Tsunami-Induced Displacement in Sumatra, 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 series of massive tsunamis, devastating 4500 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). The combined scale and severity of this event make it unique in recorded human history, but it was nonetheless 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 2006 earthquake in Java, Indonesia; the 2008 earthquake in Sichuan, China; the 2008 floods in Bihar, India; and the effects of Cyclone Nargis in Burma in 2008, with a total death toll of over three hundred thousand (EMDAT 2009).

Despite the severity, visibility and frequency of these events, our understandings of their human impacts have been severely limited by the difficulties of anticipating disasters and of data collection in their wake. Due to these limitations, few previous studies of large-scale natural disasters in the developing world have had access to data that would allow a thorough accounting of their human impacts, including a large or representative sample of the affected population, data from prior to the disaster, or data from unaffected comparison populations (Quarantelli 2001; Jacobsen and Landau 2003; Stallings 2006). Meeting the needs of the displaced is one the key policy challenges in the wake of disaster (Noji 1997), but the magnitude and nature of post-disaster population displacements are particularly unclear. In the developing world, enumerations of displaced persons typically draw on reports by government and aid agencies of unclear data quality (Reed et al. 1998), and in-depth studies have largely been conducted in refugee camps or other temporary settlements (Grais et al. 2006), ignoring displaced persons who settle elsewhere and excluding potential comparison groups of non-displaced persons. Similar limitations plague the study of environmentally-induced migration more generally, and despite a high level of interest in “environmental refugees” (e.g., Myers 2002) few

[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*.

multivariate studies have investigated environmental effects on migration in the developing world (Gray 2009).

To address these issues, we investigate post-tsunami displacement using a unique panel dataset collected as part of the Study of the Tsunami Aftermath and Recovery in Sumatra, Indonesia (STAR). This dataset includes survey data collected prior to the tsunami and each year thereafter for a large representative sample of both affected and non-affected households. Focusing on the four-month period following the tsunami, we quantify various dimensions of displacement, map rates of displacement across Sumatra, and use multivariate models to estimate the effects of tsunami damage on displacement while controlling for pre-tsunami characteristics. These analyses reveal that rates of displacement increased exponentially with the level of tsunami damage and that the decision to move from damaged areas was nonetheless significantly influenced by pre-tsunami livelihood strategies and assets. Potentially vulnerable populations such as poor households were not more susceptible to displacement in damaged areas. These results reinforce the importance of mobility as a post-disaster coping strategy, as well as the relevance of survey and statistical methods for understanding the human consequences of large-scale natural disasters.

Previous Studies

Previous studies of hazard-induced human displacement in the developing world have focused primarily on documenting the number and living conditions of the displaced. These studies have successfully described the needs of many displaced populations (e.g., Noji 1997), and drawn attention to the potentially large number of "environmental refugees" worldwide (Hugo 1997). Nonetheless these studies have revealed relatively little about who is displaced by hazards and why, both critical issues for policy-makers who are tasked with reducing hazards-related displacement (UNHCR 2006). We argue that demographic methods are particularly appropriate to provide insight into the *process* of hazards-induced displacement and have been used by few previous studies in the developing world. In applying these methods, we are guided by theoretical approaches from livelihood studies, vulnerability studies and migration studies.

Theoretical approaches

To understand the process of hazard-induced displacement, we draw on theoretical approaches from previous studies of livelihoods, vulnerability and migration. Studies of livelihoods in the developing world have highlighted the household strategies used for both preparative hazard mitigation and responsive hazard coping (Dercon 2002; Wisner et al. 2003). Households are commonly exposed to unexpected events such as natural hazards and act to mitigate these risks through asset accumulation, livelihood diversification, and participation in low-risk activities and in risk-sharing networks (Rosenzweig and Stark 1989; Ellis 2000). Following a natural disaster, households often attempt to protect their well-being by reducing consumption of non-essential goods and by drawing on social networks and public programs for credit, employment and outright assistance, though the utility of local networks may be reduced by the aggregate nature of the shock (Udry 1994; Frankenberg et al. 2003; Skoufias 2003). Out-migration, in order to reduce demands on the affected households or to seek shelter, assistance or employment, has been identified as a key post-disaster coping strategy by many previous studies (Hunter 2005, though see Paul 2005 for a counterexample). We address this literature by examining whether mobility was adopted as a coping strategy, and whether this decision was affected by household's previous levels of assets and livelihood strategies. Drawing on the work of Ellis (2000) and others, we conceptualize household assets to include labor (e.g., household composition), human capital (e.g., education), social capital (e.g., contacts and networks), physical capital (e.g., housing and equipment), financial capital (e.g., cash) and natural capital (e.g., land and vegetation).

Studies of vulnerability have investigated the biophysical and social dimensions of vulnerability to natural hazards, including the space-time pattern of hazards and the roles of social, political and economic exclusion in explaining exposure (Wisner et al. 2003). 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 how marginalized populations often by necessity live in poor-quality housing in risky areas and are not able to take preventive action, exposing them disproportionately to hazards (Cutter 1996). Within households, groups such as women, children and older adults may also be disproportionately affected (Fothergill et al. 1999). We respond to this literature by examining the large-scale spatial pattern of displacement, by developing community and household-level measures of tsunami damage, and by investigating whether women, older adults and the poor were disproportionately vulnerable to displacement.

The field of migration studies, with its focus on human mobility, is also highly relevant to hazard-induced displacement[2]. This field has highlighted the diversity and selectivity of migration. Migration occurs across a variety of spatial scales (local to international) as well as temporal scales (temporary to permanent), and migrants also differ in their types of destinations (e.g., urban and rural), motivations (e.g., economic and family) and freedom of action (forced to voluntary) (White and Lindstrom 2005). Migration tends to be selective across a variety of individual, household and origin community characteristics including age, gender, education, wealth, social networks and urbanicity. International migrants, for example, tend to be young adults from middle or upper class households who have friends or relatives in the destination (Massey and Espinosa 1997; Liang et al. 2008). These selectivities reflect decision-making processes in which potential migrants must weigh the opportunities available in the origin area against those in potential destinations, along with the uncertainty of success and the costs of migration. Previous studies indicate that hazards-induced

[2] We refer generally to a change in a person's place of residence as *mobility*, and specifically to forced or hazard-induced mobility as *displacement*. *Migration* commonly refers to a change in residence that crosses some minimum threshold of distance.

displacement is largely but not exclusively forced, short-distance, and temporary (see below), but it is unclear whether the standard selectivities of migration apply in this context (Morrow-Jones and Morrow-Jones 1991). We address this literature by comparing the determinants of mobility between tsunami-affected and unaffected populations, as well as between displacement streams defined by distance and destination.

Methodological approaches

Studies of hazards-induced migration drawing on these theoretical frameworks 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 well known to be of dubious quality (Reed et al. 1998), and this approach also provides little insight into household decision-making.

The majority of previous micro-scale studies have been conducted in refugee camps or other settlements of the displaced (e.g., Grais et al. 2006). Particularly relevant to this study, Rofi et al. (2006) interviewed a sample of 400 Indonesian households displaced by the Indian Ocean tsunami to camps and adjacent communities. This study concluded that most tsunami-induced displacement occurred within the subdistrict (*kecamantan*), and that households with more education or fewer deaths in the tsunami were more likely to be displaced to private homes instead of to temporary camps. However this and other studies conducted in settlements of the displaced have important limitations: information is not available about the non-displaced and those displaced outside of camps, and information about individuals' and households' pre-disaster characteristics and contexts must be obtained retrospectively. For these reasons this approach can only provided limited insight into the contribution of natural hazards to human mobility and into the vulnerability of certain groups to hazards-related displacement.

A smaller number of previous studies have used cross-sectional household surveys to interview a sample of both displaced and non-displaced individuals, providing additional insight into the process of displacement. This approach has been used 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, and Smith and McCarty (2009) found using telephone interviews that 25% of state residents evacuated one or more times. Multivariate analyses additionally revealed that evacuation was more common among women and mobile home inhabitants and 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 by using data from multiple cross-sectional rounds of the Current Population Survey to investigate displacement after Hurricane Katrina on the US Gulf Coast. They show that 1.5 million adults were displaced, various demographic groups evacuated at similar rates, and within one year 65% of the displaced had returned to their previous residence.

Cross-sectional household surveys have also been used to investigate environmentally-induced and conflict-induced mobility in the developing world. Cross-sectional and retrospective studies of environmental influences on migration have generally found mixed and weak effects (Munshi 2003; Henry et al. 2004; Gray 2009), suggesting that clear cases of environmentally-induced migration may be rarer than previously thought. Studies of armed conflict, in contrast, have consistently found significant positive effects of violence on displacement as expected (Morrison and May 1994, Berhanu and White 2000, Czaika and Kis-Katos In press). 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 household surveys can provide considerable insight into displacement dynamics, but this approach still has considerable limitations. Selection of a sample that is representative of the pre-disaster population of the study area is generally not possible, and information about groups such as whole departed households and those without telephones is particularly difficult to collect. Additionally, information about individuals' and households' pre-disaster characteristics and contexts must be obtained retrospectively. Panel surveys, which collect information from respondents at multiple points in time, provide advantages over cross-sectional surveys and represent the cutting edge in survey data collection. This approach allows the selection of a representative baseline sample, data collection on baseline characteristics, and analyses that account for differences in these characteristics. Given that most large-scale natural disasters occur with little warning, applications of this approach to investigate hazards-induced mobility typically must build upon previously-conducted household surveys in the affected area.

Previous studies have applied this approach to understand earthquake-induced migration in El Salvador, environmentally-induced mobility in Nepal, and household reorganization during a financial crisis in Indonesia. Yang (2008) draws on the 2000 and 2002 rounds of the El Salvador Rural Household Survey to investigate the effects of two 2001 earthquakes on internal and international migration. His analysis reveals that out-migration was lower in earthquake-affected regions but no different between damaged and undamaged households, perhaps because the earthquake limited access to credit which would have been used to finance migration. Massey et al. (2007) use data from the baseline survey and subsequent population registry of the Chitwan Valley Family Study to investigate the effects of local environmental conditions on migration, and find that poor environmental quality increased local moves by low caste individuals but had little effect on other moves. Finally, Frankenberg et al. (2003) use data from two waves of the Indonesian Family Life Survey (IFLS) to investigate mobility related to the 1997 economic crisis, revealing that individuals tended to move out of poor households and into wealthy households following the crisis. Unlike the El Salvador and Nepal surveys, IFLS includes migrant tracking, which helps to preserve the representativeness of the sample over time (Thomas et al. 2001). Other recent studies have used panel data to investigate the human consequences of natural disasters include those by Hoddinott (2006), Kazianga and Udry (2006), Carter et al. (2007) and Khandker (2007).

Our analysis draws on a panel survey data collected as part of the STAR project to investigate tsunami-induced displacement in Sumatra Indonesia. This dataset, the origin of which is described under Data Collection, provides several advantages over previous studies of hazards-induced displacement. Firstly, data on pre-tsunami household characteristics are available from a pre-tsunami survey conducted by Statistics Indonesia, allowing analyses which account for differences in these characteristics. Secondly, these data provide a representative sample of the pre-tsunami population, and the representativeness of the sample was maintained through extensive migrant tracking, allowing for analyses which generalize to the population of the study area. Thirdly, the sample is large (10,000 households) and includes areas which suffered varying degrees of tsunami damage, as well as both adjacent and distant undamaged areas, allowing comparisons between affected and unaffected populations. Finally, the dataset includes detailed information on post-tsunami mobility, as well as multiple measures of tsunami damage at individual, household and area levels. Together, these features allow us to make strong conclusions about the nature of hazards-induced mobility in post-tsunami Indonesia.

Study Context

The areas of Indonesia that were subsequently affected by the tsunami, including coastal areas of Aceh and the island of Simeulue, are predominantly rural but also include several urban areas. The largest urban area is Banda Aceh, the coastal provincial capital, with approximately 150 thousand people. Rural population densities are relatively high in the narrow coastal lowlands and lower in the mountainous interior. Key livelihood strategies in coastal areas include wet-rice agriculture, fishing, coconut cultivation and aquaculture. The lowland population is predominantly Acehnese but also includes populations descended from Javanese, Minangkabua and Chinese immigrants. The majority ethnic group on the island of Simeulue is culturally distinct and the only group that retained a collective memory of a previous tsunami, dating from a 1907 event (Gaillard et al. 2008). On mainland Aceh the most recent previous tsunami disaster occurred in medieval times (Monecke et al. 2008). The macroeconomy of Aceh is significantly dependent on the exploitation of oil and gas reserves located in northern Aceh, though revenues are largely retained by the central government (McCarthy 2007). For decades prior to the tsunami Aceh was also the site of violent conflict between the central government and an armed independence movement known as the Free Aceh Movement. This conflict is estimated to have resulted in 15 thousand deaths and 35 thousand displaced households prior to the tsunami, many from the mountainous interior where the insurgency was the most active (Schulze 2004; McCarthy 2007; Czaika and Kis-Katos 2009). The insurgency was a significant contributor to underdevelopment and high rates of poverty (World Bank 2008), and likely increased vulnerability to the tsunami.

On the morning of December 24, 2004, the tsunami was preceded in Aceh by a strong earthquake, which damaged some structures, and the retreat of water from the shore. These signals were widely recognized only on Simeulue, allowing nearly all of the population there to survive (Gaillard et al. 2008). The tsunami wave reached Aceh approximately thirty minutes after the earthquake and engulfed communities along 800 kilometers of coastline in up to fifteen meters of water while penetrating up to five kilometers inland, even further along rivers (Borrero 2005; Umitsu et al. 2007). In the worst-affected areas, low-lying communities within a few kilometers from the coast were largely destroyed. Wooden structures were completely dismantled, most of the vegetation was removed, and the majority of the population died. Further inland, uphill and in topographically sheltered areas, high flooding damaged most structures, though the majority remained standing, and a larger proportion of the population was able to survive. In the mountainous interior, communities were mostly unscathed except for some earthquake damage. After the water receded, an estimated 100 thousand housing units had been destroyed, 130 thousand people had been killed, and up to a third of critical infrastructure had been damaged (KDP 2007; World Bank 2008). Poor, middle-class and wealthy households all experienced deaths and damage. The livelihood-supporting resources of many households were also damaged or destroyed, with rice, fishing and aquaculture particularly vulnerable (Budidarsono et al. 2007).

Following the tsunami, an estimated 350 to 550 thousand Indonesians left their damaged communities (USAID 2005; Robinson 2006; KDP 2007). Many took shelter with friends and family. Others relocated to public buildings or temporary structures such as tents, before moving to large communal temporary housing (“barracks”), where much of the disaster assistance was distributed. Later most individuals moved to temporary and then permanent structures in their origin communities as the reconstruction effort progressed. Displacement was not uniform across communities. Some individuals remained behind in heavily damaged areas, and some individuals from areas that were not damaged moved to temporary settlements because of damage to infrastructure or the loss of their livelihoods.

Buoyed by an unprecedented US$7.5 billion reconstruction effort, the macroeconomic effect of the tsunami on Aceh was relatively small, and poverty and unemployment rose in 2005 but 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). At the time of our most recent fieldwork in late 2008, many formerly displaced households were in reconstructed housing, infrastructure repairs were well underway, and life appeared to have returned a semblance of normality in many previously devastated communities.

Nonetheless the scars of the tsunami were still highly visible on the landscape, some households were still struggling to reassemble their livelihoods, and memories of the tragedy were still fresh in many cases.

Hypotheses

Given the previous literature and the study context described above, we can make several predictions regarding the process of tsunami-induced displacement. Since mobility served as a central coping strategy in the wake of the tsunami, we expect that tsunami damage had large positive effects on displacement that increased with the level of damage. The impacts of the tsunami were multidimensional and included deaths, injuries, damage to assets and infrastructure, and the destruction of social networks. Therefore, we expect that individual, household and area-level measures of tsunami damage had independent positive effects on displacement. In tsunami-damaged areas, the decision to move ranged from partially voluntary to involuntary, and this process was thus distinct from voluntary migration from undamaged areas. Thus we expect that traditional predictors of migration such as age and education were more important in undamaged areas. Nonetheless, fixed assets such as land and a home likely retained people in damaged areas and liquid assets such as cash likely facilitated displacement, reflecting the partially voluntary nature of displacement. Similarly, household participation in agriculture likely retained individuals in the origin community.

In damaged areas, marginalized populations such as older adults, women, the poor, and those isolated from social networks were likely particularly vulnerable to damage and less able to cope. Therefore, we predict that these groups were more likely to be displaced given a certain level of damage. We also expect that most displacement occurred over short distances, and that displacement over greater distances was more selective, reflecting greater costs. Finally, given the poor living conditions in camps relative to private homes, we predict that tsunami damage had a larger effect on displacement to camps and vulnerable groups were more likely to be displaced to camps.

Data Collection

To test these hypotheses, we draw on a large survey dataset collected as part of the STAR project. This data collection was led by Elizabeth Frankenberg and Duncan Thomas, in collaboration with co-author Sumantri and other Indonesian colleagues, and began in early 2005. Following the tsunami, Statistics Indonesia provided access to household-level data from the February 2004 round of the Indonesian National Socioeconomic Survey (SUSENAS), which has served as baseline data and a representative sample for the post-tsunami STAR surveys. The SUSENAS survey, which is widely recognized to be of high quality, was representative at the district level and based on a stratified multistage cluster design. The first round of the STAR survey was conducted from May 2005 - May 2006 and targeted SUSENAS respondents from eleven coastal districts (*kabupaten*) of Aceh and eight coastal districts of neighboring North Sumatra[3]. These districts were selected to include many of the areas worst-affected by the tsunami as well as coastal areas that were not affected, and had a pre-tsunami population of ######. Tsunami-affected districts also include interior areas which were not directly affected, providing multiple comparison populations for those exposed to the tsunami. These and other districts have been revisited in subsequent annual rounds of the survey, with the fourth-round survey currently underway

The first-round survey attempted to recontact and interview 39,500 SUSENAS respondents from 585 original enumeration areas in 525 communities (*desas*[4]). This effort included a tracking operation which attempted to locate migrants within Aceh, North Sumatra and Java, drawing on previous successful efforts that were part of the Indonesian Family Life Surveys (Thomas et al. 2001). This paper focuses on respondents who were 15 at the time of the first round interview. Among 27,672 SUSENAS respondents who would have been in this group, 1,891 (7%) were confirmed to have died, mostly in the tsunami. Among the remaining 25,781 respondents, the STAR first-round survey successfully interviewed 22,883 (89%), either directly or through a proxy respondent. The dataset also includes sampling weights produced by the SUSENAS survey, and these weights are used in all of the analyses described below.

The STAR first-round survey included structured interviews at individual, household and community levels. These interviews repeated questions from SUSENAS and also collected additional information on conditions prior to the tsunami, since the tsunami and at the time of interview. The individual questionnaire collected information about demographic characteristics, mobility, social networks, exposure to the tsunami and other subjects. 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 moves. Locations were recorded and coded to the level of the community. Our analysis uses data on mobility from the data of the tsunami through April 2005, prior to the initiation the first round interviews in May 2005. This window captures the observed peak of mobility in the first months after the tsunami. The household interview was conducted with the household head or another adult in each sample household, and collected information about household composition, assets, livelihood activities, tsunami damage and other subjects. An interview was also conducted at the community level with a local leader in each of the original 525 sample communities, and collected information on population, infrastructure, damage from the tsunami and other subjects.

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[3] The following districts were included in the first-round STAR survey: Simeulue, Aceh Barat, Aceh Barat Daya, Aceh Besar, Aceh Jaya, Aceh Selatan, Aceh Singkil, Banda Aceh, Nagan Raya, Pidie, Sabang (in Aceh), Mandailing Natal, Nias, Nias Selatan, Padang Sidempuan, Serdang Bedagai, Sibolga, Tapanuli Selatan, and Tapanuli Tengah (in North Sumatra).

[4] *Desas*, here referred to as communities, are Indonesia's smallest administrative units, and are approximately equivalent in scale to a village in rural areas and and to a neighborhood in urban areas.

To classify the sample communities by level of damage from the tsunami and earthquake, we drew on three data sources: the community-level interviews, direct observation by the survey supervisors and an analysis of satellite imagery. In each of the sample communities, the supervisors of the household and community interviewers responded to a questionnaire estimating the level of mortality and the level of damage to structures and fields that they directly observed. To provide a biophysical measure of damage, the project team acquired and analyzed two images from NASA's Moderate Resolution Imaging Spectroradiometer for December 17, 2004, and December 29, 2004. Global Positioning System points collected in the field were used to locate sampled enumeration areas, and the proportion of land cover changed to bare earth (through scouring or sediment deposition) was manually assessed for a 0.6 km^2 area centered on each point.

Measures of damage derived from these three data sources are highly correlated and were subsequently collapsed into a single four-category indicator of damage to the enumeration area. 16% of enumeration areas were classified as severely damaged, which corresponded to high flooding and damage to the majority of structures. 16% of areas were classified as moderately damaged, indicating moderate flooding with damage to structures. 27% of areas were classified as lightly damaged, indicating peripheral flooding or earthquake damage only, and an additional 40% 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 a variety of tsunami-related outcomes derived from the household data, and performs better than alternative measures derived from these data or from publically available damage maps (e.g., USAID MAP). This measure was linked to individuals based on their place of residence at the time of SUSENAS[5]. Individual and household-level measures of damage were also derived from the household interview, allowing us to also account for variation in the level of damage between individuals and households in the same community.

In order to conduct the analyses described below we used these data sources to construct an individual-level dataset containing measures of displacement and potential predictors at level of the individual, the household and the enumeration area. This dataset excludes 647 cases that have missing data on mobility or on one or more of the core predictors, leaving 22,236 individuals in the analysis. Displacement was defined as any change in residence from December 2004 to April 2005, and thus captured moves that occurred in the first four months after the tsunami. Reflecting the nature of post-tsunami displacement, this definition encompasses moves over shorter distances (e.g., within the community) and over a shorter period (i.e., four months) than most previous studies of the determinants of migration. We also classified individuals based on the distance and destination of their moves, on whether the entire household was displaced, and on whether they returned to their origin

[5] Approximately 5% of respondents changed their community of residence between the SUSENAS survey and the tsunami, likely leading to measurement error on the area-level measure of tsunami damage for these individuals. In order to preserve the representativeness of the sample and to best use our rich data on tsunami damage to the study communities, we opt to include these individuals in the analysis and to accept a small amount of measurement error. This issue does not affect individual and household measures of damage, which were collected retrospectively in the first-round STAR survey.

community. “Within community” movers moved only within their community of origin, whereas “beyond community” movers moved at least once outside of their community of origin. Additionally, “to homes” movers moved only to other private residencies, whereas “to camp” movers moved at least once to a camp, barracks, mosque or other temporary settlement for displaced persons. “Part of household” movers were displaced but part their household was not, whereas “whole household” movers were members of a household in which all members were displaced, though not necessarily to the same destinations[6]. Finally, beyond-community movers who resided in their origin community in April 2005 were considered to “displaced beyond community and returned”.

Descriptive Results

To examine the pattern of displacement across levels of damage and across space, we first present the results of two descriptive analyses. Table 1 displays the probability of displacement by level of tsunami damage, with displacement also disaggregated by distance, destination type, whether the whole household was displaced, and whether individuals had returned to their origin community. Overall, 19% of adults were displaced, including 62% in severely damaged areas, 29% in moderately damaged areas, 14% in lightly damaged areas, and 6% in undamaged areas. Thus, even without including multivariate controls, tsunami damage clearly dramatically increased displacement. The rates of displacement in damaged areas are quite high and comparable to the rates described above for hurricanes in the United States, where the population is much more mobile (Smith and McCarty 1996, Smith and McCarty 2009). The total number of adults displaced from damaged areas, estimated as a weighted sum, is 397,167. This value is within the range of previous estimates for the total population displaced by the tsunami (USAID 2005; Robinson 2006; KDP 2007). However, given that our analysis does not include children under the age of fifteen and our sample excludes some tsunami-affected areas in northern Aceh (Figure 1), this result suggests that previous values may be underestimates. Future research will draw on survey data from northern Aceh collected in the second-round STAR survey to more precisely estimate the total number displaced.

Despite the large number displaced from damaged areas, it is nonetheless notable that 38% of individuals were not displaced from severely damaged areas, indicating that mobility was not universally adopted as a coping strategy by survivors even where most structures were damaged by the tsunami. The proportion who moved from undamaged areas is also relatively high (6%) for a five-month period, and comparable to the approximately 5% who moved in the ten months between the SUSENAS survey and the tsunami. This mobility likely reflects larger-scale effects of tsunami damage, including damage to infrastructure, to members of social networks and to the overall economy.

[6] Movers in single-member households were considered to be “whole household” movers.

The pattern of displacement by distance and destination and within households also varied between damaged and undamaged areas. Examining displacement by distance, overall 64% of movers left their community of origin (Table 1). In moderately damaged areas relatively few movers left the community (39%), and in severely damaged areas even more movers left the community (81%). This pattern likely reflects the varying spatial scale of damage across communities. In moderately damaged areas, the area of damage was likely smaller and individuals were able to find a new residence without leaving the community, whereas in severely damaged areas most of the community was likely to have been damaged, necessitating a longer-distance movement. Examining mobility across larger scales (not shown), 64% of those displaced from damaged areas moved outside their communality of origin, 44% moved outside their subdistrict of origin, 30% moved outside their district of origin, and only 5% moved outside their province of origin. This distribution is consistent with our expectation that most moves would be over relatively short distances, but it is nonetheless notable that nearly a third moved outside their district of origin. Many of these longer-distance movers went to Banda Aceh where disaster assistance and employment were more readily available.

Examining the destination of displacement, 52% of movers went to a camp or other temporary settlement at least once (Table 1). As expected, the overall probability of displacement to camps was low in undamaged areas (1%) and rises quickly with the level of damage, up to 36% in severely damaged areas. The probability of displacement only to homes also rose with the level of damage but not as dramatically. The proportion of movers who went to camps was highest in moderately damaged areas, perhaps reflecting the availability of temporary housing nearby these areas and the high levels of mortality in severely damaged areas. Examining the pattern of displacement within households, overall 71% of the displaced were members of households in which the entire household was displaced. Whole household movement represented a minority of movers in the undamaged areas (44%) and rapidly increased with the level of damage, up to 53% of individuals in severely damaged areas. These results indicate that, faced with tsunami damage, many households decided to relocate as a unit. Future analyses will examine the sequence of moves across household members.

The rate of return migration also varied with the level of damage. Among those displaced from the community, overall 42% had returned to their community of origin by April 2005. A smaller proportion of movers had returned to undamaged areas (32%), and a larger proportion had returned to moderately damaged areas (59%). These results indicate that many displaced individuals returned relatively rapidly, and are consistent with the observations that mobility from damaged areas was distinct from undamaged areas and that those displaced from moderately damaged areas moved relatively short distances. Future analyses will draw on data from subsequent survey waves to examine the process of return migration over a longer time period.

Examining the crosses between these outcomes (not shown) additionally reveals that movers who went to private homes disproportionately left their community of origin (77% of movers to private homes), were less likely to be part of a whole displaced household (58% of movers to private homes), and were less likely to return to their community of origin (40% of movers to private homes). Relative to whole-household movers to camps, single movers to private homes are likely more similar to long-distance migrants in non-disaster settings, a hypothesis we further explore below.

Taken together, the results presented in Table 1 confirm that high rates of displacement occurred from damaged areas, and that the majority of those displaced from damaged areas moved to camps, left their communities of origin, and were part of whole households that moved. To examine the pattern of displacement across space, we mapped the probability of displacement at the community level (Figure 1). Specifically, we linked individuals to their community of residence at the time of SUSENAS and derived the weighted mean probability of displacement in each community. In Figure 1, we display these values at the centroid of each community territory[7] using a shapefile produced by Statistics Indonesia. For reference we also display the zone identified by the US Agency for International Development to have been damaged by the tsunami (buffered to 10 km for visibility; USAID MAP), which has a similar spatial distribution to our enumeration-area based measure of damage (not shown).

The map reveals that high-displacement communities (greater than 75% displaced) are located almost exclusively in or near the zone of damage, and they are primarily located along the most-impacted stretch of coastline between Meulabo and Banda Aceh (Figure 1). Probabilities of displacement were also universally high on the island of Simeulue, where very few deaths occurred (Gaillard et al. 2008) and residents of damaged communities were thus able to relocate. Some communities on the island of Nias also had high levels of displacement, likely due to a severe earthquake which struck this region in March 2005 (Briggs et al. 2006). This damage occurred within our displacement window, and is captured by our measures of damage. Overall, Figure 1 reveals that displacement was heavily clustered at the community and district levels in regions that are known to have been damaged by the tsunami. The regression analyses described below complement this map by focusing on the community and smaller scales, and advance both descriptive analyses by incorporating multivariate controls.

Multivariate Analyses

To investigate the influences of tsunami damage and other factors on displacement, we estimate a series of multivariate statistical models including logistic regressions and multinomial logistic regressions. Logistic regression and multinomial logistic regression have been used widely and successfully to model voluntary migration (e.g., Massey and Espinosa 1997) and more recently to model forced migration and displacement (e.g., Engel and Ibáñez 2007). These models are appropriate for binary and multinomial outcomes respectively (Long 1997). Building on the descriptive analyses described above, we model both displacement (a binary outcome) and displacement stratified by

[7] We map these values to community (*desa*) centroids instead of to the location of the sampled enumeration areas in order to protect the confidentiality of respondents.

distance and destination (both multinomial outcomes)[8]. Consistent with the theoretical frameworks described above, we include pre-tsunami measures of demographic characteristics, household assets and livelihood activities as predictors of displacement (e.g., independent variables). This approach allows us to account for potential preexisting differences between damaged and undamaged areas and households, and to simultaneously assess the effects of a variety of household and individual-level factors on post-tsunami displacement.

To connect this analysis to the descriptive findings, we first estimate a logistic regression model of displacement including only the area-level indicators of tsunami damage as predictors, replicating results from Table 1. We then add pre-tsunami characteristics at individual, household and area levels as predictors to account their potential effects on mobility. This model has the following form:

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

where $\Pr(y_i = 1)$ is the probability of displacement as defined in Table 1, $\Pr(y_i = 0)$ is the probability of no displacement, β_0 is a constant, β_1- β_4 are vectors of coefficients for the effects of the predictors, and e is an error term. Additionally, T_a is a set of three indicators for the level of tsunami damage to the enumeration area, X_{iha} is vector of pre-tsunami individual characteristics, X_{ha} is a vector of pre-tsunami household characteristics, and X_a is an indicator for whether the enumeration area was urban prior to the tsunami.

The predictors for this and subsequent models are defined in Table 2. Individual-level predictors include the gender, age, marital status and level of education of the individual prior to the tsunami. Age is included in the model as a peicewise linear spline with a knot at age 20, which allows a nonlinear effect of age on displacement. Household-level predictors include pre-tsunami measures of household composition, well-being, asset ownership, livelihood activities and social networks prior to the tsunami. Household composition is measured as the number of minors and adults in the household, and well-being is measured as the natural logarithm of the household's per capita expenditures. We also control for ownership of a home, nonliquid assets such as land, and liquid assets such as cash, as well as for participation in an own-farm agricultural enterprise or a non-farm enterprise. Membership in social networks is captured by measures for whether the household head had access to a family member or a friend who could provide financial support. Whether the enumeration area was urban prior to the tsunami is also included as an area-level predictor. The level of damage from the tsunami is captured in these models using the four-category measure to the enumeration area described above. Pre-tsunami characteristics were derived from SUSENAS or from retrospective questions in the first round of STAR, and damage measures were derived from STAR and other data sources as described above.

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[8] Future analyses will also model the decision of households to move together versus separately as described above.

We estimate this model first for the full sample, second for damaged areas only, and third for non-damaged areas only. By including non-damaged areas as a control, the first model reveals the overall effects of tsunami damage on mobility. By allowing the determinants of mobility to differ between the two subsamples, the second and third models indicate how the process of mobility differed between damaged and undamaged areas. All three of these models, as well as the models described below, incorporate district-level fixed effects, sampling weights, and corrections for clustering and for the use of subpopulations. Given the relatively small number of districts included in the study (nineteen), we include district-level fixed effects (i.e., one dummy variable for each district) to capture differences between districts that might have influenced mobility. The coefficients for the effects of tsunami damage on displacement can therefore be interpreted as the difference in displacement between two areas in the same district with different levels of damage. Sampling weights derived from the SUSENAS survey are also incorporated to account for unequal probabilities of selection and to weight the sample to be representative of the pre-tsunami population of the study area. We also adjust the standard errors for clustering at the level of the enumeration area and for the use of subpopulations in the analysis (Kreuter and Valliant 2007). This adjustment accounts for the multilevel structure of the data (Angeles et al. 2005) with individuals nested within households, enumeration areas and districts.

To provide more detail on the process of displacement in tsunami-damaged areas, we restrict the sample to tsunami-damaged areas and use multinomial logistic regression to examine displacement across different distances and types of destination, while including additional measures of tsunami damage as predictors[9]. These models are appropriate for cases in which the outcome is selected from a mutually exclusive set of categories (Long 1997). We use these models to examine (1) whether individuals were displaced only within community, outside of it, or not at all, as well as (2) whether they were displaced to a camp, only to private homes, or not displaced (Table 1). To capture damage from the tsunami more precisely, we supplement the area-level measure of damage with additional predictors at individual and household levels. These include whether the individual was injured in the tsunami, and whether the household experienced deaths, damage or destruction of the home, damage to liquid or nonliquid assets, and damage to members of social networks composed of family or friends. These models reveal how tsunami damage influenced different kinds of displacement, whether certain groups were more vulnerable to certain kinds of displacement, and how different forms of tsunami damage influenced displacement. These models have the following form:

$$\ln\left(\frac{\Pr(y_i = m)}{\Pr(y_i = 0)}\right) = \beta_{0m} + \beta_{1m} D_{iha} + \beta_{2m} T_a + \beta_{3m} X_{iha} + \beta_{4m} X_{ha} + \beta_{5m} X_a + e$$

[9] Due to missing data on some of the additional measures of damage, these models include only 11997 of the 12654 individuals in damaged areas.

where m indicates the multinomial outcome (e.g., within-community versus beyond-community), $\Pr(y_i = m)$ is the probability of a that form of displacement, β_{0m} is an outcome-specific constant, β_{1m}- β_{5m} are vectors of coefficients for the effects of the predictors on that form of displacement. D_{iha} is a vector of predictors measuring tsunami damage at individual and household levels, and other parameters are as defined above.

Following both the logistic and multinomial logistic regressions we exponentiate the coefficients to produce odds ratios. These values can be interpreted as the multiplicative effect of a one unit increase in the predictor on the odds of that form of displacement relative to no displacement. We also perform tests for the significance of each predictor and for groups of related predictors (F-tests), as reported below.

Multivariate Results

The results of the logistic regression analyses for the full sample and for the damaged and undamaged subsamples are presented in Table 3, including odds ratios and the results of significance tests. We focus discussion on the results which provide the most insight into the process of tsunami-induced displacement.

The first column of Table 3 presents the model for the full sample including only the area-level indicators of tsunami damage as predictors. As expected, tsunami damage had large and highly significant positive effects on displacement. Relative to undamaged areas, the odds of displacement were 24.9 times higher in severely damaged areas, 6.2 times higher in moderately damaged areas, and 2.5 times higher in lightly damaged areas. These results replicate the results[10] in the first row of Table 1 and do not account for differences in pre-tsunami characteristics.

The second column of Table 3 presents the model for the full sample including controls for pre-tsunami characteristics at the level of the individual, household, enumeration area and district. F-tests reveal that overall the individual and household predictors and the district-level fixed effects had significant influences on mobility. Inclusion of these controls reduces somewhat the size and significance of the effects of tsunami damage but they remain large and significant, indicating that differences in pre-tsunami characteristics can only partially explain differences in mobility between damaged and undamaged areas. With these controls included, the odds of displacement in severely damaged areas were 15.8 times higher than in undamaged areas, 5.8 times higher in moderately damaged areas, and 1.8 times higher in lightly damaged areas. These values are large but likely understate the overall effects of the tsunami on mobility given that we use undamaged areas as the reference category, and, as described above, mobility likely increased in these areas as well due to larger-scale contextual effects of the tsunami. These results nonetheless confirm that displacement

[10] To replicate the results in Table 3, use the probabilities of displacement in the damaged areas (p_d) and the probabilities of displacement in the undamaged areas (p_u) from Table 1 to calculate the odds ratios as $(p_d(1\text{-}p_d))/(p_u(1\text{-}p_u))$.

increased dramatically with the level of tsunami damage and that mobility was commonly used as coping strategy.

The second and third columns of Table 3 present the model with controls for the damaged and undamaged subsamples. The effects of pre-tsunami characteristics in these models provide insight into how the process of mobility differed between damaged and undamaged areas. In damaged areas, displacement was lower from farm households and increased with ownership of liquid assets and of a non-farm business. Members of farm households were likely reluctant to move despite damage to the area given that they were dependent on local natural resources for their livelihoods. Non-farm businesses such as stores and trading were particularly vulnerable to the tsunami given the subsequent local declines in population, accessibility and economic activity, and members of these households likely relocated to escape this situation and to seek out new markets in destination areas. Additionally, liquid assets such as cash and jewelry were likely used to finance relocation. These results emphasize the role of displacement as a coping strategy, which, even from tsunami-damaged areas, was influenced by household assets and previous livelihood strategies.

In contrast, displacement from damaged areas was not significantly affected by individual characteristics, household composition, economic well-being, ownership of fixed assets, membership in social networks, or urbanicity. These include traditional predictors of migration such as age and marital status as well as potential indicators of vulnerability such as gender, education and economic well-being. Thus the patterns observed by previous studies of migration (e.g., that young unmarried adults are most likely to move) and previous studies of vulnerability (e.g., that marginalized populations are more likely to be affected by natural hazards) do not appear to hold for the case of post-tsunami displacement in Indonesia.

In undamaged areas, mobility was significantly influenced by age, marital status, home ownership and participation in a farm business but not by ownership of liquid assets or participation in a non-farm business. Mobility increased to age 20 and declined thereafter. Married individuals, members of farm households and homeowners were less likely to move. These effects reflect lifecourse processes and the retaining effects of non-mobile assets and livelihood strategies, and are consistent with previous studies of migration and home-leaving in non-disaster contexts (Johnson and DaVanzo 1998, VanWey 2005, Witoelar 2009). Additionally, membership in a family network significantly reduced mobility overall (second column), but only marginally in either damaged or undamaged areas. This result indicates that access to assistance from family members, or the need provide such assistance, may reduce mobility. Together these results presented in Table 3 indicate that the process of mobility was substantially different in damaged and undamaged areas. In undamaged areas, unmarried young adults with few economic ties to the community were the most likely to move, similar to what has been observed in non-disaster settings. In damaged areas, mobility was primarily a household decision and economic factors were paramount.

The results of the multinomial logistic regressions, presented in Table 4, provide additional insight into the process of displacement in tsunami-damaged areas. These models examine displacement across distances and destinations and include additional measures of tsunami damage. The first model examines displacement only within the community of origin versus beyond the community. Overall, the level of tsunami damage increased displacement both within and beyond the community but had larger and more significant effects on longer-distance movements. Within-community displacement significantly increased with damage or destruction of the home, damage to liquid assets, and damage to members of the family network. Beyond-community displacement increased with these factors as well as with individual injuries in the tsunami, damage to non-liquid assets such as land, damage to friend networks, and the overall level of damage in the area. Among the measures of damage, injury, home destruction, damage to liquid assets and severe damage to the area had the largest effects, and the effect of deaths in the household was not significant.

These results confirm our hypothesis that the tsunami had multidimensional and multiscalar effects on displacement. The tsunami forced displacement by damaging individuals' health, households' dwellings, assets and social networks, and contextual features such as services and infrastructure. The results additionally indicate that longer-distance displacement was more responsive to tsunami damage. This result is consistent with the spatial scale of the tsunami event, which often destroyed entire communities and thus encouraged survivors to seek shelter outside of the community. Longer-distance mobility was also commonly necessary to access emergency healthcare, shelter and recovery assistance. Among the measures of damage, damage to liquid assets was relatively rare (4% of individuals) but had notably large effects, likely reflecting the inability of households to cope in the wake of the tsunami without access to assets which can easily be converted into essential goods. With this predictor included, the positive effect of ownership of liquid assets in the previous model becomes non-significant, suggesting that, rather than liquid assets facilitating mobility, in fact it is damage to these assets that necessitated mobility.

The effects of pre-tsunami characteristics in this model reveal that the process of displacement differed across distances. Consistent with the previous model, both within-community and beyond-community displacement were significantly reduced by participation in a farm business. Additionally, within-community displacement was lower in urban areas and reduced by access to friends who could provide assistance. In urban areas, the small size of communities relative to the scale of tsunami damage likely reduced within-community displacement. Access to helpful friends likely reduced within-community displacement by enabling individuals to stay in their homes, or by encouraging them to remain to help others. The importance of friend-based rather than family-based networks may reflect a high correlation across family members in the level of tsunami damage. In contrast, beyond-community displacement increased with participation in a non-farm business, as observed for overall displacement, and also with years of education and the number of adults in the household. Beyond-community displacement, as defined here, is similar in scale to migration as defined by most previous studies, and the determinants of this form of displacement are indeed also more consistent with previous studies of migration. These studies have commonly observed that educated individuals from larger households are more likely to depart, reflecting reduced opportunities in the origin community and increased returns to education in destination areas.

The second multinomial model examines displacement by the type of destinations, i.e. only to a private home versus to a camp or other temporary settlement at least once. Both forms of displacement increased with various forms of tsunami damage, with the size and significance of effects larger for displacement to camps in most cases. Pre-tsunami characteristics also had distinct effects on these two forms of displacement. Similar to the results for beyond-community displacement, displacement to private homes significantly increased with education, the number of adults in the household and participation in a farm business. Displacement to temporary settlements, in contrast, increased with ownership of a non-farm business and declined with membership in a friend network. These results suggest that displacement to private homes is more similar to migration as described in non-disaster contexts (see above), and that access to a friend network can reduce displacement to camps. The positive effect of participation in a non-farm business on displacement to camps likely reflects the particular vulnerability of these livelihood strategies to the tsunami as mentioned above, as well as the attractions of aid distribution and new markets to these entrepreneurial households.

Together, the results of the multinomial models indicate that displacement beyond the community of origin and to temporary settlements were more responsive to tsunami damage, consistent with our expectations. Of particular interest, displacement beyond the community and to private homes were more similar to migration as described in other contexts, and displacement within the community and to camps were reduced by access to friends who could provide assistance.

Conclusions

This study used data from a unique longitudinal survey of households from tsunami-damaged and adjacent areas in Indonesia to examine the process of displacement in the immediate aftermath of the Indian Ocean tsunami. The results indicate that displacement increased with the level of tsunami damage at regional, community, household and individual scales, and that displacement was a key coping strategy of affected households and individuals. Damage from the tsunami was also multidimensional, and displacement was influenced by injuries, lost and damaged assets and housing, damage to members of social networks, and damage to community infrastructure and institutions. In the most severely damaged areas displacement was predominantly outside of the community, to camps or other temporary settlements, and a process that affected the entire household. Nonetheless, even in these areas many individuals were not displaced, were able to remain in their community of origin, were able to stay with friend and family in private homes, or returned quickly to their origin communities.

The results also have important implications for theory, research methods and future disaster relief efforts. Regarding theory, the analytical results strongly support the use of the livelihoods framework as a lens to examine post-disaster displacement, but only partially support the relevance of migration studies and vulnerability studies. Consistent with the livelihoods framework, the results indicate that post-tsunami displacement can be best understood as a semi-voluntary coping strategy. Individuals did not mindlessly flee to the nearest safe destination and remain there, but instead drew on their assets and networks when possible to move to preferred destinations or to remain in their homes. This process was distinct from mobility in undamaged areas and from mobility as described by previous studies of migration in non-disaster contexts. Specifically, displacement commonly affected the entire household, and was not selective for age, gender or marital status. Such differences between forced and voluntary migration are likely to be present in other settings as well (e.g., Engel and Ibáñez 2007). Finally, potentially vulnerable populations such as women, older adults, the poor and the less educated were not particularly susceptible to displacement, contrary to the predictions of the vulnerability approach. This pattern likely reflects (1) the active adoption of mobility as a coping strategy, and (2) the characteristics of the tsunami disaster, which was completely unexpected and damaged households similarly across class lines. In future research we will further test the vulnerability approach by examining who, among the displaced, returned to their origin communities, as well as the susceptibility of various populations to declines in economic well-being following the tsunami.

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 panel survey. Key elements of the STAR project, as described above, include multilevel survey data collection, multiple waves of post-disaster interviews, migrant tracking, analysis of remotely-sensed imagery, and the incorporation of a pre-disaster representative sample and baseline dataset. This approach, though costly and complex, provides numerous analytical advantages over smaller-scale approaches, including the ability to estimate causal effects and to generalize to the regional scale. 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 are open to integration 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 future studies will hopefully 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 a large proportion 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. Additionally, individuals displaced to camps were not impoverished prior to the tsunami relative to those displaced to private homes or not displaced. The implication for future relief projects is that special efforts are likely justified to reach individuals who were displaced to private homes, as well as those, who despite suffering damage, did not leave their homes. Together these groups represented a majority of adults from severely damaged areas.

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Table 1. Probabilities of displacement by level of damage.

Outcome	Severe	Moderate	Light	None	All	Definition
Any displacement	61.6%	29.3%	14.2%	6.3%	19.2%	Moved out of the home by April 2005
Within community	11.8%	18.0%	4.9%	2.0%	6.8%	Moved out of the home but only within the community
Beyond community	49.8%	11.3%	9.4%	4.2%	12.3%	Moved at least once out of the community
Beyond community as proportion of displaced	80.9%	38.6%	65.8%	67.6%	64.4%	Beyond community / any displacement
To homes	25.7%	9.4%	8.8%	5.1%	9.2%	Moved only to private homes
To camp	35.8%	19.9%	5.4%	1.2%	9.9%	Moved at least once to a camp, barracks or mosque
To camp as proportion of displaced	58.2%	67.9%	38.0%	19.2%	51.7%	To camp / any displacement
Part of household	8.5%	8.1%	6.1%	3.5%	5.6%	Moved but one or more household members did not move
Whole household	53.0%	21.2%	8.1%	2.7%	13.6%	Entire household moved[1]
Whole household as proportion of displaced	86.1%	72.4%	57.0%	43.7%	71.0%	Whole household / any displacement
Displaced beyond community and returned	19.3%	6.7%	4.1%	1.4%	5.2%	Moved out of the community but returned by April 2005
Returned as proportion of displaced	38.7%	59.4%	44.0%	32.8%	42.1%	Returned to community / displaced beyond community
Full sample	18.7%	12.5%	21.3%	47.6%	100.0%	Individuals ages 15 and older at the time of STAR1

N=22236

[1]Includes single-member households in which the individual moved

Table 2. Definitions and mean values for the predictors.

Predictor	Mean	Level	Unit	Source	Definition
Female	0.52	Indiv	1/0	STAR0	Reference is male
Age	35.5	Indiv	years	STAR0	Age in years, spline at age 20
Married	0.60	Indiv	1/0	STAR0	Reference is single, divorced and widowed
Education	7.97	Indiv	years	STAR0	Years of formal education
Household minors	1.49	HH	#	STAR0	Household members below age 15
Household adults	3.58	HH	#	STAR0	Household members ages 15 and older
Log(pce)	12.7	HH	rupiah	STAR0	Logarithm of per capita expenditures
Home ownership	0.84	HH	1/0	STAR1	Ownership of a house
Nonliquid assets	0.79	HH	1/0	STAR1	Ownership of land or other nonliquid assets
Liquid assets	0.42	HH	1/0	STAR1	Ownership of cash or jewelry
Farm business	0.52	HH	1/0	STAR1	Participation in an own-farm agricultural enterprise
Non-farm business	0.32	HH	1/0	STAR1	Participation in a non-agricultural enterprise
Family network	0.82	HH	1/0	STAR1	Head had a family member that could provide assistance
Friend network	0.65	HH	1/0	STAR1	Head had a friend that could provide assistance
Urban	0.24	EA	1/0	STAR0	Reference is rural
Injury	0.01	Indiv	1/0	STAR1	Injured in tsunami
Household deaths	0.11	HH	#	STAR1	Household members killed in tsunami
House damaged	0.18	HH	1/0	STAR1	Home damaged in tsunami but not destroyed
House destroyed	0.08	HH	1/0	STAR1	Home destroyed in tsunami
Nonliquid assets damaged	0.12	HH	1/0	STAR1	Nonliquid assets damaged in tsunami
Liquid assets damaged	0.04	HH	1/0	STAR1	Liquid assets damaged in tsunami
Family damaged	0.13	HH	1/0	STAR1	Family members of head experienced damage in tsunami
Friends damaged	0.10	HH	1/0	STAR1	Friends of head experienced damage in tsunami
Severe damage	0.12	EA	1/0	multiple	Severe tsunami damage to the community
Moderate damage	0.19	EA	1/0	multiple	Moderate tsunami damage to the community
Light damage	0.21	EA	1/0	multiple	Light tsunami damage to the community

N=22236 individuals; sample size is smaller for some damage measures due to missing data.
Ind=individual, HH=household, EA=enumeration area

Table 3. Logistic regression models of displacement for the full sample, the damaged subsample and the undamaged subsample.

Predictor	Full	Full	Damaged	Undamaged
Severe damage	23.864***	15.812***	8.494***	-
Moderate damage	6.180***	5.773***	3.088**	-
Light damage	2.480***	1.806**	-	-
Female	-	0.943	0.955	0.902
Age spline (<20)	-	1.036	1.005	1.137**
Age spline (>20)	-	0.995	0.998	0.983**
Married	-	0.909	1.023	0.615***
Education	-	1.014	1.015	1.020
Household minors	-	0.978	0.964	1.028
Household adults	-	1.056	1.051	1.080
Log(pce)	-	0.928	0.787	1.498
Home ownership	-	0.884	1.080	0.590**
Nonliquid assets	-	0.935	0.945	0.892
Liquid assets	-	1.352**	1.527***	0.934
Farm business	-	0.670***	0.696*	0.638**
Non-farm business	-	1.486**	1.627**	1.238
Family network	-	0.796*	0.794	0.856
Friend network	-	0.894	0.830	1.117
Urban	-	0.831	0.812	0.846
F-test individual	-	2.79*	0.70	8.98***
F-test household	-	3.70***	3.87***	2.27*
F-test districts	-	13.14***	21.70***	9.33***
N	22236	22236	12654	9572

* p<0.05, ** p<0.01, *** p<0.001

Table 4. Multinomial models of displacement by distance and destination type for the damaged subsample with additional measures of damage.

	Distance		Destination	
Predictor	**Within community**	**Beyond community**	**To home**	**To camp**
Injury	2.523	5.807***	3.417*	5.736**
Household deaths	0.810	1.027	0.923	1.079
House damaged	1.708*	2.047***	1.622**	2.311***
House destroyed	2.347**	4.270***	2.721***	4.071***
Nonliquid assets damaged	0.630	1.736***	1.525*	0.795
Liquid assets damaged	9.137***	5.071***	4.951***	8.770***
Family damaged	1.662*	1.665**	1.483*	1.747**
Friends damaged	1.334	1.528*	1.738**	1.254
Severe damage	3.622	2.965***	2.019*	7.326***
Moderate damage	1.561	2.067*	1.593	2.688
Female	0.995	1.013	1.031	0.952
Age spline (<20)	1.025	1.000	1.031	1.001
Age spline (>20)	1.000	1.000	0.999	1.000
Married	1.228	0.887	0.983	1.015
Education	0.996	1.036*	1.056**	0.973
Household minors	0.962	1.002	0.985	0.969
Household adults	1.109	1.100**	1.112**	1.078
Log(pce)	0.903	1.149	1.234	0.899
Home ownership	1.512	0.830	0.985	0.914
Nonliquid assets	1.298	0.787	1.022	0.864
Liquid assets	1.022	1.091	1.090	1.049
Farm business	0.539**	0.715*	0.538***	0.869
Non-farm business	1.423	1.524**	1.260	1.904**
Family network	0.778	0.886	0.945	0.700
Friend network	0.585**	0.851	0.799	0.704*
Urban	0.210***	1.155	0.946	0.562
F-test damage	9.70***	26.38***	18.30***	19.78***
F-test individual	1.31	2.00	3.31**	0.59
F-test household	4.05***	2.09*	2.29**	3.33***
F-test districts	13.01***	134.68***	6.68***	430.67***

N= 11997 individuals

* p<0.05, ** p<0.01, *** p<0.001

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