Aging and Well-Being After a Disaster

Elizabeth Frankenberg
Duke University

Cecep Sumantri
SurveyMETER

Duncan Thomas
Duke University

September 2013

Keywords: tsunami, disaster, Indonesia.

Financial support from the Hewlett Foundation, MacArthur Foundation (05-85158-000), National Institute for Child Health and Human Development (HD052762, HD051970), National Institutes on Aging (AG031266), National Science Foundation (CMS-0527763), Fogarty International Center at the National Institutes of Health and the World Bank is gratefully acknowledged.

Introduction

Disasters are threats to population well-being that derail socioeconomic progress, strain social safety nets, and require complex assistance and recovery interventions. Over the last decade alone, Indonesia, Sri Lanka, Pakistan, China, Haiti, and Japan have all experienced natural disasters with death tolls in the tens of thousands. The high mortality disasters in recent years, combined with predictions that these events will increase in frequency as a result of global warming and rising population densities in vulnerable areas, have catalyzed heightened interest in more fully understanding the factors that shape vulnerability to disasters' impacts and that underlie trajectories of disaster recovery over the longer term.

Several challenges impede building a deeper understanding of the demographic impact of and process of recovery from disasters. These include the difficulty of studying events of catastrophic magnitude, the limited size and representativeness of the samples and follow-up periods of available data, and consequently the relative lack of empirical studies focusing on longer-term outcomes for large representative populations (National Research Council (NRC) 2006, Galea and Maxwell 2009, Sastry and Vanlandingham 2009). An obvious interest from an empirical perspective is to identify the population sub-groups who suffer the most devastating and longest-lasting impacts of disaster, as well as those who recover more quickly.

This study uses population-representative longitudinal survey data to analyze three questions that in combination shed light on the evolution of adult well-being in the tsunami's aftermath:

1) How were the tsunami's immediate impacts distributed spatially?
2) What are the temporal dimensions of changes in patterns of living arrangements and time use that the tsunami may have induced?
3) How do the immediate and medium-term impacts of the tsunami vary as a function of gender and age?

These questions are not ones for which the scientific evidence base is well-developed. Many studies of disasters focus on one or a few communities known to be affected because of their geographic location, but do not consider impacts on other communities where direct effects may be muted or nil, but indirect effects may be substantial (or also non-existent). Duration of impact can only be assessed with data from multiple time points, but longitudinal data is relatively rare (repeated cross-sections are rare as well, and also potentially problematic if high or selective mobility occurs in a disaster's aftermath).

With respect to demographic sub-groups, older adults are frequently construed as particularly vulnerable in the context of disaster (Ngo 2001). Several factors contribute to this characterization. Certainly and frailty and the prevalence of disabilities increase with age, and in some contexts older adults are relatively more isolated and have fewer resources than their prime age counterparts (Hutton 2008). With respect to mortality, older adults have been disadvantaged in a number of recent disasters, such as Hurricane Katrina and heat waves in France and Chicago. Among survivors of disasters, however, age does not always emerge as a risk factor for subsequent well-being (Kohn et al 2005, Adams et al 2012). Factors such as limited physical strength and access to resources are also mentioned in discussions of gender differences in vulnerability to natural disasters (Neumayer and Plumper 2007).

The context for our work is the Sumatra-Andaman earthquake of December 26, 2004 and the tsunami it spawned. The event 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 6,500 households living in districts along the coast of the Indonesian provinces of Aceh and North Sumatra.

The Study Setting

The provinces in which the survey is conducted are located in the northwestern half of the island of Sumatra. The provinces of Aceh and North Sumatra encompass coastal lowlands, urban areas, and a sparsely-populated central mountain range. The ethnic composition of the two provinces differs. 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).

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).

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).

Data: The Study of the Tsunami Aftermath and Recovery (STAR)

Implementing surveys 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 often 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. In designing and fielding the data collection and analysis for STAR we worked closely with our collaborators at SurveyMETER, an Indonesian NGO, and with Statistics Indonesia. We drew baseline information from the 2004 National Socioeconomic Survey (SUSENAS) which was collected in February and March 2004. SUSENAS is a broad-purpose large-scale household survey that represents the population at the

level of the *kabupaten* (district, similar to a U.S. county). SUSENAS uses a multi-stage clustered sampling strategy in which enumeration areas are sampled, followed by the sampling of households within each area (Surbakti 1995).[1]

In STAR we followed up respondents from the 2004 SUSENAS. We selected all respondents who were living in a *kabupaten* with a coastline along the southern and northwestern coasts of Aceh and North Sumatra (including the islands of Pulau Weh, Simuelue, and Nias). Some 26,927 respondents living in these 14 *kabupaten* make up the STAR baseline sample; they are drawn from 407 enumeration areas in 367 villages (*desa*) that include both coastal and inland locations. 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 (many of these communities were not affected by the tsunami at all, as they were on the opposite side of Sumatra from the tectonic plate boundaries where the quake occurred).

By design our study encompassed 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 the tsunami damage zone.

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 in or near the 2004 community, that member was interviewed about the survival status and location of all 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 have continued to track the respondents and have interviewed them annually five times since the tsunami.

We restrict attention here to surviving respondents who were 20 or older at the first follow-up survey (14,545 age-eligible respondents). Of these respondents, 620 (just over 4 percent) were confirmed dead at the first follow-up. Among survivors, we interviewed 93% in the first follow up wave. Among those we failed to interview in the first follow up, 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. By the end of the last follow-up (which concluded in 2010), we had interviewed a full 99% in at least one of the waves.

Respondents provided information about a number of topics. Here we focus on the tsunami's immediate and short-term impacts in terms of survival status, exposure to trauma, loss of kin, property damage, and migration shortly after the tsunami. We also consider receipt of housing assistance in the tsunami's aftermath, and the evolution over time of two outcomes potentially affected by the tsunami: residence in a home owned by a family member and reporting working as an activity in the week before the interview.

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 407 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 three-category indicator of damage to the enumeration area. This indicator classifies 23 percent of enumeration areas as severely damaged, 56 percent of areas as somewhat damaged, and 21 percent as undamaged by the tsunami (though we note that some of these experienced earthquake damage). The damage 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 the built and natural environment (Frankenberg et al. 2008, 2011). We link the measure to individuals based on the location of their residence at the time of the pre-tsunami baseline.

Variation in the Tsunami's Immediate and Medium-term Impacts

We start with a description of the immediate and medium-term impacts of the tsunami, highlighting spatial variation in these impacts. Table 1 displays a series of indicators for respondents based on the area in which they were living at the time of the pre-tsunami baseline. Those areas are broken down into three damage zones. Although many respondents move after the tsunami, in these analyses, we fix their location based on their pre-tsunami residence.

The first indicator we consider is survival status, presented as the percent of baseline respondents who died in the tsunami. Among respondents between the ages of 20 and 64 who were living in the heavy damage zone at baseline, 13% were killed in the tsunami. In other areas

less than 1% of adults in this age range died. Mortality is the most spatially concentrated indicator that we consider. This finding makes sense given location-specific variation in the force with which the waves struck the shore, the key role of topographical features such as the direction of the shore relative to the direction of the wave and the slope of the land, and the water's loss of power as it moved inland.

Many of those who survived the tsunami were exposed to life-threating experiences, witnessed others perish, or lost family members in the disaster. These events have the potential to affect well-being far into the future through life-changing impacts on family structure and mental health.

Indicators that require close proximity to the force of the tsunami as it came ashore are reported by respondents at a rate that is five times higher in the heavy damage zone than in the zone without damage. These include being caught in the water or injured, and seeing a friend or family member struggle in the water. Because closely-related family members were likely to be physically near one another when the waves hit, losing a spouse, child, parent, or sibling is also much more common for respondents from the zone of heavy damage. On the other hand, in areas of some damage, one of every three respondents heard or saw water from the tsunami, and one in four lost a relative. Losing a relative was also fairly common for respondents from areas without tsunami damage (probably because of outmigration from interior villages to the cities and towns on the coast). Clearly the tsunami's impacts were not confined solely to the areas in which death rates were high.

In the hardest hit communities, the tsunami destroyed everything in its path. Damage or destruction of a home or other property may also exert strong negative effects on well-being. Nearly two-thirds of respondents in the heavily damaged areas report damage to their home due to the earthquake or tsunami, as do a quarter of those in areas that experienced some damage. Rates

of property damage are much lower in areas without tsunami damage. In some of these areas the damage is likely to reflect the impact of the earthquake rather than the tsunami.

After the tsunami, many people left their homesites. In some cases the tsunami had destroyed their house, and even the land on which it stood. In the heavily damaged area some three-quarters of adult respondents changed residence within four months of the disaster, but one quarter stayed where they were.[2] In areas of some damage, where the force of the tsunami was not as intense, the fractions are reversed, with one quarter relocating and the other three-quarters remaining in place. In neither area is the more common choice even close to universal, suggesting that for many, staying versus going was a choice rather than a necessity.

Decisions about whether to leave were no doubt influenced by options for relocating. Were homes of friends or family available, or was makeshift housing the only option? In heavily damaged areas about half of our adult respondents relocated to temporary housing, as did about 20% of those from areas of some damage.

Rates of property damage in the areas that the tsunami did not affect were relatively low. About 8% of respondents report damage to their home, most likely because of the earthquake. In these areas 11% of respondents changed residence in the four months after the disaster, and about 4% report living in temporary housing.

Several key points emerge from the statistics discussed thus far. Some aspects of the tsunami's impact, such as mortality, were concentrated in a zone close to the coast in Aceh's northwestern half. In these areas many survivors were exposed to potentially traumatic experiences during the event and lost immediate family members. But damage to kinship networks and property was considerably more widespread, and the ensuing months saw great upheaval in who was living where.

To explore the duration of the upheaval, we consider whether, in each survey wave, adult respondents are living in a home that is owned by a family member. Although this measure does

not have a strict welfare interpretation, it is measured consistently before and after the tsunami and it should be responsive to the housing assistance that flowed into Aceh in the tsunami's aftermath.

The time path of this indicator is traced by damage zone. Before the tsunami, in 2004, 83% of respondents were living in an area that subsequently sustained heavy damage live in a family-owned home. By 2005, only 56% of these people were living in a family-owned home. Over time, the percentage of these respondents living in a family-owned home rises: to 72% in 2006, to 83% in 2007, and to 87% in 2008 and 2009, which exceeds the pre-tsunami rate. Among those people who, before the tsunami, were living in areas that received some damage, there was a smaller decline in the percentage living in family-owned homes (7 percentage points) and about half that gap was erased during reconstruction.

In the tsunami's aftermath assistance from the Indonesian government and from the international donor community flowed in as part of, at the time, the largest reconstruction effort ever mounted in a developing country. A goal of the effort was to "Build back better." Construction of housing and provision of building materials were key forms of assistance. Overall 57% of respondents in the heavy damage zone report receiving housing assistance of some form.[3] In areas of some damage a similar if fainter pattern emerges. About 17% of respondents report receiving housing aid.

The evolution of the indicator of living in a family owned home suggests that the process of rebuilding and recovery in Aceh was steady, but that at least on some dimensions it took years, not months, before pre-tsunami levels were re-established.

Another dimension that we can consider over time is labor force participation. In addition to its impact on living arrangements through the destruction of residences, the tsunami affected people's jobs. Along the coast, fishing boats and aquaculture facilities were destroyed, as were croplands. Rice paddies that were inundated with salt water were not suitable for rice production and were either re-purposed towards crops that tolerate saline soils, such as peanuts and

vegetables, or treated and brought back to production after several years. Though the effects were muted further inland, the loss of transportation and communication infrastructure likely took a toll there as well. On the other hand, there was much to be done with respect to debris removal, and eventually, the reconstruction of roads, bridges, and buildings. As the reconstruction effort was rolled out work opportunities increased, particularly in physically-demanding work like construction.

Panel F of Table 1 displays the percentage of men who report having worked during the week preceding the survey, in 2004, the year before the tsunami and in each of the post-tsunami surveys. Interestingly, there is no dip in working in 2005. By the end of the study period, employment rates have risen, a little in the relatively undamaged areas, but by ten percentage points for men who were living in the heavily damaged areas at the time of the tsunami. These figures may mask important changes with respect to hours and earnings, types of jobs, or in participation for sub-groups of men, but they suggest that the tsunami did not create disruptions in employment over the long-term.

To this point we have described spatial variation in the tsunami's impact over the short- and medium-term. Some of the outcomes considered also vary considerably by gender: they are displayed in Table 2 which distinguishes men and women within each damage zone.

The difference in mortality rates between men and women is stark. Among those living in areas that sustained heavy damage, 9% of adult men perished, but 17% of women died. The female death rate is nearly two times higher than the male death rate. Other research indicates that part of this gap can be attributed to strength and gender-specific differences in swimming ability (Frankenberg et al. 2011).

The gender difference in survival has implications for differences in other markers of exposure as well. Male survivors are markedly more likely than female survivors to have been caught in the water or injured, to have witnessed family and friends struggle, and, because they are

more likely to have survived than women, they are more likely to have lost a close family member. Men are also more likely than women to have experienced most of the other immediate and short-term consequences of the tsunami, but the differentials are not quite as stark as for the markers implying close proximity to the water as it came ashore. Though the rates of exposure are an order of magnitude lower in the other zones, the gender differences are quite similar across zones.

Multivariate models of variation in tsunami impacts

We have established that many of the tsunami's effects extend beyond the zone of heaviest damage, and that among those who were living in areas that sustained heavy damage, men were more likely to survive the tsunami, which left them more vulnerable than women to some of the disaster's other impacts. We now turn to multivariate models. In these models we further explore the impact of gender and establish the impact of age on various outcomes, controlling for socio-economic status.

The models we estimate take the following form:

$$\theta_{it} = \alpha + \beta\, MALE_{it} + \gamma\, AGE_{it} + \delta\, X_{it} + \mu_c + \varepsilon_{ict} \qquad [1]$$

The outcomes θ are those introduced in Table 1. We include an indicator variable for whether the respondent is male. We include two indicator variables for age, one for those 35 to 49 years, and another for those 50 to 64 years (age 20-35 serves as the omitted category). We also control for a vector, *X*, of socioeconomic status markers: education (years of attainment) and household resources (the log of monthly per capita household expenditures), both measured before the tsunami. (Frankenberg et al, 2013 provides an in depth discussion of variation by education in the impact of the tsunami.)

We stratify our results by whether the respondent lived, before the tsunami, in a community that was damaged by the tsunami.[4] By comparing the results for respondents from damaged communities to the results for respondents from communities not directly damaged by

the tsunami, we can assess the extent to which post-event patterns differ as a function of the disaster. However, even within zones, communities are quite heterogeneous with respect both to pre-disaster conditions and the disaster's impact. To address this heterogeneity we include community (enumeration area) fixed effects, μ_c, which absorb the influence of all community-specific variation that does not change over time and that affects the outcome, θ, in a linear and additive way.

The models are estimated by ordinary least squares. The outcome variables are dichotomous and are multiplied by 100, so that the coefficients indicate the difference relative to the reference group in percentage points. Unobserved heterogeneity across individuals is captured by ε_{ict}. Estimates of variance-covariance matrices and all test statistics take into account clustering at the enumeration area level and are robust to arbitrary forms of heteroskedasticity (Huber, 1981). F-statistics for the joint significance of the two age coefficients are presented in the tables.

Results for death and trauma are presented in Table 3. For ease of interpretation the first two rows report the prevalence (by damage dichotomy). Results from the multivariate models are reported in the lower panels, separately by damage area. We display the coefficients for age and gender, but not for the other control variables.

The models in which the outcome is death are estimated separately by gender, and only for respondents from the heavy damage zone, where risks of death were hugely elevated. Among males, middle-aged men between 35 and 49 face the same level of risk as those 20-34 years of age. Older men, however, are at significantly higher risk, with a mortality rate almost 7 percentage points higher than that for the youngest men. Among women, the excess risk with age kicks in much earlier. Risks for those aged 35 to 49 are 8.4 percentage points higher than the levels for women age 20 to 34. For women 50-64 years of age the differences is 10.7 percentage points. The small gap between middle-aged and older women is interesting. It is not clear how to interpret

this, but it is possible that age-related declines in physical strength begin earlier for women than men.[5]

We turn now, for those who survived the tsunami, to measures of exposure to trauma. We pool males and females in these models and so begin by discussing the coefficient for gender. In the damaged areas, for each measure, men's rates of exposure are 3.4 to 4 percentage points higher than the rates for females. The pattern is similar for male and female respondents from undamaged areas, but the differences are slightly smaller. The mechanism by which gender differences emerge likely differs across areas. In the damage zone, men were more likely to survive to tell the story of the harrowing events of the tsunami (whereas the women who experienced these things perished during the event). In the zone without direct damage, the differences by sex may be linked to differences in daily activities, which might take men further from home and closer to the tsunami's path on the day it took place, despite the fact that they reside out of its immediate reach.

Age differences in exposure do not exhibit the same pattern across the two areas. In the damaged area respondents 35-49 are just as likely to be exposed to traumatic aspects of the tsunami as their younger counterparts (the coefficient estimates are close to zero and not statistically significant), whereas those 50-64 are less likely to have been exposed (given the age differences in survival, those that were exposed may well have died). In undamaged areas the effects of age are not very precisely estimated, but they are negative and of a similar magnitude across age groups and indicators (the one exception is that seeing or hearing the water come ashore is five percentage points less likely for those 50-64 than for the youngest respondents, which is statistically significant). As with women, perhaps older adults were less likely to be away from the relatively safe locations of their homes on the day the water came ashore.

We turn next to loss of family. Losing a spouse, child, parent, or sibling is a little over twice as likely in the damaged areas as it is in the undamaged areas. But in both areas, such a loss is significantly more likely as one ages. One explanation may be that older adults are farther along

in the process of building families and thus have more close kin and more physically-dispersed close kin at risk of death. In the damaged areas, males are about a percentage point less likely than females to have lost a close family member. The coefficient is small relative to those for age, but the result is somewhat puzzling given that the gender difference goes the opposite direction in the summary statistics presented in Table 2.

If we broaden out and look at loss of any relative, the gender effects are not statistically significant in either area, nor are the effects of being middle-aged (35-49) rather than younger. The oldest respondents, however, have rates of loss that are 4-6 percentage points higher than their younger counterparts.

These results point to an interesting age gradient in disaster impacts. Although older adults are less likely themselves to have been exposed to traumatic sensory experiences of the tsunami, they are more likely than their younger counterparts to have lost family. To the extent that traumatic experiences have different impacts on mental and physical health than loss of kin, the intermediate and longer-term consequences of the tsunami may diverge by individuals' ages at the time of the disaster.

Table 4 turns the spotlight on property loss, migration, and residence in temporary housing. With respect to prevalence of these impacts, between one quarter and one third of residents of the damaged areas experienced damage to their home or other assets, and similar fractions changed residence and lived in temporary housing. The likelihood of property damage is 5-8% in undamaged areas. Nevertheless 11% of residents of undamaged areas changed residence and about 4% lived in temporary housing.

In damaged areas older respondents, especially those aged 50 to 64, are significantly more likely to have experienced property damage. But age does not affect the likelihood of changing residence or living in temporary housing. Nor, for that matter, does gender.

Quite a different story emerges in undamaged areas. There are no age- or gender-related differences in the experience of property damage. But males and the youngest respondents are more likely than females and older respondents to change residents or live in temporary housing. Given the relatively low levels of property damage, these demographic differences in the propensity to relocate soon after the tsunami are likely to reflect a different set of drivers—perhaps ones that are completely unrelated to the disaster.

Living in a family-owned home is an outcome that is closely related to decisions about relocation in the tsunami's aftermath. While it is not clear that living in a home owned by a family member is necessarily welfare-improving relative to other choices, doing so was by far the most common living arrangement before the tsunami. Moreover, the disaster had unquestionable potential to disrupt families' propensities for sharing one roof, while the provision of housing assistance may have facilitated the resurrection of these arrangements. We explore these dynamics in Table 5, using data from the 2004, 2005, 2006, and 2009 waves of STAR.

Before the tsunami, levels of living in a home owned by a family member were similar across damaged and undamaged areas. The percentage dips in 2005, particularly in damaged areas, but then begins to rise, so that by 2009, rates have returned to their pre-tsunami level.

Patterns by age and sex from multivariate models are presented in lower rows. In neither area is being male related to living in a family-owned home in 2004 or 2005. But beginning in 2006 in damaged areas, males are significantly less likely to live in family-owned homes. The same is true in undamaged areas by 2009. Males were also less likely to receive housing assistance in damaged areas (the effect is negative but not significant in undamaged areas, where rates of receipt are much lower).

With respect to age, there are no differences in the outcome in 2004 for those 35-49 relative to those 20-34, but those 50-64 were more likely to live in a home owned by a family member. This pattern holds across the damage zones. In 2005, there is a strong positive

relationship between age and living arrangements in both damage zones. This relationship persists throughout the study period, growing stronger with time, and exhibiting no difference in coefficient size across damage zones. The pattern does not reflect age differences in receipt of housing assistance, which are non-existent (presented in the last column of Table 5), although it may be related in some way to the increase in housing stock in the years after the tsunami.

Another outcome for which the evolution can be traced starting before the tsunami is work. We examine this outcome in Table 6. Because rates of labor force participation differ so markedly between men and women (in Indonesia and worldwide) we stratify these results by sex and begin our discussion with men.

Recall from Table 1 that men's presence in the labor force was high throughout the study period, did not appear to dip after the tsunami, and in fact increased over time for men from the most heavily damaged areas. When we examine working in a multivariate context, focusing on age, an interesting pattern appears. Although before the tsunami age confers a very large advantage with respect to working (and one that is not different across the two zones), this advantage erodes significantly in 2005, disappearing completely for men age 50 to 64 in the damage zone. By 2006 the same thing has happened to older men in the undamaged zone, and the gap between younger and middle-aged men has decreased by some 15 percentage points as well. In 2009 middle-aged men are only 3 to 6 percentage points more likely to report work than men aged 20-34, and men 50 to 64 are significantly less likely to be working than young men (by 15 and 8.6 percentage points in the damaged and undamaged zone, respectively).

Despite their much lower rates of participation overall, the pattern is remarkably similar for women. The age gap that has middle-aged women working more than their younger counterparts in 2009 is larger than that gap for men, and the lower rates of work for older women relative to their younger counterparts is smaller than it is for men. In both instances the gender difference

may arise because younger women have more demands on their time for childcare relative to older men (whereas for men these demands are minimal).

These results suggest substantial and complicated changes in the labor market after the tsunami. The changes perhaps began in the areas that were heavily damaged, but the effects transcend the tsunami's direct reach.

Discussion and Conclusions

This paper attempts to shed light on three questions: the spatial concentration of tsunami impacts, the evolution of disaster impacts over time, and gender and age differentials in impacts of selected post-disaster outcomes. The analyses show that the degree of spatial concentration of impacts varies greatly depending on the indicator, but certainly the disaster's effect extended beyond a narrow coastal band. Over time, one indicator, living in a family-owned home, shows an initial response but eventually returns to pre-tsunami levels. Another, employment, shows no discernible change immediately after the tsunami, but a great deal of change over the next five years. Finally, there are relatively strong impacts of age and gender on a number of outcomes, but these impacts differ by indicator and in many instances by damage zone, and defy succinct summary. In some ways the paper raises more questions than it answers, but suggests the utility of investigating these questions in further detail. Here we offer a few observations on our findings.

With respect to the question of spatial concentration, one important methodological point is that it is only by having data from across a wide array of communities that we can address this question. Had we focused solely on "ground zero"—that is the communities almost completely destroyed by the disaster, and on the people remaining in those communities, we would miss the experiences of many affected individuals.

With respect to the question of how impacts play out over time, we note the advantages of having a sample that is population-representative pre-tsunami and that allows us to control for pre-tsunami characteristics. Here we use the data to explore trends, but in next steps we will more

fully exploit the fact that we have data on individuals over time to delve deeper into what explains trends in living arrangements and work. It will be useful to consider time trends that emerge in SUSENAS data from other provinces as well, as a means of establishing what patterns are present in provinces very far away from Sumatra's northern end. Although our sample covers many square miles of Aceh and North Sumatra, the impact of the disaster on Aceh's economy and labor market was likely province-wide.

With respect to age and gender impacts, it is clear that being female and being older put individuals at an enormous survival disadvantage in the heavy damage zone. In some ways, though, the perhaps more limited mobility of these demographic groups served to protect them from some of the most traumatic experiences, in that those outside the heavy damage zone were less likely to be exposed to the traumatic impacts of the disaster.

Finally, we note that many of the paper's findings are interesting, but that it is difficult to know how to interpret them in terms of well-being. Is it an advantage or disadvantage to live in a family-owned home, or for women's labor force participation to rise? Considering these questions more fully will require a more detailed look at the situations of those for whom the changes are occurring, as well as the introduction of additional indicators of well-being with more clear cut interpretations.

References

Adam, V., S. Kaufman, T. Van Hattum, and S. Moody. 2011. "Aging Disaster: Mortality, Vulnerability, and Long-Term Recovery Among Katrina Survivors." Medical Anthropology. 2011 May; 30(3): 247–270. doi: 10.1080/01459740.2011.560777 PMCID: PMC3098037 NIHMSID: NIHMS291634

Borrero, J. 2005. Field data and satellite imagery of tsunami effects in Banda Aceh. *Science* 308(5728): 1596.

Doocy, S., Y. Gorokhovich, G. Burnham, D. Balk, and C. Robinson. 2007. Tsunami mortality estimates and vulnerability mapping in Aceh, Indonesia. *American Journal of Public Health* 97(S1):S146-S151.

Drexler, E. 2008. *Aceh, Indonesia: Securing the Insecure State*. Philadelpia: University of Pennsylvania Press.

Frankenberg, E., J. Friedman, T. Gillespie, N. Ingwersen, R. Pynoos, I. Rifai, B. Sikoki, A. Steinberg, C. Sumantri, W. Suriastini, and D. Thomas. 2008. Mental health in Sumatra after the tsunami. *American Journal of Public Health* 98(9):1671-1677.

Frankenberg, E., T. Gillespie, S. Preston, B. Sikoki and D. Thomas. 2011. Mortality, the family and the Indian Ocean tsunami. *The Economic Journal* 121(554): F162-182

Frankenberg, E., B. Sikoki, C. Sumantri, W. Suriastini and D. Thomas. 2013. Education, Vulnerability, and Resilience after a Natural Disaster. Ecology and Society 18 (2): 16. [online] URL: http://www.ecologyandsociety.org/vol18/iss2/art16/

Galea S. &Maxwell A. 2009.Methodological Challenges in Studying the Mental Health Consequences of Disasters.*Mental Health and Disasters*. Neria Y. (Ed); Galea S. (Ed) ; Norris FH (Ed); New York, NY, US; Cambridge University Press, 7.

Gillespie, T., E. Frankenberg, M. Braughton, A. Cooke, T. Armenta, and D. Thomas. 2009. Assessment of natural hazard damage and reconstruction: A case study from Banda Aceh, Indonesia. California Center for Population Research Working Paper 001-09.

Huber, P. 1981. *Robust Statistics*. Wiley, New York.

Hugo, G. 1996. Environmental concerns and international migration. *International Migration Review* 30(1): 105-131.

Hutton, David. 2008. "Older People in Emergencies: Considerations for Action and Policy Development." World Health Organization.

Kohn, R., I. Levav, I. Garcia, M. Machuca, and R. Tamashiro. 2005. "Prevalence, risk factors, and aging vulnerability for psychopathology following a natural disaster in a developing

country." International Journal of Geriatric Psychiatry. Article first published online: 22 AUG 2005 DOI: 10.1002/gps.1369

Le Billon, P. and A. Waizenegger. 2008. Peace in the wake of disaster? Secessionist conflicts in the wake of the 2004 Indian Ocean Tsunami. *Transactions of the Institute of British Geographers* 32(3): 411-427.

McAdoo, B., N. Richardson, and J. Borrero. 2007. Inundation distances and run-up measurements from ASTER, QuickBird and SRTM data, Aceh coast, Indonesia. *International Journal of Remote Sensing* 28(13-14): 2961-2975.

Missbach, A. 2011. *Separatist Conflict in Indonesia: the Long-Distance Politics of the Acehnese Diaspora.* New York: Routledge.

Ngo, E. (2001). "When Disasters and Age Collide: Reviewing Vulnerability of the Elderly." *Nat. Hazards Rev.* 2, SPECIAL ISSUE: THE SECOND ASSESSMENT IN ACTION: MULTIDISCIPLINARY PERSPECTIVES ON SUSTAINABLE HAZARDS MITIGATIONS, 80–89

NRC. 2006. *Facing Hazards and Disasters: Understanding Human Dimensions*. National Research Council, Committee on Disaster Research in the Social Sciences. National Academies Press.

Neumayer, E. and T. Plumper. 2007. The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life expectancy, 1981-2002. *Annals of the Association of American Geographers* 97(3):551-566.

Ramakrishnan, D., S. Ghosh, V. Raja, R. Vinuchandran, and A. Jeyram. 2005. Trails of the killer tsunami: A preliminary assessment using satellite remote sensing and GIS techniques. *Current Science* 88(5): 709-712.

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

Schulze, K. 2006. Insurgency and counter-insurgency: Strategy and the Aceh conflict, October 1976 - May 2004. In *Verandah of Violence: Aceh's Contested Place in Indonesia*, ed. A. Reid, 225-271. Singapore University Press: Singapore.

Stange, G. and R. Patock. 2010. "From Rebels to Rulers and Legislators: The Political Transformation of the Free Aceh Movement (GAM) in Indonesia." Journal of Current Southeast Asian Affairs. 29(1): 95-120.

Surbakti, S. 1995. *SUSENAS: A Continual Data Source for Analysis of Welfare Development*. Statistics Indonesia.

World Bank. 2008. *Aceh Poverty Assessment 2008.* Washington D.C.: World Bank

Figure 1
Study Sites in Aceh Province

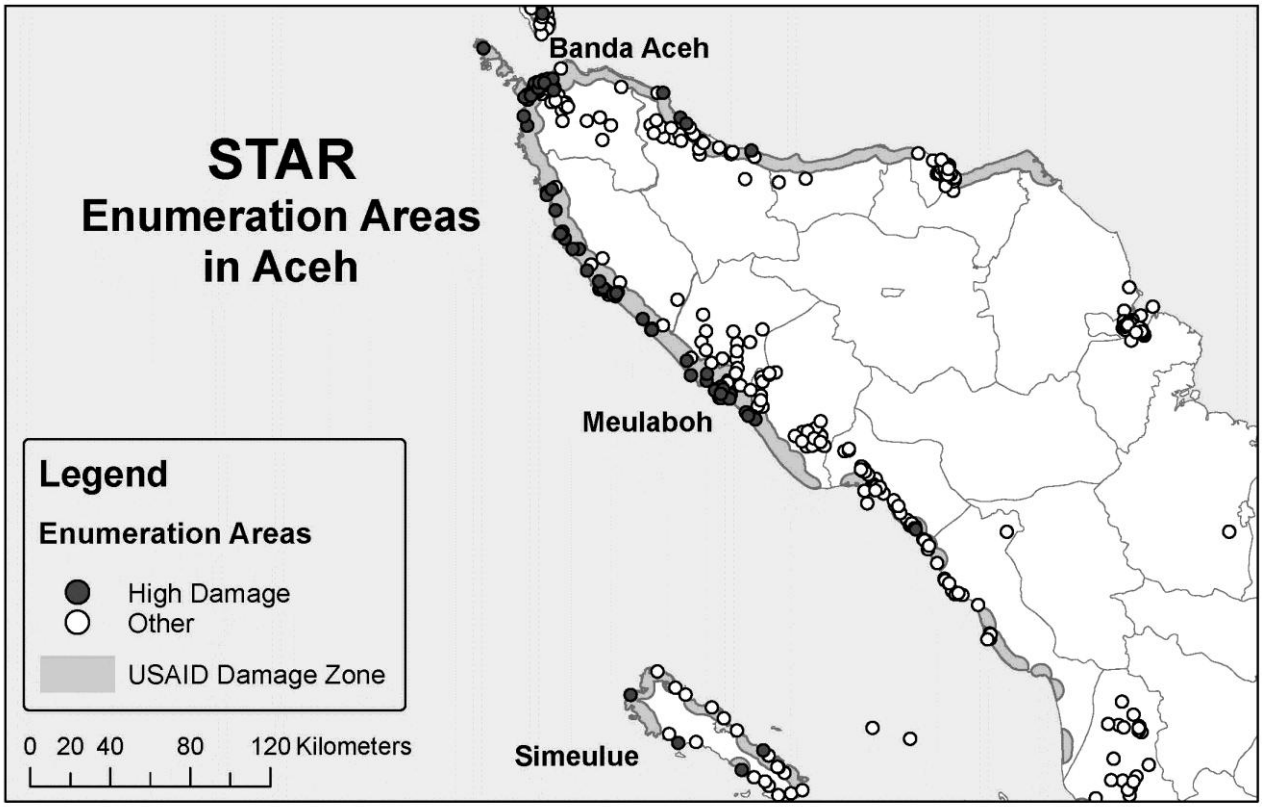

Table 1
Summary Statistics by Tsunami Damage Zone

	Damage		
	Heavy	Some	None
A. Immediate Impacts (%)			
Died	13	1	0
Saw or heard water	80	34	17
Caught in water or injured	31	5	3
Saw family or friends struggle	41	7	5
Lost a Spouse, Child, Parent, Sibling	34	7	6
Lost any family	61	26	25
B. Short-term impact on property and migration (%)			
Damage to the home	62	25	8
Damage to other Assets	66	14	2
Changed residence*	73	26	11
Lived in temporary housing*	50	18	4
C. Time Path of Living in a Family-Owned Home (%)			
2004	83	90	91
2005	56	83	88
2006	72	86	89
2007	83	87	89
2008	87	87	89
2009	87	87	90
D. Receipt of Housing Assistance (%)	57	17	10
E. Time Path of Reporting Work in the Past Week (for men)			
2004	80	86	87
2005	80	85	85
2006	86	88	89
2007	89	88	89
2008	92	89	87
2009	90	90	89
F. Background Characteristics			
Age	36	37	37
Education (years)	9	8	8
N	3085	8244	3216

Table 2
Summary Statistics by Tsunami Damage Zone and Gender

	Heavy Damage		Some Damage		No Damage	
	Males	Females	Males	Females	Males	Females
Immediate Impacts (%)						
Died	9	17	0.4	0.7	0.1	0.7
Saw or heard water	82	77	38	31	19	16
Caught in water or injured	36	26	7	4	4	2
Saw family or friends struggle	46	36	9	5	6	4
Lost a Spouse, Child, Parent, Sibling	36	31	7	8	6	6
Lost any family	63	58	27	26	23	25
Short-term impact on property and migration (%)						
Damage to the home	64	59	27	24	8	8
Damage to other Assets	70	62	15	13	6	5
Changed residence*	75	71	28	25	13	10
Lived in temporary housing*	53	47	19	16	6	4
N	1552	1664	4147	4097	1516	1569

* in the first four months after the tsunami

Table 3
Immediate Impacts of the Tsunami: Death and Trauma

	Death*		Exposure at Event			Death of Family	
	Males	Females	Saw or heard water	Caught in water or injured	Saw family or friends struggle	Spouse, Child, Parent, Sibling	Any Family
Prevalence:							
Damaged Areas	9%	17%	45%	12%	15%	14%	35%
Undamaged Areas			17%	3%	5%	6%	24%
Multivariate Regression Results							
Damaged Areas							
Male			3.899**	3.430**	4.020**	-1.240*	-0.068
(reference: female)			[0.789]	[0.598]	[0.664]	[0.573]	[0.829]
Age at First Follow-Up							
35-49	0.887	8.406**	-0.08	-0.021	-0.682	3.542**	1.089
	[1.554]	[1.772]	[0.839]	[0.713]	[0.719]	[0.686]	[0.874]
50-64	6.843**	10.711**	-2.692*	-1.631*	-2.411**	5.859**	4.063**
(reference: 20-34)	[2.193]	[2.529]	[1.133]	[0.782]	[0.883]	[1.025]	[1.222]
Observations	1,569	1,516	9,264	9,264	9,264	9,264	9,264
F statistic, age coefficients	4.87**	9.19**	3.55*	2.48	3.76*	23.72**	5.54**
Undamaged Areas							
Male			3.441**	1.954**	2.360**	-0.701	-2.954+
(reference: female)			[1.169]	[0.685]	[0.812]	[0.903]	[1.525]
Age at First Follow-Up							
35-49			-2.376	-1.492	-1.677	2.849**	0.679
			[1.738]	[0.851]	[1.129]	[0.895]	[1.547]
50-64			-5.180**	-1.366	-2.063+	7.878**	6.504**
(reference: 20-34)			[1.554]	[0.898]	[1.105]	[1.442]	[2.329]
Observations			2,789	2,789	2,789	2,789	2,789
F statistic, age coefficients			5.56**	1.7	1.85	17.2**	4.0*

* estimated for heavily damaged areas only

Includes controls for education, per capita expenditure levels, and community fixed effects. * p<.05, **p<.01

Table 4
Short-term Impacts: Property Damage and Migration

	Damage to the home	Damage to other assets	Changed residence*	Lived in temporary housing*
Prevalence:				
Damaged Areas	34%	27%	38%	26%
Undamaged Areas	8%	5%	11%	4%
Multivariate Regression Results				
Damaged Areas				
Male	0.031	0.749	-0.273	0.867
(reference: female)	[0.453]	[0.441]	[0.632]	[0.506]
Age at tsunami				
35-49	1.886*	1.14	-0.49	-0.92
	[0.819]	[0.884]	[0.916]	[0.667]
50-64	5.237**	1.990*	-0.991	0.183
(reference: 20-34)	[1.180]	[0.920]	[1.050]	[0.859]
Observations	9,264	9,264	9,264	9,264
F statistic, age coefficients	10.15**	2.51	0.46	1.36
Undamaged Areas				
Male	0.004	0.104	2.602*	1.579**
(reference: female)	[0.641]	[0.536]	[1.032]	[0.534]
Age at tsunami				
35-49	0.028	0.192	-3.777**	-1.884*
	[1.079]	[0.947]	[1.248]	[0.771]
50-64	0.48	0.018	-3.523*	-1.121
(reference: 20-34)	[1.085]	[1.212]	[1.421]	[0.819]
Observations	2,789	2,789	2,789	2,789
F statistic, age coefficients	0.1	0.02	5.03**	3

* In the first 4 months after the tsunami
Includes controls for education, per capita expenditure levels, and community fixed effects. * p<.05, **p<.01
Standard errors (in parentheses) are adjusted for heteroskedasticity at the community level.

Table 5

Receipt of Housing Assistance and Time Path of Housing Arrangements

	Home Owned by Family Member				Receipt of housing assistance
	2004	2005	2006	2009	
Prevalence:					
Damaged Areas	87%	76%	82%	87%	29%
Undamaged Areas	91%	86%	89%	90%	10%
Multivariate Regression Results					
Damaged Areas					
Male	-0.097	-0.658	-1.429**	-1.872**	-0.877*
(reference: female)	[0.370]	[0.469]	[0.478]	[0.460]	[0.414]
Age at tsunami					
35-49	1.05	2.685**	5.593**	7.501**	-0.543
	[0.788]	[0.893]	[0.849]	[0.865]	[0.761]
50-64	5.037**	7.514**	9.311**	10.606**	-0.638
(reference: 20-34)	[0.854]	[0.997]	[0.935]	[0.969]	[0.964]
Observations	10,257	10,257	10,257	10,257	10,257
F statistic, age	18.96**	28.56**	50.31**	63.97**	0.36
Undamaged Areas					
Male	-0.425	0.002	-0.611	-2.406**	-0.579
(reference: female)	[0.538]	[0.777]	[0.824]	[0.773]	[0.644]
Age at tsunami					
35-49	-0.935	3.876**	5.396**	8.377**	-0.195
	[1.181]	[1.446]	[1.255]	[1.357]	[1.140]
50-64	2.826*	9.021**	9.721**	10.482**	-0.81
(reference: 20-34)	[1.298]	[1.850]	[1.467]	[1.524]	[1.092]
Observations	2,985	2,985	2,985	2,985	2,985
F statistic, age	3.44	11.9**	22.4**	27.6**	0.3

Includes controls for education, per capita expenditure levels, and community fixed effects. * p<.05, **p<.01

Standard errors (in parentheses) are adjusted for heteroskedasticity at the community level.

Table 6

Time Path of Work as an activity in the past week

	Females				Males			
	2004	2005	2006	2009	2004	2005	2006	2009
Prevalence:								
Damaged Areas	39%	39%	43%	50%	85%	84%	88%	90%
Undamaged Areas	31%	38%	40%	45%	87%	85%	89%	89%
Multivariate Regression Results								
Damaged Areas								
Age at tsunami								
35-49	15.290**	16.529**	16.208**	10.654**	25.328**	12.338**	9.712**	3.259**
	[1.493]	[1.616]	[1.697]	[1.839]	[1.574]	[1.382]	[1.217]	[0.993]
50-64	12.811**	9.329**	4.366+	-2.615	17.929**	-2.808	-0.081	-14.986**
(reference: 20-34)	[2.160]	[2.387]	[2.484]	[2.385]	[2.187]	[2.034]	[1.862]	[1.787]
Observations	4,137	4,137	4,137	4,137	3,628	3,628	3,628	3,628
F statistic, age	53.4**	52.5**	47.8**	24.9**	145**	57.7**	41.5**	46.2**
Undamaged Areas								
Age at tsunami								
35-49	19.296**	12.555**	15.737**	9.904**	24.165**	17.480**	9.924**	5.506**
	[3.042]	[2.763]	[2.949]	[3.320]	[2.609]	[2.561]	[2.460]	[1.961]
50-64	17.844**	6.715	8.120+	-4.199	18.174**	8.567*	0.089	-8.612*
(reference: 20-34)	[3.876]	[4.196]	[4.133]	[4.935]	[2.841]	[3.709]	[3.104]	[3.460]
Observations	1,306	1,306	1,306	1,306	1,053	1,053	1,053	1,053
F statistic, age	20.5**	10.7**	14.7**	9.2**	42.9**	25.7*	9.6**	13.9**

Includes controls for education, per capita expenditure levels, and community fixed effects. * p<.05, **p<.01

Standard errors (in parentheses) are adjusted for heteroskedasticity at the community level.

Notes

[1] 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).

[2] We measure moving as a change in residence within four months of the tsunami because fieldwork for the first survey began in May 2005, five months after the disaster.

[3] Questions about receipt of housing assistance are asked at the household level. Our measure indicates the percentage of respondents who were living, in at least one of the post-tsunami waves of data collection, in a household in which the male or female head reports having received housing assistance.

[4] Because levels of death and labor force participation vary substantially across men and women, for these outcomes we stratify by gender as well as by degree of damage.

[5] Younger women are better educated than older women, and it is possible that they are more likely to know how to swim, but we have no evidence to suggest that this is the case.