Studying Displacement after a Disaster Using Large Scale Survey Methods: Sumatra after the 2004 Tsunami

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Abstract

Understanding of human vulnerability to environmental change has advanced in recent years, but measuring vulnerability and interpreting mobility across many sites differentially affected by change remains a significant challenge. Drawing on longitudinal data collected on the same respondents who were living in coastal areas of Indonesia before the 2004 Indian Ocean tsunami and were re-interviewed after the tsunami, this paper illustrates how the combination of population-based survey methods, satellite imagery and multivariate statistical analyses has the potential to provide new insights into vulnerability, mobility and impacts of major disasters on population well-being. The data are used to map and analyze vulnerability to post-tsunami displacement across the provinces of Aceh and North Sumatra and to compare patterns of migration after the tsunami between damaged areas and areas not directly affected by the tsunami. The comparison reveals that migration after a disaster is less selective overall than migration in other contexts. Gender and age, for example, are strong predictors of moving from undamaged areas but are not related to displacement in areas experiencing damage. In our analyses traditional predictors of vulnerability do not always operate in expected directions. Low levels of socioeconomic status and education were not predictive of moving after the tsunami, although for those who did move, they were predictive of displacement to a camp rather than a private home. This survey-based approach, though not without difficulties, is broadly applicable to many topics in human-environment research, and potentially opens the door to rigorous testing of new hypotheses in the literature.

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

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Introduction

Human vulnerability to natural hazards and environmental change has long interested geographers and other social scientists. In recent years, major advances have occurred in vulnerability conceptualization (Wisner et al. 2004; Ribot 2010) and mapping (Barnett et al. 2008; Gillespie et al. 2007). Nevertheless, consistent cross-site definition and measurement of vulnerability continues to be challenging (Adger 2006). Some studies define vulnerability without reference to actual responses to environmental shocks (e.g., Cutter, Boruff, and Shirley 2003), others focus on small-scale studies that are not obviously generalizable (e.g., Paul 2005). In the developing world studies of populations after large-scale disasters[1] typically describe individuals displaced to camps, providing little information about individuals who settled elsewhere or were not displaced (Bakewell 2008; Grais et al. 2006; Jacobsen and Landau 2003; Stallings 2006).

These studies have shaped our understanding of displacement, but aspects of their design have significant implications for the impact of research on vulnerability. If conclusions about vulnerability do not transcend specific, possibly self-selected groups of respondents and cannot be replicated elsewhere, the relevance of the research with regard to planning for or responding to environmental change is compromised. Recognizing the value of collecting information systematically on a large scale, in 2009, the Global Network of Civil Society Organizations for Disaster Reduction began collecting survey data worldwide from government officials and community representatives on local governance and its role in creating disaster-resilient communities (GNDR 2009).

The methods of probability sampling, population-representative longitudinal household surveys and multivariate analysis have the potential to inform our understanding of vulnerability in the face of a natural disaster, particularly when integrated with geo-referenced environmental data. Combining these methods, it is feasible to select a study sample that is representative of the at-risk population and to conduct surveys that measure outcomes consistently from individuals and sites that are differentially affected by the disaster. Analyses of those data have the potential to provide a rich description of the disaster's impacts, illuminate heterogeneity of the impacts and yield generalizable knowledge. The results of such an approach offer a complementary perspective to in-depth studies of specific sub-populations and provide insights into the extent to which conclusions from those studies are broadly applicable.

This paper contributes to research on vulnerability by describing a large-scale data collection effort in conjunction with analyses of population mobility and vulnerability in the context of the 2004 Indian Ocean tsunami. One of our goals is to illustrate the challenges and potential value of greater integration of population-based survey methods with human-environment research with respect to disasters and mobility.

The Sumatra-Andaman earthquake of December 26, 2004 and the tsunami it spawned caused immense death and destruction in countries bordering the Indian Ocean. Indonesia was hardest hit, with some 160,000 deaths (World Bank 2008). To provide evidence on the tsunami's consequences, we designed and fielded a large-scale population-representative longitudinal survey (STAR, the Study of the Tsunami Aftermath and Recovery) that tracked and interviewed members of approximately 10,000 households who were living in districts along the coast of the Indonesian provinces of Aceh and North Sumatra prior to the tsunami.

A key feature of STAR is that the baseline is a population-representative survey fielded before the tsunami (the February/March 2004 wave of the National Socioeconomic Survey, or SUSENAS which is a large cross-section survey conducted bi-annually by Statistics Indonesia). Collaborating with Statistics Indonesia, a population-representative sample was selected based on individuals' locations before the tsunami. Specifically, 525 enumeration areas in districts spread along the coast of Aceh and North Sumatra were selected, which generated a baseline for STAR of individuals who were interviewed in those areas for the 2004 SUSENAS. The first follow-up survey, implemented between May 2005-May 2006 covered areas that were directly affected by the tsunami as well as areas not directly affected which, to some extent, serve as comparison groups for the affected population. We sought to identify all baseline respondents who survived the tsunami, track and interview them. We faced many challenges. The first was ascertaining survival status. Overall, about 5% of the target sample died in the tsunami. In heavily damaged areas, over one-third of the population perished. We have determined survival status for over 98% of the original respondents and, in spite of the difficulties, located and interviewed 93% of the survivors.

The survey data have been integrated with contextual data on tsunami damage from multiple sources. For each study site we derived measures of damage from a comparison of satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) a few days before and then after the tsunami. These data are cross-validated with image-based damage measures released by USAID and the German Space Agency. Additionally we designed and fielded community-level surveys in each village to provide estimates of damage and measure changes in access to markets, services, and economic opportunities.

The survey and satellite imagery data are combined to map, describe, and analyze displacement and population mobility after the tsunami.[2] Displacement and mobility are key outcomes in research on vulnerability to environmental change (Piguet 2012), yet few studies have analyzed representative survey data from before and after exposure to a disaster (some exceptions are Halliday 2006; Groen and Polivka 2008; Gray and Mueller 2012a, 2012b). To provide insight into these processes we use migration histories reported by survey respondents for the four months after the tsunami to calculate and map community-specific rates of mobility. We then use multivariate methods to identify the major socio-economic and demographic characteristics of individuals and their households that are predictive of who changes residence, who leaves their village, and who enters a camp, while controlling for factors that are correlated with tsunami damage. Our results suggest that while post-disaster moves may be the last resort for those most disadvantaged before the event, these moves are made by individuals across the entire socioeconomic spectrum, indicating that post-disaster mobility has a complex and nuanced relationship with vulnerability.

Theoretical and Empirical Approaches to Vulnerability and Displacement

Vulnerability studies

Vulnerability has been defined as "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner et al. 2004). In previous studies of this issue, qualitative and spatial methodologies have been more prominent than survey and statistical methods (Chambers 1994; Eakin and Luers 2006).

An important strand of research focuses on how social, economic and political processes create context-specific vulnerability to environmental change. Seminal work on earthquake risk in mountain environments examines damage relative to settlement patterns after major earthquakes and concludes that safe development is feasible in marginal areas, given technology, but seldom practiced particularly during periods of rapid development (Hewitt 1983). Others note that "vulnerability does not fall from the sky" (Ribot 2010), but is produced by unequal power relationships between elites and others (Wisner et al. 2004).

A second strand of research describes living conditions of persons displaced by natural hazards, noting the displaced often resettle in vulnerable areas and are disadvantaged relative to the host population (Mutton and Haque 2004; Groen and Polivka 2008). Although few studies examine pre-existing social factors that contribute to displacement (for exceptions see Findlay and Geddes 2011; Myers, Slack, and Singelmann 2008; Paul 2005), a common assumption is that the poorest are most vulnerable to displacement and that post-disaster mobility is a negative outcome.

A third strand of research, which focuses on the spatial mapping of vulnerability based on exposure to natural hazards, projected environmental trends, and socio-economic status, suggests that the spatial distribution of vulnerability is concentrated in poor and marginalized areas (Cutter, Boruff, and Shirley 2003; Fothergill, Maestas and Darlington 1999; Neumayer and Plumper 2007). Typically multiple indicators of vulnerability are combined into a single index to identify populations and locations likely to suffer disproportionately from environmental hazards. Component indicators include poverty, residence in a female-headed household, rented home, or rural area, and employment in a natural-resource-dependent sector (Cutter, Boruff, and Shirley 2003; Hahn, Riederer, and Foster 2009; Tate 2013). Weaknesses of these studies are that the indices weight component indicators arbitrarily (Barnett, Lambert and Fry 2008) and rarely incorporate actual disaster impacts (Cutter 2010).

Environmental influences on population mobility

Although many studies note the potential for environmental factors to influence mobility, the literature on "environmental refugees" was stimulated primarily by Myers' predictions (1997, 2002) that environmental change would create hundreds of millions of refugees in the near future. For years the predictions were widely cited (Piguet 2012), leading to a debate on the claims' empirical foundation and appropriate approaches for investigating this phenomenon. Over time, skepticism has increased, as evidence indicates that most environmentally induced moves are short-distance, temporary and possibly voluntary (Gemenne 2011; Piguet, Pécoud, and de Guchteneire 2011).

Nonetheless, displacement remains a key outcome of interest in this era of rapid environmental change. Qualitative approaches and analyses of aggregate data have made important contributions to knowledge (Findlay and Geddes 2011; Paul 2005; Marchiori, Maystadt, and Schumacher 2012; Myers, Slack, and Singelmann 2008; Saldaña-Zorrilla and Sandberg. 2009). However, key gaps remain in understanding differential vulnerability of sub-populations to displacement over large areas or after large-scale disasters.

An emerging literature uses survey and statistical methods to investigate the effects of natural hazards on population mobility. These include studies of hurricanes in the United States (Fussell, Sastry, and VanLandingham 2010; Groen and Polivka 2008), droughts in Burkina Faso, Ethiopia, and Mexico (Gray and Mueller 2012a; Henry, Schoumaker, and Beauchemin 2004;

Nawrotzki, Riosmena, and Hunter 2012), earthquakes in El Salvador (Halliday 2006; Yang 2008), and flooding in Bangladesh (Gray and Mueller 2012b). While these studies and our research combine survey data with multivariate methods, prior research does not have the richness of before-and-after surveys conducted on a large, population-representative sample in areas affected by the natural disaster and comparable areas not directly affected. For example, two months after the Indian Ocean tsunami, Rofi, Doocy and Robinson (2006) interviewed a sample of 388 Indonesian households that had relocated to sixteen camps and surrounding communities in two districts in Aceh, Indonesia. As we show below, this design misses important population subgroups, such as those who remained in the damaged communities.

Research design

Our theoretical and methodological approach to examining vulnerability after an environmental disaster is grounded in migration and vulnerability studies and in concepts of sustainable livelihoods. Following Hugo (1996), we conceptualize post-disaster mobility as a coping strategy that occurs along a spectrum from forced displacement to largely voluntary migration (see also Hunter 2005; Naik 2009). Other strategies that may complement or substitute for mobility include drawing down assets, accessing public assistance and social networks, and changing labor force participation and spending patterns (Rosenzweig and Stark 1989; Udry 1994; Dercon 2002; Frankenberg, Smith, and Thomas 2003; Skoufias 2003; Wisner et al. 2004). Some of these are facilitated by access to human, social, financial and physical capital, as noted by the sustainable livelihoods framework (Ellis 2000). The vulnerability approach predicts that individuals with the least access to capital will be the most likely to be displaced. This view appears regularly in the hazards literature but the idea that mobility may be a positive post-disaster strategy is not widely recognized. It is, however consistent with a large literature on migration determinants, which shows that in many contexts migrants tend to come disproportionately from better-off households (White and Lindstrom 2005).

So who is most vulnerable to hazards-induced displacement? In combination, the theories and evidence suggest that the question is empirical, that the answer depends in part on the nature of the disaster, and that local context is important.

The Study Setting

The Indonesian provinces of Aceh and North Sumatra encompass coastal lowlands, urban areas, and a sparsely-populated central mountain range. The indigenous population of Aceh is predominantly Acehnese and Gayo, while the population of North Sumatra includes Coastal

Malays, Bataks, Pesisirs, Mandailings, and Nias Islanders. Both provinces include immigrants of Javanese, Minangkabau and Chinese descent (Hugo 2002).

From 1977 onward Aceh was the site of a low-intensity civil war between the Indonesian government and the Free Aceh Movement (GAM) (Schulze 2006). This struggle, rooted in conflicts over religion and natural resource revenues, resulted in human and property rights violations by both sides and generated migration to Malaysia, Scandinavia, the United States, Australia, and various other countries (Missbach 2011: 85).

The Indonesian government changed course in Aceh after Suharto's resignation in 1998, establishing a human rights commission and initiating a peace process (Schulze 2006). Negotiations broke down in 2003, martial law was imposed, and GAM retreated to Aceh's interior (Drexler 2008: 202; Le Billon and Waizenegger 2008). From 1999-2003 the conflict is estimated to have displaced some 100,000 people with most moving short distances and only temporarily (Nah and Bunnell, 2005; Aspinall 2008; Czaika and Kis-Katos 2009).

On December 26, 2004, the most powerful earthquake ever recorded occurred off Aceh's coast, generating a tsunami that engulfed communities along 800 kilometers of coastline along the island of Sumatra (Doocy et al. 2007). Experiences of the tsunami varied considerably across locations. The height and inland reach of water on shore was a complicated function of slope, wave type, water depth, and coastal topography (Ramakrishnan et al. 2005). At the beachfront in Banda Aceh, water depths were approximately 9 meters, but further inland rarely exceeded the height of a two story building (Borrero 2005). In the worst-affected areas almost all structures were destroyed, vegetation was swept away, and a large fraction of the population died. Further inland, uphill, and in topographically sheltered areas, flooding caused damage and deposited debris but structures remained largely intact. In the mountainous interior, communities sustained earthquake damage but were unharmed by the tsunami (McAdoo, Richardson, and Borrero 2007).

Estimates of post-tsunami population movement suggest that 350,000-550,000 Indonesians left damaged communities (Robinson 2006; KDP 2007). Some sheltered with family and friends, others relocated to public buildings or makeshift shelters before moving to temporary communal housing or returning to their original sites of residence. Still others remained behind in the damaged areas. Meanwhile some individuals from areas not directly damaged moved to temporary settlements because of damage to roads and communications which affected their livelihoods.

The tsunami also changed the political landscape of Aceh. GAM declared a unilateral cease-fire after the tsunami and eight months afterward GAM and the Indonesian Government signed a Memorandum of Understanding (Le Billon and Waizenegger 2008). In August, 2006 Indonesia's president signed the Law on the Governing of Aceh (LoGA), allowing local political parties and independent candidates to run for provincial offices (Stange and Patock 2010). Though the LoGA was controversial, the developments brought lasting peace and two elections to the province (Stange and Patock 2010). The changes occurred in part because the tsunami focused the international spotlight squarely on Aceh. An unprecedented US$7.5 billion reconstruction effort began, shortening the tsunami's effects on poverty and unemployment (World Bank 2008).

Design of the Study of the Tsunami Aftermath and Recovery

Implementing a population-based survey after a major disaster is difficult. People quickly relocate, complicating construction of a sample that represents the population at risk of exposure when the event occurred.

Information on welfare and coping after disasters typically comes from in-depth interviews or small rapid-assessment surveys of respondents remaining either near the site or in refugee camps. These groups are not likely to represent the full population exposed to the event, nor do the designs provide a way to benchmark respondents' experiences during and after the disaster against their situations beforehand or against individuals in unaffected communities.

STAR is designed to address these issues. Our approach builds on an international inter-disciplinary collaboration that spans two decades and reaches back to the first waves of the Indonesia Family Life Survey in the 1990s. In designing and fielding the data collection and analysis for STAR we worked with our collaborators at SurveyMETER, an Indonesian NGO, and with Statistics Indonesia.

Drawing on our experience with SurveyMETER and Statistics Indonesia studying the impact of the 2002 Bali bombing, we drew baseline information drawn from the 2004 National Socioeconomic Survey (SUSENAS) which was collected in February and March 2004, prior to the tsunami. SUSENAS, a broad-purpose large-scale household survey that represents the population at the level of the *kabupaten* (district, similar to a U.S. county), uses a multi-stage clustered sampling strategy in which enumeration areas are sampled, followed by the sampling of households within each area (Surbakti 1995).[3]

STAR followed up respondents from the 2004 SUSENAS. We selected all respondents who were living in a *kabupaten* with a coastline along the south and northwesterly coasts of Aceh and North Sumatra (including the islands of Pulau Weh, Simuelue, and Nias). Some 39,500 respondents living in these 19 *kabupaten* make up the STAR baseline sample; they are drawn from 585 enumeration areas in 525 villages (*desa*) We excluded some of the communities along the north coast where the security situation was most unstable (and where SUSENAS fieldwork was potentially disrupted) although some of those areas sustained light damage from the tsunami.

When we drew the sample, little information was available about which communities had been affected by the tsunami. We selected areas expected to be at risk, as well as coastal and interior communities where risks were likely to be low or non-existent. Damage assessments for a large area from high resolution satellite imagery only became available about a year after the tsunami, too late to inform sample selection.

By design, therefore, STAR encompasses respondents from communities where destruction ranged from extreme to non-existent, so that we could compare the lives of respondents from damaged areas to the lives of respondents from undamaged areas and thereby measure the tsunami's impact. Figure 1 displays the study sites relative to an indicator of the tsunami damage zone.

Designing the STAR questionnaires was challenging. We included the 2004 SUSENAS questions (to allow direct comparisons), items from other surveys we conducted in conjunction with Indonesia's 1998 financial crisis and the 2002 Bali bombing, and additional questions designed to measure the impact of the tsunami. Trauma psychologists advised on the inclusion of questions on potentially painful topics. We intentionally excluded questions on individual experiences of the armed conflict because we believed they would be unsettling for the respondents and possibly compromise their trust in us.

Most interviewers were university students from Aceh or North Sumatra. We trained them intensively for four weeks, including a week of field practice. Teams assigned to Aceh began fieldwork near Banda Aceh to facilitate close initial supervision. Post-tsunami interviews began in May 2005, which afforded time to design field protocols and questionnaires so that we maximized chances to relocate the original respondents, and to assemble personnel, financial, and logistical resources necessary for the survey.

Field conditions in Aceh were extremely difficult. We planned a field period of four months, but we ultimately extended it to 12 months because of the complexity of the work. In several districts extreme housing shortages made tents essential. We visited many sites five or more times to find and interview respondents. The political landscape also affected our work, which we limited to daylight hours before the peace agreement was signed.

In the first re-survey we mounted an extensive effort to identify all survivors and interview them in their pre-tsunami location or wherever they had moved. For each household interviewed in 2004 we generated a preprinted roster listing each member's name, age, sex, and relationship to the household head. When an original household member was found, that member was interviewed about the survival status and location of all other household members. If no original household member could be found we collected information from up to three informants (friends, neighbors, or local leaders) on the survival status and possible whereabouts of each original member and checked rosters of the dead and missing. With information from origin areas, we followed movers and interviewed them in their new locations anywhere on the islands of Sumatra or Java. (We estimate that 426 baseline respondents moved outside these areas; we did not try to locate and interview them for cost reasons.) We have continued to track the respondents and have interviewed them annually five times since the tsunami and will re-interview them again 10 years after the tsunami.

We restrict attention here to surviving respondents who were age 15 years or older at the first 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 dead at the first follow-up. Among survivors, about 93 percent were from pre-tsunami households in which we interviewed at least one person after the tsunami. Among those we failed to interview, most had moved and were not relocated despite extensive tracking efforts. Less than 1 percent of baseline respondents refused to participate in the follow-up, consistent with our experience in other longitudinal surveys in Indonesia.

Ultimately, 22,390 of the age-eligible surviving respondents were individually interviewed. Among other topics, respondents provided information about their location at the time of the tsunami and any changes in residence between the tsunami and the interview. Our measures of mobility draw on this information. Respondents also reported on socio-demographic characteristics, social networks, economic status, health, well-being, and exposure to the tsunami.

For respondents re-interviewed after the tsunami, comparing their answers in the first wave of the survey relative to the second provides information on data consistency across waves—a consideration that is particularly important given concerns regarding data reliability in Aceh during the conflict. Because the tsunami dramatically changed the lives of respondents and their communities, few characteristics measured at baseline are likely to be the same in the follow-up. We cannot assess reliability by comparing name and gender because they are used to identify respondents in each survey wave, but exact age is not used for this purpose. Thus, a comparison of age reported at baseline and age of the same respondent at the follow-up (accounting for the hiatus between interview dates) provides direct evidence on data quality. The correlation is 0.95 indicating a high level of test-retest reliability. Comparing this correlation between respondents living in Aceh versus North Sumatra at baseline indicates the extent to which reliability differs between the two provinces. The correlations are 0.93 and 0.96, respectively, indicating that reliability did not differ substantially between the two provinces.

As discussed above, when we designed the sample we did not know precisely which sample areas were damaged and which were not. Drawing on data from multiple sources, we created measures of damage for each of the 585 sites. 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 study site. One measure was constructed by comparing satellite imagery from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) for December 17, 2004 to imagery for December 29, 2004 (nine days before and three days after the tsunami). The proportion of land cover that changed to bare earth between image dates (through scouring or sediment deposition) was manually assessed for a 0.6 km^2 area centered on each GPS point. This measure was cross-validated with other estimates of damage derived from remotely sensed imagery that were prepared by the USGS, USAID, the Dartmouth Flood Observatory, and the German Aerospace Center (Gillespie et al., 2009).

In addition to the satellite imagery, we use information from two sources "on the ground." In each *desa* as part of our survey, local leaders provided their own assessments of the extent of destruction to the built and natural environment and our survey supervisors completed a questionnaire that detailed damage due to the tsunami and earthquake based on direct observation.

We combine the information to construct a four-category indicator of damage to the enumeration area. This indicator classifies 16 percent of enumeration areas as severely damaged, 17 percent of areas as moderately damaged, 26 percent of areas as lightly damaged (indicating peripheral flooding or earthquake damage only), and an additional 41 percent 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 and extent of damage to houses and land (Frankenberg et al. 2008, 2011). We link the measure to individuals based on their place of residence at the time of the pre-tsunami baseline.

Measuring Post-Tsunami Mobility and its Relationship to Tsunami Damage

Each respondent in STAR was asked to report their 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. The timing of within-*desa* moves was recorded, as were destinations of cross-*desa* moves. Displacement immediately after the tsunami is defined as any move after the tsunami but before May 2005 (when the first follow-up began). This measure is refined by distinguishing people who stayed within their pre-tsunami *desa* from those who moved outside it.

Desa boundaries are emphasized because of their salience in day-to-day life. They are very familiar to respondents, reflecting the importance of the *desa* as the local administrative unit with an office, elected leader and responsibility for development programs (World Bank 2004). After the tsunami, about two-thirds of the people who moved relocated outside their origin *desa.* We also consider the residence to which individuals moved, distinguishing those who spent time in a camp, barracks, mosque or other temporary settlement from those who moved only to private homes. About half the people who moved in the four-month study period stayed in a camp or temporary settlement.

We begin by assessing variation in patterns of movement by degree of tsunami damage. The spatial distribution of movement and its association with the extent of damage is illustrated in Figure 1, which maps each survey enumeration area with a marker indicating the level of post-tsunami mobility and displays a band indicating tsunami damage that was developed by USAID (buffered to 10 km for visibility; Gillespie et al. 2009). Communities in which more than 75 percent of adults changed residence (darkest circles) are primarily located along the most tsunami-impacted stretch of coastline between Banda Aceh and Meulaboh, but rates were also high on the islands of Simeulue and Nias. Rates are markedly lower for communities that lie on Aceh's northern coast (east of Banda Aceh), although this area sustained some tsunami damage. Some communities in North Sumatra have relatively high mobility as well, reflecting lighter tsunami damage that is not captured by the USAID indicator but that we measure by our methods. By showing the degree of variation in mobility, even among communities near one another and with ostensibly similar levels of damage (as characterized by USAID), this map helps illustrate the value of data collected in a standardized way as part of a clustered household survey implemented in a large number of sites.

Table 1 provides additional descriptive information. Overall about one in five adult respondents changed residences in the four months after the tsunami (19.1%). But the movement rate in severely damaged areas is ten times higher than in undamaged areas (63.7% versus 6.3%). The difference in rates is an estimate of the extent of tsunami-induced displacement in the severely damaged areas. It will underestimate displacement if some people in undamaged areas moved because of the tsunami. Our data suggest that about half a million people were displaced, of whom some 300,000 were living in severely damaged areas. Our estimate is consistent with others in the literature (for example, KDP 2007).

Although a large share of the population was displaced from heavily damaged areas, fully one-third of the adults living in these areas at the time of the tsunami did not move. Even in badly-damaged areas residential change was far from universal, demonstrating the critical importance of including both post-event destinations and pre-event areas of origin in the data collection design.

Other columns of Table 1 focus on destinations. Among those who moved away from their home, 64% also moved to a different *desa*, and 51.5% stayed at a camp or shelter at some point (the other half stayed only in private homes).

In the severely damaged communities just over half the surviving adults left the *desa*, and about a third spent at least some time in a camp, barracks, or mosque. For individuals from these communities, had we focused only on people we could find in camps, or only on people who remained in their *desa*, we would have missed over half the population directly affected by the tsunami.

Figure 2 adds a temporal dimension to the analysis. 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. In February and April, differentials by damage zone are almost non-existent, but in March movement was greatest for those from heavily and moderately damaged areas. The reason for the March spike emerges clearly in the lower panel of the figure, which displays, by month, the percentage of people who moved to a camp for the first time. In January, around half the moves made by people from damaged areas were to camps, whereas in March moves are almost entirely made up of people who moved to a camp for the first time, when, presumably, space became available.

Multivariate Analyses of Population Mobility after the Tsunami

Multivariate regression models are used to identify individual, household, and community characteristics associated with displacement. Among movers, we distinguish those who are more likely to move outside their communities relative to remaining close to their homes, and those likely to move to camps or shelters relative to private homes. The models include a broad set of covariates displayed in Table 2.

Covariates in panels A and B are measured prior to the tsunami and so do not reflect its impact. These include age, gender, marital status, and education which are powerful predictors of migration in non-disaster contexts with young, better educated males being the most likely to move (Sjaastad, 1962; Stark, 1991; Massey et al 1987). After a disaster, however, the vulnerability literature suggests that older, female, and less educated people, and those from female-headed households, are the most likely to be displaced and to end up in camps (Cutter, Boruff, and Shirley 2003; Wisner et al. 2004).

Covariates in panel B provide insights into the influence on movement of socio-economic status, livelihoods, and wealth, also measured prior to the tsunami. First, pre-tsunami household expenditure is a marker of current resources available to the household; the models include the logarithm of per capita expenditure. Second, wealth is captured by whether, before the tsunami, the household owned various assets, including a home, a farm or a non-farm enterprise. Third, because resource availability and risk management strategies are 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 before the tsunami is indicated by whether the household head had access to a family member or a friend who could provide financial support.[4]

As discussed above, we expect features of the local context to influence post-tsunami mobility. The first set of models include several *desa*-level characteristics in panel C: whether the site was urban, whether the village leader reported any political security incidents in the five years before the tsunami[5], and our index of damage, which is included as an indicator variable for each of three damage zones (undamaged areas are the excluded category).

Our second more comprehensive approach allows each *desa* to have its own baseline rate of mobility, reflecting tsunami damage to the area as well as other contextual factors. This approach accounts for the fact that 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.

To estimate tsunami effects on mobility while allowing each *desa* to be distinct, we also present extended models that capture the tsunami's impact through respondent reports of trauma and loss in panel D. These models are restricted to respondents who were living in areas that were damaged (according to our damage measure) at baseline. Individual and household-level indicators of damage to assets and livelihoods allow us to account for the considerable variation in the degree of damage sustained by individuals and households from the same *desa*. These additional covariates include whether at least one household member died because of the tsunami, whether the home was damaged, whether assets were destroyed, and whether members of the household social network were affected by the tsunami.

We use logistic regression to model each outcome. The model takes the following form for our first set of estimates:

$$\ln\left(\frac{\Pr(y_i=1)}{\Pr(y_i=0)}\right) = \beta_0 + \beta_1 X_{ihc} + \beta_2 X_{hc} + \beta_3 X_c + e_{ic} \qquad [1]$$

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. X_{ihc} is a vector of individual characteristics and X_{hc} is a vector of household characteristics, all measured prior to the tsunami. X_c is a vector of the *desa* characteristics, described above. Because some contextual features that affect the propensity to move may not be observed, in a second set of models, we replace X_c with a vector of *desa* indicators (i.e., fixed effects), α_c, which absorb all observed and unobserved characteristics of *desa* that affect movement in a linear and additive way:

$$\ln\left(\frac{\Pr(y_i=1)}{\Pr(y_i=0)}\right) = \gamma_0 + \gamma_1 X_{ihc} + \gamma_2 X_{hc} + \alpha_c + \varepsilon_{ic} \qquad [2]$$

In a third set of models, we extend the household covariates to include individual- and household-specific indicators of damage and loss caused by the tsunami itself. Under the plausible assumption that the tsunami was not anticipated, none of the covariates reflect choices made in preparation for the tsunami and so we treat the covariates as uncorrelated with unobserved heterogeneity, e_{ic}, and ε_{ic}. Since the sample is clustered at the *desa* level, estimation of standard errors allows unobserved heterogeneity to be correlated within *desa* (Huber 1981).

Multivariate Results

Table 3 presents results from the multivariate analysis. 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 different from one is indicated beside the coefficient. Wald tests for the joint significance of groups of covariates are reported at the foot of the table.

Model [1], estimated for all respondents, is reported in the first column of Table 3. Overall, the individual and household characteristics are significant predictors of movement (as indicated by the Wald χ^2 tests at the foot of the table). With respect to age, the odds of migration increase until age 20 and then decline. Females have significantly lower odds of moving after the tsunami than do males, as do individuals who can identify sources of potential assistance. Owning a non-farm business before the tsunami, however, is associated with greater odds of moving. Not surprisingly, tsunami damage had large positive effects on mobility. Relative to undamaged areas, the odds of displacement were 25 times higher in severely damaged areas, almost 7 times higher in moderately damaged areas, and over twice as high in lightly damaged areas. All of these effects are significantly different from equal odds. Moving probabilities do not vary significantly with whether the *desa* is urban or whether a political security incident occurred.

Model [2] is reported in the second column, where *desa* indicators replace the observed *desa*-level characteristics in model [1]. Overall, individual and household characteristics remain significant predictors of mobility. In these models, comparisons are drawn between people who lived in the same *desa* before the tsunami. The probability of moving is not related to gender or age but the better educated are more likely to move. Owning a non-farm business is not related to moving but those within a *desa* who own a farm business are substantially less likely to move, as are those who have a network to call on for assistance. The contrasts between models 1 and 2 underscore the importance of fully accounting for the local context—when we do so, traditional markers of vulnerability, such as being older or female, are unrelated to migration.

Results from estimating [2] separately for respondents from damaged and undamaged areas are in the third and fourth columns of Table 3. These models indicate that the patterns in column 2 mask important differences between the two types of areas. The size and significance of differences between the area-specific estimates are reported in the fifth column.[6]

In undamaged areas the probability of a move rises with age among teenagers (age 15-20), then declines. This result may reflect the tradition of *merantau*, whereby young men leave their communities for a time to explore new areas (Peacock, 1973: 109). In damaged areas people of all ages were at equal risk of displacement. As column 5 indicates, the difference in the relationship between age and displacement for damaged relative to undamaged areas is significant. In undamaged areas, married people are far less likely to move than single people. In damaged areas, however, married individuals are more likely to move (and the difference across areas is significant).

With respect to household characteristics, a significant difference between damaged and undamaged areas emerges with respect to being in a household headed by a woman. In damaged areas being part of a female-headed household is positively associated with a move, whereas in undamaged areas the reverse is true. Owners of a farm business before the tsunami were less likely to move. People with access to potential assistance were less likely to move from damaged areas. The direction of this effect is the same in undamaged areas but the coefficient is not significant. Taken together, as the Wald test in column 5 shows, these characteristics have significantly different relationships with movement from damaged relative to undamaged areas.

These results suggest that the process of mobility in damaged areas differs from undamaged areas, as expected, but also that traditional indicators of vulnerability do not reliably predict displacement from damaged areas. In undamaged areas, the results are consistent with studies of mobility in non-disaster contexts, where being younger, unmarried, and from a household that is not engaged in farming have emerged as important predictors of migration. That we find the same suggests movers from undamaged areas after the tsunami were not primarily driven by the tsunami.

In damaged areas the traditional patterns of migration do not hold. Instead, tsunami-induced displacement appears to be a distinct process. Displacement was equally likely across the age spectrum, but married individuals moved more than others. Overall, mobility for those from damaged areas was less selective for household and individual characteristics. Contrary to expectations, traditional indicators of vulnerability such as low education and low economic status were not associated with increased displacement. Members of farm households were actually less likely to be displaced. Only for female headship does the hypothesized relationship emerge with members of these households being more vulnerable to displacement.

The sixth column of Table 3 extends the analysis of mobility in damaged areas by adding individual- and household-level indicators of tsunami damage. If damage to the house occurred, a respondent is more likely to have been displaced. This is not true for other assets, but having family or friends who suffered losses in the tsunami is also associated with a significantly higher likelihood of movement, suggesting that loss of social networks contributes to displacement. Death of a household member did not have an independent effect on displacement once the other forms of damage were controlled. Exposure to the tsunami was multidimensional, with damage to housing and to social networks key factors leading to displacement. More generally, demographic characteristics were weaker predictors of movement than attributes indicative of strong ties to the land or community.

The final two columns of Table 3 place the spotlights on destinations of movers. First, we examine whether movers stay in or move out of the *desa* where they lived at the time of the tsunami. Second, we examine whether the respondents who moved after the tsunami stayed in a camp or stayed in a private home.[7] Although married individuals and those whose home was damaged are more likely to change residences, they are actually less likely to move out of the *desa.* This is consistent with the stronger local ties of those who are married. Traditional vulnerability indicators do not predict longer-distance displacement.

Regarding the type of destination, individuals who moved to a camp instead of a private home tended to be disadvantaged. They were less educated, lived in households headed by females, and were from households with lower spending levels. Individuals were also more likely to move to a camp if a household member died in the tsunami. Thus, unlike the other dimensions of mobility described above, displacement to a camp conforms to the predictions of the vulnerability literature. These findings underscore the importance of broadening studies beyond individuals in camps in order to accurately capture the full population affected by the disaster.

Finally, as a supplementary analysis we consider whether the effects of tsunami damage on mobility are modified by previous occurrences of security-related incidents at the *desa* level. We extend the model reported in column 6 by allowing all of the predictors to interact with the occurrence of a political security incident in the *desa* since the year 2000. The results (in Appendix 1) indicate that the effects of gender, female headship and disruption to the social network differed between tsunami-damaged areas that had experienced incidents and those that had not. In areas with security incidents, women and members of female-headed households were less likely to be displaced, but disruption of social networks had larger positive effects on movement. These results likely reflect complex differences in women's roles in communities with a history of security incidents. For example, if women in these communities had established patterns of daily life that were relatively independent of men (who may have been away from the community as a result of the political situation), the women may have been hesitant to disrupt these patterns by moving to a new area with potentially different expectations for women's behavior (Siapno 2008; Siapno 1997: 324).

Taken together, the multivariate results reveal that factors associated with movement after the tsunami vary strongly as a function of damage from the event, but it was not the case that women, the elderly, and the poor were forced to flee, while the better-off remained in place. Instead, ties to the land and the social fabric of the community discouraged moving, whereas damage to housing or to social networks encouraged it. Our results are consistent with previous studies which have emphasized the role of social capital in disaster response (Adger 2003; Wisner et al. 2004). Moreover, educated individuals and those from non-farm households were more likely to move from damaged areas, again suggesting that post-tsunami displacement was not a strategy solely for the desperate. While traditional measures of vulnerability such as poverty, low education and membership in a female-headed household did serve to increase entry into camps, consistent with predictions of the literature on vulnerability to natural hazards, these characteristics are not predictive of post-disaster mobility measured more broadly.

Conclusions

This paper illustrates how the integration of large-scale population survey data with satellite imagery can be used to investigate patterns of displacement and mobility in the aftermath of a large-scale disaster. The methods are applicable to studies of disaster responses in other settings. Key elements of the design are summarized to highlight the strengths and weaknesses of the approach and discuss the implications of the results for theory and policy on disasters and displacement.

Five elements of the STAR study design are worth emphasizing. First, access to survey data collected before the event provided both a baseline against which to measure tsunami impacts and a population-representative sample for follow-up. STAR has established the feasibility of this design even after a major natural disaster. Second, baseline and follow-up data were collected in both tsunami-damaged areas *and* in adjacent and more distant areas, providing comparison groups and allowing us to compare the rates and drivers of mobility for individuals from damaged versus undamaged areas. The results highlight the differences between disaster-induced mobility and other forms of migration. Third, survey data based on standardized questionnaires designed specifically for this project were collected at individual, household and *desa* levels. The data support examination of individual behavior across over 500 study sites while controlling for household characteristics and contextual features. Fourth, and especially important for a study of mobility, movers were tracked to their destinations. This strategy reduced a key source of loss to follow-up in many longitudinal surveys and thereby helped preserve the sample's representativeness. Fifth, measures of tsunami damage were derived from a variety of data sources, including satellite imagery, interviews with community leaders and eyewitnesses, and household and individual reports. These data allowed us to construct location-specific measures of damage, as well as to capture the multidimensional nature of tsunami impacts at the household scale.

All study designs have weaknesses and ours is no exception. We have described difficulties in designing and fielding the survey. More generally, most large-scale multi-purpose household surveys trade-off asking a large sample of respondents about a broad array of domains of well-being against including extensive open-ended and in-depth questions on a smaller sample. The survey captures outcomes such as the decision to move, timing and destination of each move but we miss nuances and idiosyncratic factors that drove those choices. For example, we cannot precisely identify the factors that drive timing differences in decisions to move, though a clearer understanding of this process would enrich our study. The survey did not include responsive questioning to probe the specifics of respondents' situations and so we cannot delve into how previous community-level security events affect the ways women navigate daily life. Qualitative methods would allow a more targeted investigation into these questions.

The scale of the survey does support estimation of multivariate models, which lets us investigate the competing effects of a variety of factors on mobility while directly accounting for differences between study sites. The results yield several insights that are difficult to extract from other study designs.

Previous accounts of disaster-induced mobility in the developing world are commonly predicated on the idea that the process is completely distinct from voluntary migration, representing a last-ditch strategy arising out of desperation (e.g. Myers 2002). This is not consistent with mobility following the Indian Ocean tsunami. Displacement from damaged areas *was* distinct from migration from undamaged areas, and was less selective overall. Nevertheless these two forms of mobility shared some characteristics, for example lower mobility for farm households and higher mobility for educated individuals. Other indicators of vulnerability (poverty and female headship) failed to predict overall displacement but did predict entry into camps, suggesting that post-tsunami displacement consists of a combination of mobility strategies, some of which vary in desirability. These results are consistent with conceptualizations of forced migration that emphasize the agency of the displaced, the importance of social networks and studies that highlight the complex nature of responses to disasters.

Our results have important implications for relief efforts. Disaster relief has traditionally emphasized residents of camps or other temporary settlements (e.g. UNHCR 2006). Our results indicate that about a third of individuals displaced from heavily-damaged communities found shelter exclusively in private homes. Moreover, about one-third of the people living in the most heavily damaged areas were not displaced although their lives were severely disrupted by the tsunami. Half of those who owned a home lost it, 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 investing resources to reach individuals displaced to private homes and those who did not move away may be important. Together these people represent more than half the population living in areas severely damaged by the tsunami.

A goal for this paper is to describe the application of survey and statistical methods in vulnerability research. Studies using similar methods have provided new insight into other topics in human-environment geography, such as tropical deforestation (Pan et al. 2007), forest product collection (Pattanayak and Sills 2001), and climate variability and poverty (Skoufias and Vinha 2012). Considerable opportunities exist for human-environment geographers to integrate survey and statistical methods, as well as to combine these methods with the ethnographic and GIScience approaches. Integrating survey and statistical methods with human-environment geography has the potential to enhance generalizability and replicability of the evidence and have a far reaching impact on the scientific and policy communities.

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Notes

[1] Following recent reviews (NRC 2006, IPCC 2012), we refer to biophysical events that place humans at risk as natural hazards, and to cases in which hazards overwhelm societal coping mechanisms as disasters.

[2] 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 (Deng 1998). 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 (see Hugo 1996). We recognize that for many individuals the change reflects displacement in that it occurred as a direct result of the tsunami.

[3] The 2004 SUSENAS survey occurred before the events that brought peace to Aceh in 2005, which complicated fieldwork both in 2004 and 2005, particularly in rural areas along Aceh's north coast. We implemented a number of procedures to address possible data quality issues as a result of the security situation (they are described in more detail below).

[4] 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.

[5] Our *desa*-level questionnaire included a history section, in which leaders were asked to report (since 2000) any of various events of significance, including issues of political security. Of the 981 events reports, just over 10% involved political security, of which only 26 (or less than 3%) were described as conflict (typically between GAM and the Indonesian government).

[6] 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 and estimated with the full sample and all the covariates.

[7] 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 7 (for distance) and column 8 (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.

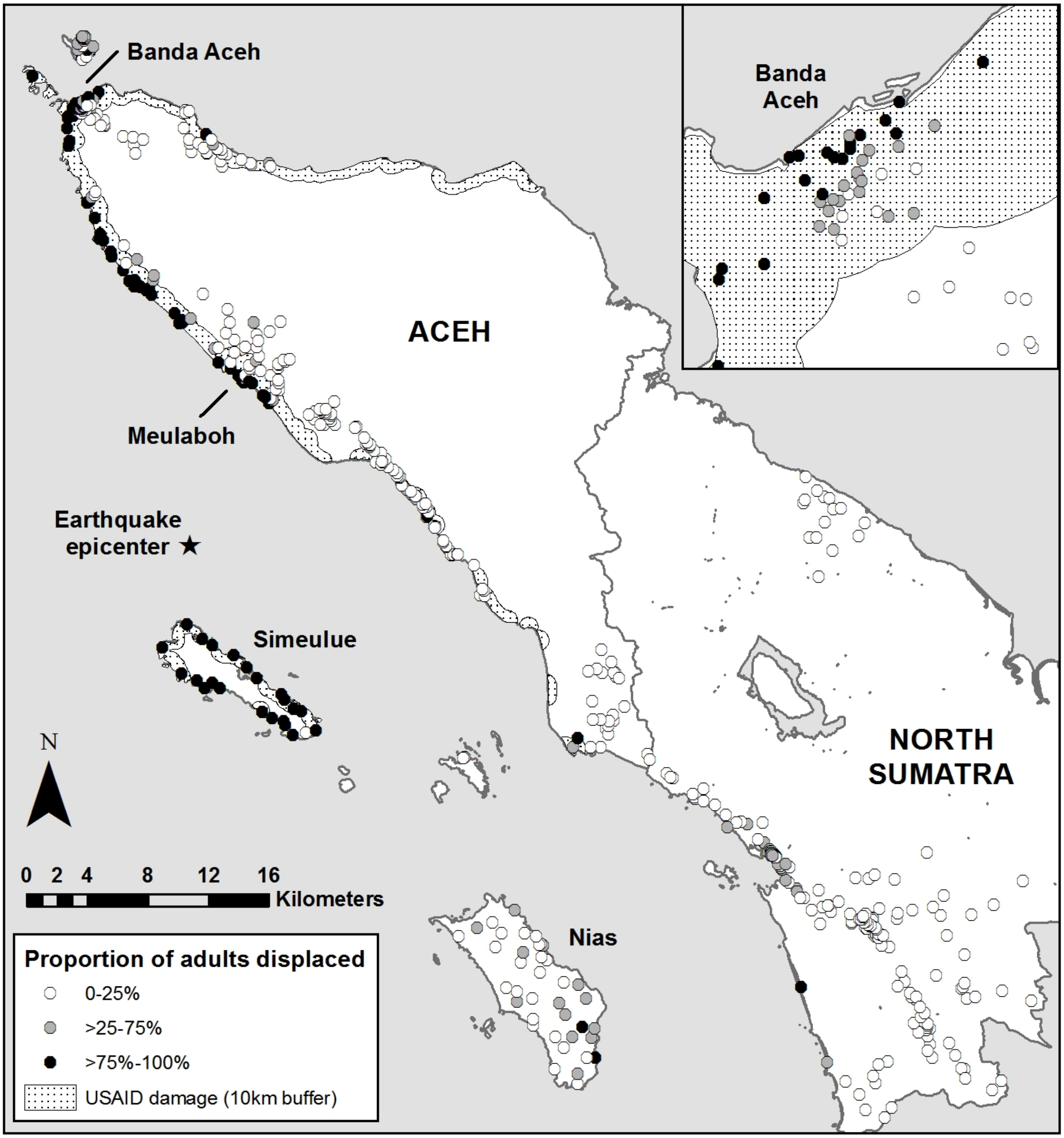
Banda Aceh
ACEH
Meulaboh
Earthquake epicenter
Simeulue
N
0 2 4 8 12 16
Kilometers
Nias
NORTH SUMATRA
Proportion of adults displaced
0-25%
>25-75%
>75%-100%
USAID damage (10km buffer)
Banda Aceh

Figure 2

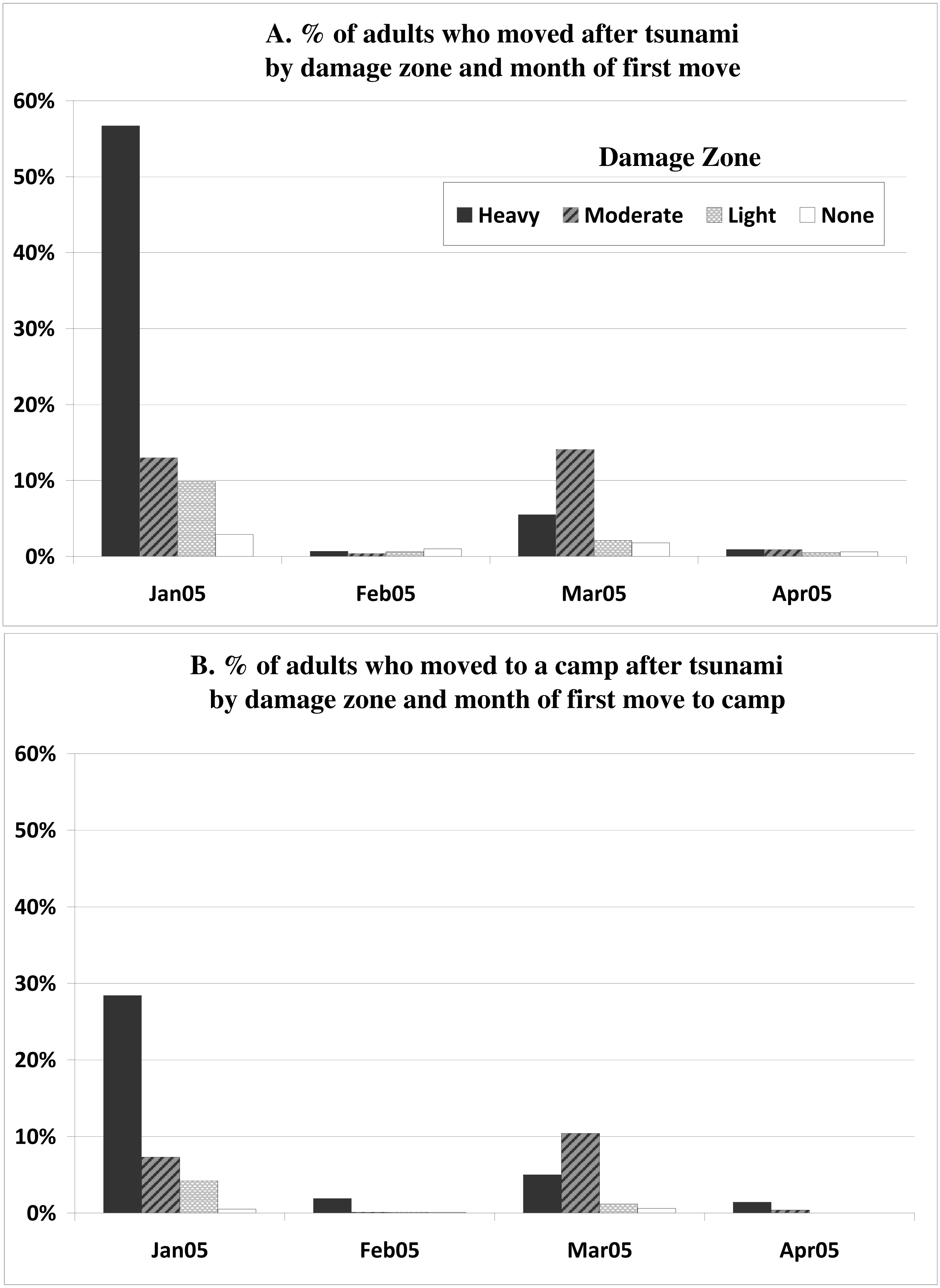
A. % of adults who moved after tsunami
by damage zone and month of first move
Damage Zone
Heavy
Moderate
Light
None
60%
50%
40%
30%
20%
10%
0%
Jan05
Feb05
Mar05
Apr05
B. % of adults who moved to a camp after tsunami
by damage zone and month of first move to camp
60%
50%
40%
30%
20%
10%
0%
Jan05
Feb05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

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

	All	Damage zone				Definition
		Severe	Moderate	Light	None	
Any mobility	19.1	63.7	28.4	13.1	6.3	Moved from pre-tsunami home by April 2005
Moves within and beyond the desa:						
Beyond *desa*	12.3	52.3	11.3	8.2	4.2	Moved out of the *desa* at least once
Within *desa*	6.9	11.4	17.1	5.0	2.1	Moved from home but remained within *desa*
Percentage of movers that left *desa*	64.1	82.1	39.8	62.2	67.2	Moved beyond *desa* 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	27.0	10.2	7.6	5.1	Moved to private homes only
Percentage of movers that went to a camp	51.5	57.6	64.0	42.0	19.1	Spent time in camp conditional on moving
Number of individuals:	22,390					
Distribution of respondents	100	13	18	26	43	
Distribution of enumeration areas	100	16	17	26	40	

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		
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	
farm business	52	
non-farm business	32	
Number of male adults (age≥15)	1.7	
Number of female adults (age≥15)	1.8	
Number of children (age<15)	1.7	
HH head has access to assistance	88	Can identify a source of financial assistance
Contextual characteristics		
Urban (%)	24	Reference is rural
Incident related to political security (%)	12	Occurrence since 2000
Tsunami damage:		Reference is undamaged
severe (%)	12	
moderate (%)	21	
light (%)	20	
Tsunami-related loss and trauma to the HH		
Death of one or more HH members (%)	3	
Damage to assets (%)		
house	19	
other assets	13	
Disruption to social network (%)	16	

Table 3. Results from the logistic regression analysis of post-tsunami mobility (odds ratios and significance tests).

Predictors	Moved after tsunami						Moved out of *desa*	Moved to camp
	All areas		Not damaged	Damaged areas	Difference	Damaged areas		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Respondent characteristics prior to tsunami								
Female	0.91 *	1.01	0.93	1.04	1.10	1.04	1.01	0.95
Age spline (<20)	1.05 *	1.04	1.20 **	0.98	0.90	0.98	0.96	1.00
Age spline (>20)	0.99 *	0.99	0.98 **	1.00	1.01	1.00	1.00	1.00
Married	0.89	0.93	0.46 **	1.27 *	2.59 **	1.29 *	0.62 *	1.27
Education	1.00	1.04 **	1.04	1.04 *	0.98	1.04 *	1.02	0.93 **
Household characteristics prior to tsunami								
HH head is female	0.81	1.04	0.66	1.27	1.99 *	1.24	0.57	1.85 *
HH per capita expenditure	0.95	1.08	1.66	0.84	1.10	0.79	1.45	0.52 **
HH owns home	0.84	0.93	0.73	1.05	1.41	1.01	0.71	1.00
farm business	0.83	0.72 **	0.63 *	0.77 *	1.21	0.71 **	0.96	1.59
non-farm business	1.73 **	1.05	0.99	1.07	1.09	1.03	0.96	1.04
Number of male adults	1.04	1.09	1.00	1.10	1.17	1.09	1.07	1.03
Number of female adults	1.06	1.07	1.08	1.06	1.05	1.08	1.07	0.86 *
Number of children	1.00	1.00	1.06	0.98	1.03	0.98	0.97	1.09
Potential assistance	0.56 **	0.66 **	0.91	0.58 **	0.72	0.53 **	0.86	0.86
Contextual characteristics								
Urban	0.98							
Incident related to political security	0.94							
Tsunami damage: severe	25.29 **							
moderate	6.54 **							
light	2.32 **							
Tsunami-related loss and trauma to the HH								
Death of one or more HH members						0.75	1.43	1.97 **
Damaged in tsunami: house						1.49 *	0.59 *	0.76
other assets						1.23	1.51	0.87
Disruption to social network						2.54 **	0.64	1.27
Wald X^2 test: Joint significance								
Contextual characteristics	41.9 **							
Individ and HH characteristics	6.6 **	3.3 **	6.4 **	2.4 **	3.2 **	5.2 **	2.9 **	5.4 **
Desa-level fixed effects		475.0 **	621.2 **	24401.7 **	582.6 **	702.3 **	72.1 **	86.4 **
Sample size	22390		9625	12765	22390	12765	5294	5294

Notes: Significance at 5%(*) and 1%(**) based on robust standard errors that take into account clustering of households and arbitrary heteroskedasticity.

Table A1. Results from the analysis allowing interactions between security incidents and other characteristics in tsunami-damaged areas (odds ratios and significance tests).

Predictors	Moved after tsunami			
	Main effects		Interactive effects	
Respondent characteristics prior to tsunami				
Female	1.09		0.63	*
Age spline (<20)	0.96		1.16	
Age spline (>20)	1.00		1.00	
Married	1.39	**	0.48	
Education	1.03		1.04	
Household characteristics prior to tsunami				
HH head is female	1.40		0.36	*
HH per capita expenditure	0.84		0.53	
HH owns home	1.03		0.89	
farm business	0.78		0.60	
non-farm business	0.98		1.55	
Number of male adults	1.11		0.87	
Number of female adults	1.06		1.13	
Number of children	1.00		0.75	
Potential assistance	0.53	**	0.94	
Tsunami-related loss and trauma to the HH				
Death of one or more HH members	0.61		4.01	
Damaged in tsunami: house	1.44	*	1.72	
other assets	1.15		1.66	
Disruption to social network	2.30	**	2.57	**

Notes: Model also includes *desa*-level fixed effects, not shown. Significance at 5%(*) and 1%(**) based on robust standard errors that take into account clustering of households and arbitrary heteroskedasticity. Sample size is 12,765.