] Consistent with recent reviews of the field (NRC 2006, ICSU 2008), we refer to biophysical events that place humans at risk as *natural hazards*, and to cases in which hazards overwhelm societal coping mechanisms as *natural disasters*.

[2] A frequently used definition of displacement refers to people or groups "who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters" (Deng 1998).

[3] In the literature a change in a person's place of residence is typically referred to as *mobility*. When this change is either forced by or reflects a voluntary response to a hazard or disaster, it is referred to as *displacement*. *Migration* commonly refers to a change in residence that crosses some minimum threshold of distance. In this paper we examine change of residence and refer to it as mobility because we are analyzing individuals across a continuum of disaster-related destruction. We recognize that for many individuals the change reflects displacement in that it occurred as a direct result of the tsunami.

[4] Recall that Rofi et al (2006) restrict attention to people who moved within the kecamatan. We find that among people who moved, about 20 percent moved left the *kecamatan* and among people who moved to a private home, 25 percent left the *kecamatan.*

[5] We estimate that approximately 5 percent of respondents changed villages between the pre-tsunami interview in February 2004 and the time of the tsunami. We do not have detailed information or GPS positions for these locations and so we assign each respondent to the place

he/she was living at the time of the pre-tsunami interview and interpret our estimates as measures of the "intent-to-treat" of the tsunami. These are thus likely to be lower bounds of the impact of the tsunami. Pre-tsunami mobility is unrelated to any of the tsunami-related covariates in our models and so, for our purposes, can be treated as random noise due to measurement error. Excluding these respondents from our analyses has no substantive impact on any of our inferences or conclusions.

[6] All statistics are weighted to take into account sampling probabilities in the pre-tsunami baseline.

[7] Note that Rofi et al (2006) miss the people who moved to camps in the second wave in March 2006 and the one-third of people who did not move away from the place in which they were living at the time of the tsunami.

[8] Information about ownership of assets and networks is missing for a very small number of cases (< 0.5 percent). To account for this missing data, we include indicator variables that identify these cases in the regression models.

[9] For example, respondents who were, prior to the tsunami, living in areas that were moderately or heavily damaged had completed, on average, 0.4 years more education than other respondents (t statistic=7.5). After sweeping out *kecamatan*-level differences, the gap is 0.1 years (t statistic=1.1). The inclusion of *desa* fixed effects adds very little: the education gap is 0.1 years (t statistic=0.8). In the regression models presented below, there are no substantive differences between models that include *kecamatan* or *desa* fixed effects.

[10] The estimates reported in Table 1 are the percentage of people who moved in damaged area *d*, p_d, and the percentage who moved in the undamaged area, p_u. The odds of moving in the damaged area d is $p_d / (1-p_d)$ and so the odds relative to moving in the undamaged area is given by $[p_d / (1-p_d)]/[p_u / (1-p_u)]$ which is the odds ratio in the first column of Table 3.

[11] The inclusion of individual and household characteristics in the model has little impact on the differences in mobility across damage zones. It is the addition of sub-district indicators that reduces these effects, likely in part by capturing larger-scale effects of tsunami damage.

[12] Age was included in the model as a spline with a knot at age 20, which allows a nonlinear effect of age on mobility with a peak at age 20.

[13] The reported differences in column 5 are odds ratios calculated using the coefficients on interactions between a binary indicator for tsunami damage and each of the covariates included in the model (other than the damage indicators) and estimated with the full sample and all the covariates.

[14] This is consistent with research that indicates damage within the community affected post-tsunami mental health net of the impact of individual exposure to trauma and loss (Frankenberg et al. 2009b).

[15] The estimates in the final three columns of Table 3 can be interpreted as the outcome of a two-step or nested process in which an individual chooses whether or not to move and, conditional on that choice, the individual chooses the destination. The first step is reflected in column 6 and the second step in column 6 (for distance) and column 7 (for type of destination). We have also

estimated the model using a multinomial logit specification which imposes the assumption of the independence of irrelevant alternatives. The coefficient estimates for these models and the models reported in the table are very similar for both the choice between staying in the desa or going outside the desa and for moving to a camp or to a private home. Since the multinomial logit estimates impose more structure, the standard errors are smaller and some of the odds ratios in those models are significant but not in the models reported in the table.

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Table 1. Percentage of people who moved by level of damage and destination.

	All	Damage zone				Definition
		Severe	Moderate	Light	None	
Any mobility	19.2	63.8	28.4	13.1	6.3	Moved from pre-tsunami home by April 2005
Moves within and beyond community:						
Beyond community	12.5	52.6	11.9	8.3	4.2	Moved out of the desa at least once
Within community	6.7	11.2	16.5	4.9	2.0	Moved from home but remained within desa
Percentage of movers that left community	65.0	82.4	42.0	63.1	67.4	Moved beyond community conditional on moving
Residence type:						
Camp or shelter	9.9	36.7	18.2	5.5	1.2	Moved to a camp, barracks or mosque at least once
Private home	9.3	27.1	10.2	7.6	5.1	Moved to private homes only
Percentage of movers that went to a camp	51.5	57.5	64.0	42.0	19.1	Spent time in camp conditional on moving
Distribution of respondents	100	12	21	20	47	
Distribution of communities	100	16	17	26	41	

Number of individuals: 22,390

Table 2. Definitions and mean values of covariates used in regression models.

Covariate	Mean	Notes
Individual characteristics prior to tsunami		
Female (%)	52	Reference is male
Age (years)	36	Age entered as spline with knot at 20
Married (%)	60	Reference is single, divorced or widowed
Education (years)	8.0	Years of formal education
Household characteristics prior to tsunami		
Number of children (age<15)	1.7	
Number of male adults (age≥15)	1.7	
Number of female adults (age≥15)	1.8	
HH head is female (%)	12	Reference is male HH head
HH per capita expenditure (log)	13	Specified as logarithm(per cap expenditure)
HHs that own assets (%)		
home	84	
other non-liquid assets	79	
liquid assets	42	
farm business	52	
non-farm business	32	
HH head's social network (%)		
HH head access to assistance from		
family members	82	
friends	65	
HH living in urban area (%)	43	Reference is rural
Tsunami-related loss and trauma		
Respondent injured in tsunami (%)	1	
At least one HH member died in tsunami (%)	3	
Assets damaged in tsunami (%)		
house	19	
other non-liquid assets	12	
liquid assets	4	
HH head's social network affected by tsunami (%)		
family members	13	
friends	10	

Table 3. Characteristics that predict mobility after the tsunami.

	Moved after tsunami						Moved	Moved
	All areas		Not damaged	Damaged areas	Difference	Damaged areas	out of desa	to camp
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Tsunami damage zone								
Severe	26.39**	11.65**		5.50**		3.31**	1.49	1.94
Moderate	5.94**	4.92**		2.13*		1.88*	1.60	1.90
Light	2.27**	2.08**						
Respondent characteristics prior to tsunami								
Female		0.98	0.94	0.99	1.05	1.02	0.99	0.89
Age spline (<20)		1.05*	1.18**	1.00	0.84**	1.00	0.94	0.99
Age spline (>20)		0.99	0.99*	1.00	1.01	1.00	0.99	1.00
Married		0.87	0.43**	1.10	2.55**	1.05	0.67	1.14
Years of education		1.02	1.05	1.02	0.97	1.02	1.04	0.91**
Household characteristics prior to tsunami								
Number of children (age<15)		0.99	1.04	0.97	0.94	0.98	0.97	1.10
Number of male adults		1.08	0.96	1.09	1.14	1.09	1.03	1.01
Number of female adults		1.05	1.10	1.02	0.93	1.05	1.11	0.91
HH head is female		0.92	0.57	1.07	1.87	1.02	0.78	1.40
HH ln(per capita expenditure)		0.93	1.72*	0.74	0.43**	0.85	1.34	0.64*
HH owns home		1.06	0.69	1.30	1.89*	0.92	0.70	0.70
other non-liquid assets		0.88	0.77	0.90	1.17	0.86	0.60	0.70
liquid assets		1.29**	1.11	1.40**	1.26	1.10	1.50*	0.93
farm business		0.66**	0.66*	0.70**	1.05	0.66**	1.00	1.55*
non-farm business		1.30*	1.01	1.43*	1.41	1.22	0.99	1.28
Potential assistance from family member		0.82	0.74	0.83	1.13	0.77	0.73	0.95
from friend		1.00	1.16	0.90	0.78	0.82	1.25	0.93
Urban		0.81	1.20	0.66	0.54	0.73	3.54**	0.61
Impact of tsunami								
Resp injured in tsunami						4.84**	1.67	1.73**
HH member died in tsunami						1.15	4.28**	1.64*
Damaged in tsunami: house						1.85**	0.82	1.20
other non-liquid assets						1.28	1.82*	0.73
liquid assets						5.53**	1.08	1.24
Family mems exp damage from tsunami						1.69**	0.88	1.20
Friends exp damage from tsunami						2.51**	0.54**	1.14
Wald X2 test: Joint significance								
Damage zones	69.2**	18.4**		3.0**		6.5**	0.7	1.6
Individ and HH characs		4.4**	7.1**	12.2**	4.5**	7.8**	3.1**	5.4**
Sub-district fixed effects		283.3**	1,155.6**	1,232.6**	145.9**	30,515.6**	68.7**	5,163.0**
Sample size	22,390		9,625	12,765	22,390	12,765	5,293	

Notes: Coefficients are logit odds ratios. Signifcance at 5%(*) and 1%(**) based on robust standard errors that take into account clustering of households and arbitrary heteroskedasticity.

FIGURE 1 CAPTION

Figure 1. Map of the study communities with the proportion of adults displaced.

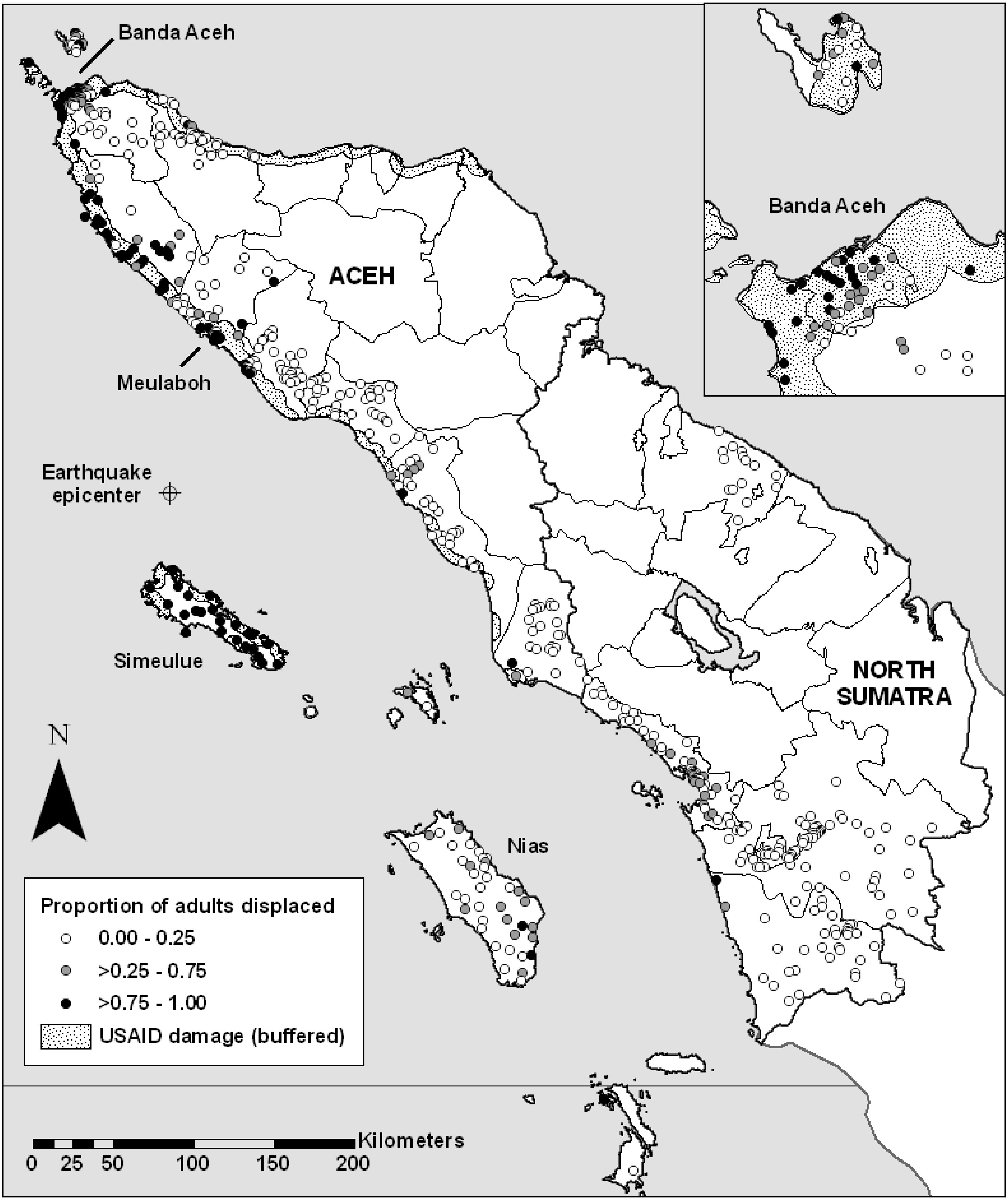
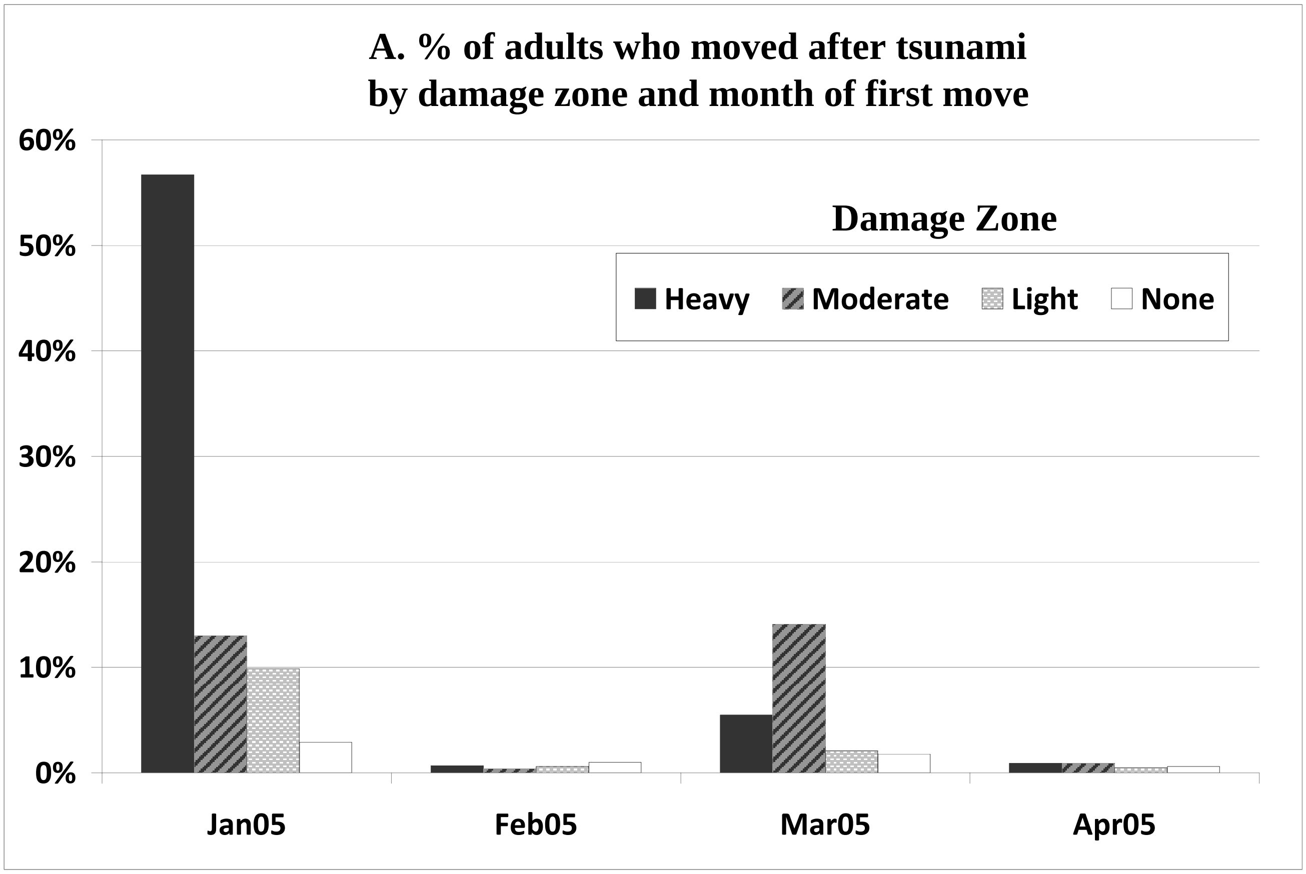
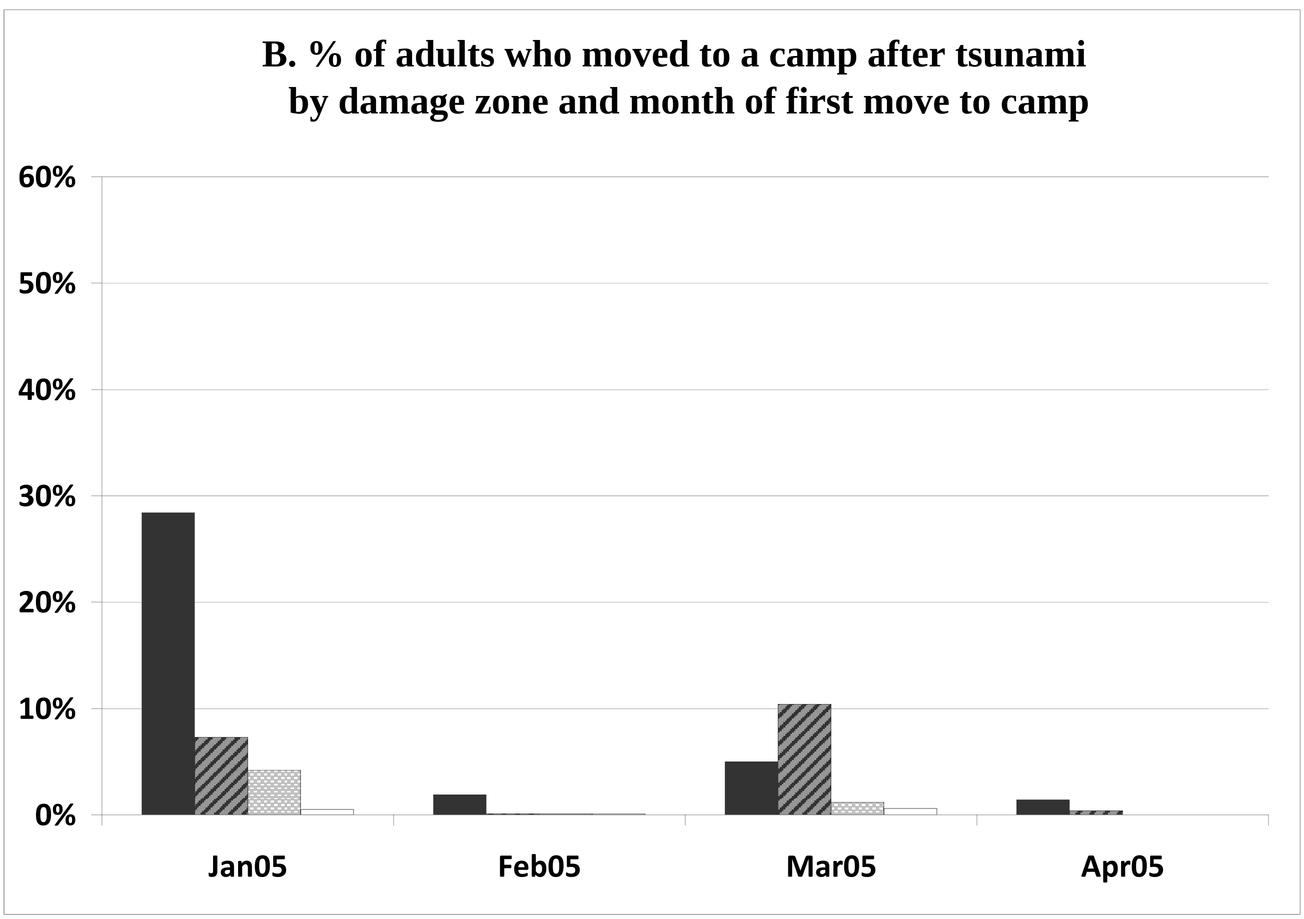

Banda Aceh
ACEH
Meulaboh
Earthquake epicenter
Simeulue
Nias
NORTH SUMATRA
N
Proportion of adults displaced
0.00 - 0.25
>0.25 - 0.75
>0.75 - 1.00
USAID damage (buffered)
Kilometers
0 25 50 100 150 200

Figure 2


A. % of adults who moved after tsunami
by damage zone and month of first move
60%
50%
40%
30%
20%
10%
0%
Damage Zone
Heavy
Moderate
Light
None
Jan05
Feb05
Mar05
Apr05


B. % of adults who moved to a camp after tsunami
by damage zone and month of first move to camp
60%
50%
40%
30%
20%
10%
0%
Jan05
Feb05
Mar05
Apr05