The Evolution of Well-Being in the Aftermath of a Disaster: Evidence from Aceh and North Sumatra

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October 2014

Keywords: tsunami, natural disaster, reconstruction, recovery, Indonesia.

Prepared for the conference on "The Demography of Disasters: Implications for Future Policy on Development and Resilience," Australian Demographic and Social Research Institute. 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 family and 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 such disasters will increase in frequency as a result of global warming and rising population densities in vulnerable areas, have catalyzed heightened interest in better understanding the factors that shape vulnerability to the wide-ranging immediate and longer-term impacts of disasters' impacts, as well as understanding the mechanisms that underlie variation in trajectories of disaster recovery at the individual and community level.

Several major challenges exist with respect to developing a deeper understanding of the demographic and socio-economic impact of disasters and the process of recovery. These include the difficulty of studying events of catastrophic magnitude, particularly those that are unanticipated, the limited size and representativeness of study samples and follow-up periods of available data, and consequently the relative lack of empirical studies focusing on longer-term outcomes for large population-representative samples (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 large-scale population-representative longitudinal survey data collected from individuals and households living along the coast of the island of Sumatra, Indonesia, before and after the 2004 Indian Ocean earthquake and tsunami. Respondents were interviewed about 10 months before the tsunami, the year after the tsunami, and then annually thereafter for four more years. These data are used to address 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 over the short and medium term?
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 for several reasons. After a disaster that results in substantial displacement, it is a challenge to construct a sample that is representative of the population that was affected by the disaster. Duration of impact can only be assessed with data from multiple time points, but longitudinal data are rare. If migration after a disaster is selective, comparisons of repeated cross-sections of populations living in areas affected by the disaster are difficult to interpret unless detailed retrospective data are also collected. Many studies of disasters focus on one or a small number of communities known to be affected because of their geographic location, but do not consider impacts on other communities where direct effects may be minimal but indirect effects may be substantial.

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 frailty and the prevalence of disabilities increase with age, and in some contexts older adults are relatively more isolated, may have fewer resources than their prime age counterparts, and if assets are destroyed, older adults may have more limited opportunities for rebuilding after the disaster (Hutton 2008). With respect to mortality, older adults have emerged as disadvantaged in a number of recent disasters, including 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 7,700 households living in districts along the coast of the Indonesian provinces of Aceh and North Sumatra.

The Study Setting

Aceh and North Sumatra are located in the northwestern half of the island of Sumatra. The provinces encompass coastal lowlands, urban areas, and a sparsely-populated central mountain range. From 1977 onward, Aceh was the site of a civil war between the Indonesian government and the Free Aceh Movement (GAM) (Schulze 2006). After President Suharto's resignation in 1998, the Indonesian government established a human rights commission and initiated a peace process, but negotiations broke down in 2003, martial law was imposed, and GAM retreated to Aceh's interior (Drexler 2008: 202; Le Billon and Waizenegger 2008; Schulze 2006).

On December 26, 2004, one of the most powerful earthquakes ever recorded occurred off Aceh's coast, generating a tsunami that engulfed communities along 800 kilometers of Sumatra's coastline (Doocy et al. 2007). Experiences of the tsunami varied considerably across locations because the height and inland reach of the water as it came ashore 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 the tsunami destroyed almost all structures, swept away crops and vegetation, and killed large fractions of the population. In these areas the tsunami decimated networks of families and friends and damaged or destroyed property and other assets. 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. Eight months later in August 2005, GAM and the Indonesian Government signed peace a agreement that is still in place. These changes occurred in part because the tsunami focused the international spotlight squarely on Aceh. Over US$7 billion was pledged for the reconstruction effort. Indonesia established a Bureau for Reconstruction and Rehabilitation (BRR) which succeeding at converting most of the pledges into resources that totaled about US$6.3 billion. The Indonesian government and donor organizations each contributed some US$2.3 billion, with the remainder of resources being provided by non-governmental organizations. In the years that followed, BRR coordinated the construction of 140,000 houses, 4,000 kilometers of road, 270 bridges, some 1,700 schools, 1,100 health facilities, and 1,000 government buildings (Nicol, 2013, p 7, 281). In addition to its impacts on housing and infrastructure, it is thought that the massive reconstruction effort has resulted in reduced poverty and unemployment in Aceh and North Sumatra (World Bank 2008).

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

In the absence of a pre-disaster baseline, implementing a population-representative survey after a major disaster is difficult. People quickly relocate, complicating construction of a sample that represents the population that was at risk of exposure when the event occurred. As a result, much of the information about welfare and coping after disasters is based on 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 entire population that was 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 communities that were not directly affected by the disaster.

STAR is designed to address these challenges. 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 round of the National Socioeconomic Survey (SUSENAS) which was collected in February and March 2004 by Statistics Indonesia. SUSENAS is a broad-purpose large-scale household survey that is population-representative 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 selected all the enumeration areas included in the 2004 SUSENAS in 15 coastal *kabupaten* so that the baseline survey covered over 33,000 individuals. We sought to find and interview every surviving baseline respondent. In Aceh, 13 *kabupaten* with a coastline along the southern and northwestern coast were selected along with two *kabupaten* on the west coast of North Sumatra.[2] This baseline sample included 487 enumeration areas in 430 villages (*desa*) and covered both coastal and inland locations.

By design our study encompasses respondents from communities where destruction ranged from extreme to non-existent, so that it is possible to compare the lives of respondents who were living in areas that were damaged by the tsunami with the lives of respondents from areas not directly affected, and thereby measure the impact of the tsunami's destruction. Figure 1 displays the study sites relative to the tsunami damage zone as measured by a comparison of high

resolution satellite imagery a few days before and a few days after the tsunami in each of our enumeration areas.

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 with a ten-year follow-up conducted in 2014-15.

In this research, we restrict attention to surviving respondents who were 25 to 69 years of age at the first follow-up survey and who at the time of the 2004 survey were living in one of the survey communities eligible for the first follow up survey. Among these 13,217 age- and location-eligible individuals who participated in the 2004 survey, 1,079 (just over 8 percent) were confirmed dead at the first follow-up. Survival status could not be ascertained for 274 (2 percent). They are treated as survivors and eligible for follow-up. Among survivors at the first post-tsunami interview, by the end of the fifth follow-up (which concluded in 2010), we had obtained some post-tsunami information (from the individual or from their household) for 97%. 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.

Respondents provided detailed information about the demographic, health, social and economic domains of their own lives and their families. They also told us about their experiences of the tsunami and we begin with a description of the tsunami's immediate and short-term impacts as measured by survival status, exposure to trauma, loss of kin, and property damage. We proceed to describe the evolution over time of three indicators of well-being that are potentially affected by the tsunami and subsequent reconstruction: residence in a home owned by a family member, whether the respondent is a widow or widower, and whether the respondent reported working as an activity in the week before the interview. In each case and for each respondent, we compare the indicator before and after the tsunami – to measure the immediate impact of the tsunami - and then describe how the indicator evolved over the subsequent five years – to assess the longer-term impacts. Our analytical file is restricted to individuals who survived to 2009 and provided individual data in the first, second, and fifth follow-up waves (N=8,516).

When we designed the sample we did not know precisely which enumeration areas were damaged by the tsunami and which were not. Drawing on data from multiple sources, we created measures of damage for each of the 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 20 percent of enumeration areas as severely damaged, 52 percent of areas as somewhat damaged, and 28 percent as undamaged by direct effects of the tsunami (though some of these experienced earthquake damage as well as indirect effects of the tsunami). 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. These locations are indicated on Figure 1 which distinguishes heavily damaged enumeration areas from other areas in Aceh province. The importance of GPS-based location-specific measures of damage is highlighted by the inclusion on the map of damage areas that were identified by the USAID rapid mapping services, one of six extent-of-damage products created for the area after the tsunami.

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. We compare residents of areas that were heavily damaged to individuals in other areas, which include areas that were somewhat damaged or only indirectly affected by the tsunami. Since many respondents in areas that were damaged moved after the tsunami (Gray et al, 2014), in these

analyses we locate each respondent in the enumeration area in which they were living at baseline, before the tsunami.

The first indicator we consider is survival status, presented as the percent of baseline respondents who died in the tsunami. Among respondents age 25-69 years who were living in the heavy damage zone at baseline, 23% were killed in the tsunami. In other areas 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. Individual, household and community characteristics that are predictive of survival are discussed in detail in Frankenberg et al (2011).

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 roughly seven times higher in the heavy damage zone than in the zone with limited 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, although because the heavily damaged areas included coastal towns and cities that were an attractive destination for migrants, loss of close kin occurred for residents in the area of more limited damage as well. Clearly these experiences of the tsunami 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 also exerts strong negative effects on well-being including the economic viability of the individuals and communities. Nearly six in ten respondents in the heavily damaged areas report damage to their home due to the earthquake or tsunami, as do almost one quarter of those living in the areas that experienced limited damage.

Several key points emerge from the evidence presented 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.

As discussed in the introduction, after the tsunami, a well-organized and well-financed reconstruction effort was implemented. Provision of housing either in-kind or in the form of grants for repairs and rebuilding was a central component of the reconstruction effort. Among our respondents, 53% of those who were living in heavily damaged communities at the time of the tsunami subsequently benefitted from housing assistance during the five years after the tsunami, as did 13% of those originally from communities where damage was limited.[3]

Some of the outcomes we are considering vary considerably by gender as well as by damage zone. They are displayed in columns 3-8 of Table 1 (separately by damage zone). For individuals living at the time of the tsunami in communities that were heavily damaged, the difference in mortality rates between men and women is stark. Among adult men, 18% perished, whereas 27% of women died. Other research indicates that part of this gap can be attributed to strength and gender-specific differences in swimming ability (Frankenberg et al. 2011).

This 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 and to have witnessed family and friends struggle. Male survivors

are also more likely than female survivors to have experienced the other immediate and short-term consequences of the tsunami, but these differentials are not quite as stark as for the markers implying close proximity to the water as it came ashore and, therefore, higher mortality rates for females relative to males. Though the rates of exposure are an order of magnitude lower in the other zone, for markers indicative of proximity to the water at the time of the tsunami, the gender differences echo the same pattern as in the heavy damage zone.[4]

Longer term 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 turn next to examine three key indicators of well-being: whether the respondent is living in a home owned by themselves or a family member, whether the respondent was working in the week before the interview and whether the respondent was widowed at the time of the interview. Results are reported in Tables 2, 3 and 4, respectively. For each indicator, we describe the immediate upheaval by comparing the indicator before the tsunami (reported in column A), the year after the tsunami (in column B) and then for two years and five years after the tsunami (in columns C and D, respectively). Changes in the year after the tsunami, relative to the year before the tsunami are reported in column E. The evolution of each indicator between one year and five years after the tsunami is reported in column F. Column G reports the change between the pre-tsunami baseline and the 5 year follow-up.

In each table, results are presented separately for males (in panel 1) and females (in panel 2). Results for each outcome for the sample of all 25-69 year olds are presented at the top of the table and then separately by four age groups. In each case, we focus on whether patterns differ

depending on whether, before the tsunami, respondents were living in communities that were heavily damaged by the tsunami (in the first row of each block) relative to those living in other areas that experienced limited or only indirect damage (in the second row). The percentage point difference is reported in the third row along with the standard error of that difference (taking into account clustering at the primary sampling unit and heteroskedasticity of arbitrary form). These comparisons provide direct evidence on the extent to which post-event patterns differ as a function of the disaster.

We begin by considering whether, in each survey wave, adult respondents are living in a home that is owned by a family member, presented in Table 2. Although this measure does not have an unambiguous welfare interpretation, it reflects at least three dimensions of the impact of the tsunami: damage to personal networks, loss of property ownership, and destruction of economic assets. In addition, the indicator provides direct evidence on one key marker of the impact of the housing assistance that flowed into Aceh in the tsunami's aftermath. Those flows are also indicative of new economic opportunities that emerged.

Beginning with Column A of the first panel of Table 2, in 2004, before the tsunami, 80.6% of male respondents who lived in areas subsequently heavily damaged lived in a family-owned home. By 2005, only 59.6% of these males were living in a family-owned home (column B)—a 21 percentage point decline (column E) and testimony to the destructive impact of the tsunami on property and economic livelihoods. Over time, however, the percentage of these male respondents living in a family-owned home steadily rises: to 72% in 2006, and to 85.2% by 2009 (column D), an increase relative to the year after the tsunami of 25.6 percentage points (column F), which exceeds the fraction who lost a home, so that by 2009, more males in the heavily damaged areas were living in family-owned homes than before the tsunami (column G).

Among those who, before the tsunami, were living in areas that received some damage, 93.1% lived in a family-owned home in 2004. The disaster appears to have affected this group as

well, in that the percentage falls to 88.5% in 2005, but this decline is much smaller than what is observed for individuals in the heavy damage zone. In 2005, the gap between individuals from the heavily damaged zone versus the zone of limited damage is almost 30 percentage points—but it falls in each successive survey year. By 2009, the difference is 7.8 percentage points—smaller, in fact, than what was observed prior to the tsunami in 2004.

Difference-in-differences estimates of changes between heavy and limited damage areas are reported in the third row of columns E, F and G. They confirm that both the widening of the difference between zones from 2004 to 2005 (a 16.4 percentage point increase in the size of the gap) and the strong reversal of that difference in the post-tsunami period from 2005 to 2009 (a 21.1 percentage point make-up) are large and statistically significant. By 2009, the gap between zones is 4.7 percentage points smaller than it was in 2004 (a change that is not statistically significant). In other words, despite the dramatic difference between zones that the tsunami created, by 2009 the differences between zones are not statistically distinguishable from those in place before the tsunami, in 2004.

Panel 2 of the table reports results for females age 25 through 69. The patterns are essentially identical. Rows 2 through 5 of Table 2 explore the dynamics separately across four age groups of males and females. The overall patterns are roughly the same although the impact of the tsunami fell most heavily on younger males and females (ages 25-44) living in heavily damaged areas, and those groups also experienced the greatest post-tsunami growth. Among males ages 25-34 and females age 35-44, the fraction living in a family-owned home is about 8 percentage points higher 5 years after the tsunami relative to before the tsunami if they were living in areas that were heavily damaged relative to other areas. This increase is statistically significant and suggests that younger adults in the heavily damaged areas benefited more from the reconstruction effort than older adults in those areas.

The evolution of these trends in 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 several years before pre-tsunami levels were restored (or in this case, actually improved).

Our second marker of the impact of the tsunami is participation in the formal and informal labor force. 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, the tsunami created work opportunities, such as debris removal, and eventually, the reconstruction of roads, bridges, and buildings. As the reconstruction effort was rolled out, work opportunities increased in physically-demanding work such as construction, as well as in the provision of services for those in the construction sector.

Table 3 follows the same format as Table 2 and provides information regarding the percentages of men and of women who report having worked during the week preceding the survey interview in each wave.

Prior to the tsunami, males are about twice as likely as females to be working in either the formal or informal sector and employment rates tend to be higher in areas that sustained limited damage relative to the heavily damaged areas. Among males of all ages, employment rates vary only modestly as a result of the tsunami and reconstruction effort. Specifically, in the year after the tsunami, there is a small decline in employment rates in heavily damaged areas with a larger decline in other areas. Employment bounces back to above pre-tsunami rates in heavily damaged areas within two years and exceeds the pre-tsunami rate; the bounce is not as large in other areas

and employment of males remains about 5 percentage points lower than it was prior to the tsunami in 2004. This overall stability masks substantial variation within age groups.

Among 25-34 year old males, in 2004 the deficit in the fraction working relative to males of the same age in other areas is large (15 percentage points) and statistically significant. This gap is completely erased in the year after the tsunami by a substantial increase in employment rates among young adult males in heavily damaged ages, for whom employment rises from 74.5% to 87.6%. No change in employment occurs among same-age males in other areas. Subsequently employment rates creep up slightly in all areas.

In contrast, among 45-54 year old males, a very large and statistically significant 10.7 percentage point decline in employment occurs immediately after the tsunami among those who were living in heavily damaged areas. The decline among those living in other areas is half the size. Employment rates continue to decline among those who were living in heavily damaged areas and, 5 years, after the tsunami, these men are 8.8 percentage points less likely to be working than men who were living in other areas. Prior to the tsunami, almost all men in this age group were working and there were no difference across the two damage zones. Lower employment rates 5 years after the tsunami among those who were living in heavily damaged areas is not a reflection of aging alone since the decline is much smaller among men in other areas. Rather, it reflects a significant shift in the economic fortunes of these men, which they are likely to carry well into the future.

Prior to the tsunami, 80% of older males (age 55-69) who were living in heavily damaged areas were working. This rate is significantly lower than the employment rate among men of the same age in other areas (90.7%). The tsunami took a heavy toll on employment of males from the heavily damaged areas in the form of a 17 percentage point decline in the fraction working in the year after the tsunami. But the decline was the same size for men from areas that were not heavily damaged. In the following year, a substantial recovery in employment occurred for males from

heavily damaged areas, but older men from other areas experienced no such recovery. As a result, five years after the tsunami, employment rates are 11.6 percentage points lower than before the tsunami among men from heavily damaged areas, but the decline among older males from other areas is twice as large (23.5 percentage points). Apparently, older males who were living in areas that were heavily damaged have delayed leaving the labor market (retirement) relative to the pace of retirement for same-age men living in other areas.

As shown in panel 2 of Table 3, the labor market experience of females in the aftermath of the tsunami is entirely different. Prior to the tsunami, 38.7% of females in areas that were subsequently heavily damaged were working and females in those areas were substantially less likely to be working than females from other areas. However, in the year after the tsunami, employment rates rose by 6.7 percentage points among females who were living in heavily damaged areas and declined by 5.5 percentage points among females living in other areas. Employment rates rose thereafter, particularly among females from other areas and, 5 years after the tsunami, 50% of females from heavily damaged areas were working (an 11.4 percentage point increase since before the tsunami) while 55% of females from other areas were working (a 6.7 percentage point increase). These very large increases in the fraction of women working in the labor market are concentrated among younger females (age 25 to 44) although a modest rise in employment rates occurs among females age 45 to 54. Recall that for males, employment rates in this age group declined substantially, especially among males from heavily damaged areas. It is possible that as demand for construction workers rose, males in this age group were relatively disadvantaged but that age was not a factor in the service sector. Among females age 55 to 69, employment rates in heavily damaged areas declined slightly (from 37.3% to 34.2%) but fell far more among females from other areas (49.1% to 37.9%). These declines, for females from heavily damaged communities, are much smaller than the declines for females from other areas, and again

indicate that older adults from heavily damaged areas delayed retirement in the aftermath of the tsunami.

In sum, the tsunami resulted in substantial shifts in the composition of the labor force. Among those who were living in areas that were heavily damaged by the tsunami, a substantial increase occurred in the fraction of young males and both young and middle-age females working. This increase was accompanied by a large decline in employment rates of middle-age males and a modest decline among older males and females, at least relative to the much higher exit rates among those of the same age who were living in other areas. The impacts on occupations, earnings and economic prosperity are described in Frankenberg et al (2013).

The final indicator we examine is whether or not the respondent was a widow (or widower) at the time of the survey. Whereas the other indicators, living in a family-owned home and working, reflect changes in economic livelihoods, changes in widowhood reflect changes in family life. The tsunami took a terrible toll on mortality, particularly for females, which resulted in unprecedented increases in the fraction of prime age adults whose spouse died and substantial disruption to the marriage market. Contrasts of widow/widowerhood between heavily damaged and other areas are likely to be particularly stark, given the strong link between mortality and the spatial reach of the water. They are also likely to vary by gender given the greater loss of life among women.

As shown in Table 4, before the tsunami, in 2004, differences in the proportions widowed are small and not statistically significant. The similarities between areas hold for males and for females, and when all ages are combined as well as for the specific age groups. At all ages, females are more likely to be widows than are males and the probability of being widowed rises with age, especially for females.

For males, the situation after the tsunami is completely different. Among those who were living before the tsunami in areas that were heavily damaged, the fraction who were widowered

rises almost six-fold from 1.1% to 6.4% in the year after the tsunami, a statistically significant increase. There is a small increase in the fraction of males widowered in other areas and, as a result, the difference in widowerhood rates between the two areas increases to 4.8%, a large and statistically significant gap.

In the following year, the fraction of males who living in heavily damaged areas that are widowers declines substantially which cuts the gap between those from heavily damaged and other areas by half. This decline is driven by remarriage of males whose wives died in the tsunami. Five years after the tsunami, the rates of widowerhood are slightly higher among those from heavily damaged areas but the gap, relative to males from other areas is small and not statistically significant.

The evolution in widowerhood rates over time in heavily damaged and other areas is repeated for each of the four age groups, in panels 2 through 5 of Table 4. The rate of increase in widowerhood is greatest for the youngest group, but from a very low base, and declines with age. The subsequent decline in the year after the tsunami and beyond is greatest among 35-44 year olds and 45-54 year olds. By 2009, 35-45 year olds are the least likely to be widowers – a remarkable shift relative to the pre-tsunami status. Five years after the tsunami, the widowerhood gap between males from the heavily damaged areas, relative to other areas, is small and not statistically significant for any of the four age groups.

For males of all ages, there has been remarkable recovery in this dimension of family life, after the very large increase in widowerhood rates caused by the high mortality of the tsunami. In sharp contrast, the evolution of widowhood among females after the tsunami is completely different.

Overall widowhood rates are higher in the year after the tsunami but the increase does not differ between females from heavily damaged relative to other areas. In the following years,

widowhood rates rise slightly in all areas. No gap in widowhood emerges between those who were in heavily damaged areas relative to other areas.

The overall pattern masks substantial variation across ages. Among younger females, there was a bigger increase in widowhood rates among those who were living in heavily damaged areas as a result of the tsunami. For example, among 35-44 year olds who were living in heavily damaged areas, widowhood rates rose three-fold from 4.1% to 12.3% as a result of the tsunami. Among females of the same age in other areas, the increase was less than 1% and this gap in widowhood is both large and statistically significant. While a small fraction of these widows remarried, widowhood rates remained remarkably stable for all females age 25-44 who were living in heavily damaged areas and, five years after the tsunami, there are no differences in widowhood rates for females of any age group from heavily damaged relative to other areas. This mimics the pattern for males, albeit through a completely different path. Specifically, very few of the females whose husbands died in the tsunami remarried, but those husbands who survived the tsunami and were living in areas that were heavily damaged were less likely to die then husbands of females who were living in other areas. For a discussion of the impacts of these changes on post-tsunami fertility and repopulation, see Nobles, Frankenberg and Thomas (2015).

Discussion and conclusions

This paper addresses three questions: the spatial concentration of the tsunami's impacts, the evolution of indicators of living arrangements and time use, and whether patterns differ by gender and age.

With respect to spatial concentration, the disaster’s impacts were widespread. Although elevated risks of death were concentrated among those residing close to the coast at the time of the tsunami, the deaths affected large shares of the population in the sense that people were at risk of losing family and friends regardless of pre-tsunami location. Property damage was also a factor in

both heavily damaged and other areas. The tsunami was a dramatic shock to both networks and assets, particularly for those close the coast, but to some degree for those from other areas as well. With respect to immediate impacts by gender, it is clear that being female put individuals at an enormous survival disadvantage in the heavy damage zone. For those from areas outside that zone, however, women were less likely than men to experience some of the most traumatic exposures to the tsunami.

These patterns raise an important methodological point. Only by having data from across a wide array of communities can we address the question of spatial impact. 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.

In considering how impacts play out over time, two aspects of our study design are critical: having a sample that is population-representative pre-tsunami from which we can document patterns before the disaster, and following individuals from that sample over time, even when they move. Here we use the data to explore trends, but next steps will more fully exploit the fact that we have data on individuals' transitions over time. It will be useful to consider time trends that emerge in SUSENAS data from other provinces as well, as a means of establishing patterns present in provinces far 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 the temporal evolution of indicators of living arrangements and time use, the degree to which differences between damage zones in 2009 resemble differences between zones in 2004 is truly striking. We consider living in a family-owned home, working, and being widowed for adult males and females, stratified by whether before the tsunami they lived in location that sustained heavy damage, or did not. In almost all cases, when we compare the

difference in an indicator between 2004 and 2009 for those from heavily damaged communities to the difference between 2004 and 2009 for those from other communities, this difference-in-differences is not statistically significant. By 2009, the difference (or lack thereof) between zones observed in 2004 has been restored. This pattern holds for living in a family-owned home, for women's labor force participation, and for being a widower or widow. Only for men's labor force participation is there a significant difference in the trend over time by damage zone. Recovery on these dimensions from a disaster on the scale of the tsunami is possible, it seems, but it takes years not months.

This overall finding should not be construed as indicating that the tsunami had little impact. Indeed changes between 2004 and 2005 are dramatically large for many outcomes and sub-groups (consider that the percentage in a family owned home fell from 80% to 60% between 2004 and 2005 for men from heavily damaged communities). But changes between 2005 and 2009 were also large, often reversing what happened between 2004 and 2005.

Nor should this overall finding be construed to say that the impact was evenly distributed. Clearly, looking across age groups and gender, for some outcomes either males or females, or particular age groups, experience more churning over the period for than others. With respect to gender and age, for example, the patterns for living in a family owned home are nearly identical for men and women. For work, changes over time are similar for the youngest men and women in the heavy damage zone and the percentage working rises sharply over time. For the other age groups the increases in work are stronger for women than for men. But for those who are older, regardless of gender, the tsunami appears to have delayed stopping work for those from heavily damaged areas but not for those from other areas. With respect to widowhood, men from the heavily damaged communities experience a sharp rise, then a fall in being widowed. Patterns for women, on the other hand, are nearly identical regardless of damage zone.

In closing, we make two important additional points. First, the measures we examine do not necessarily have a clear interpretation 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 examining in more detail the trajectories of respondents and how those trajectories relate both to pre-tsunami levels of socio-economic status and to the degree of initial impact of the tsunami. While it is useful to describe additional indicators of well-being, it is unclear how to weigh the benefits of potential economic gains in the tsunami's aftermath against the cost of loss of family and friends. Moreover, describing the transitions that individuals have navigated and the evolution of markers in their lives over time can only provide limited evidence on the longer-term implications of these choices. By following the same respondents over time, into the future, we are better able to trace out the impacts over the longer term of the shock of the tsunami, the reconstruction effort and behavioral choices made by the respondents to the upheavals around them. See, for example, Cas et al (2014) for a description of the lives of children orphaned by the tsunami.

Second, we note that the evolutions of the outcomes we consider are not a result of independent processes. As an example, consider widowhood. For being widowed, the differences between men and women are dramatic. It appears that for men, at least some of those whose wives were killed wanted to remarry and had the opportunity to do so. For women, it is unclear whether the patterns we observe reflect choice, opportunity, or both. But for both men and women, the decision to remarry likely reflects other aspects of the post-tsunami environment, such as whether their children survived the tsunami and provided a connection to the family life that existed before the tsunami, and whether the reconstruction program offered opportunities to rebuild assets either by returning to pre-tsunami sources of livelihoods or by exploiting new opportunities.

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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.

[2] Some of the *kabupaten* along Aceh's north coast where excluded because the security situation remained unstable throughout much of 2005. Although some of those areas sustained light damage from the tsunami, many of these communities were not directly affected by the tsunami.

[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] We located respondents according to where they lived at the time of the tsunami, but this does not preclude the possibility that they were close to a vulnerable area when the waves came ashore, for example if they were visiting family or friends.

Figure 1 .Location of enumeration areas in Aceh Province, Sumatra

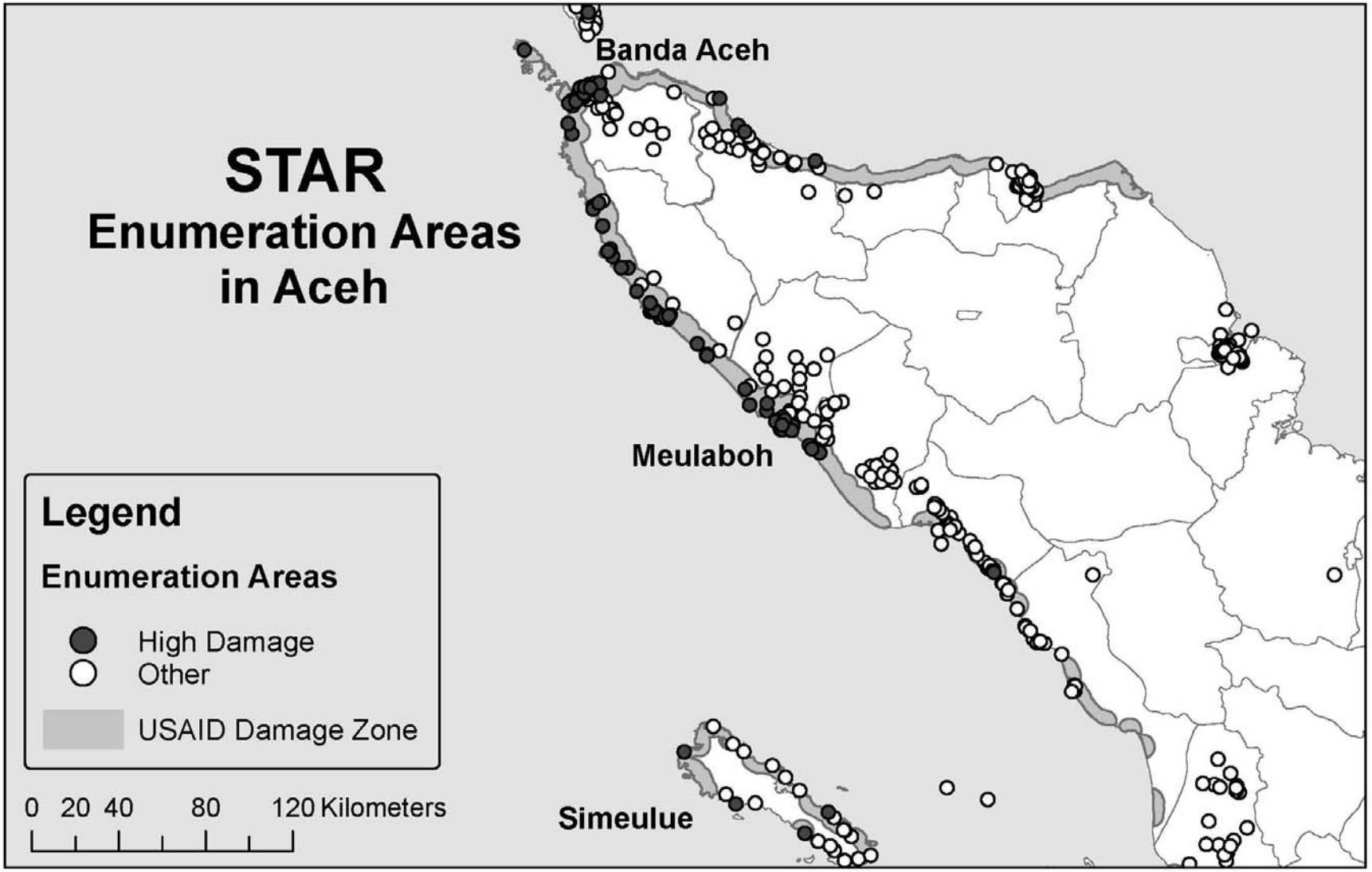

Table 1 : Immediate impacts of the tsunami and receipt of housing assistance in its aftermath

by extent of tsunami-related damage in location respondent was living before tsunami and gender of respondent

	All respondents		Heavily damaged areas			Other areas		
			Respondent		Difference	Respondent		Difference
	Heavily damaged	Other areas	Male	Female	[Std err]	Male	Female	[Std err]
% of respondents who								
1. Died	23	1	18	27	-8.2*	1	1	0
					[1.8]			[0]
2. Caught in water or injured	32	4	38	26	11.9*	6	3	2.8*
					[2.9]			[0.6]
3. Saw family or friends struggle	41	5	47	36	10.8*	7	4	3.8*
					[2.9]			[0.7]
4. Lost a spouse, child, parent, sibling	35	10	37	33	4.5	10	10	-0.6
					[2.9]			[0.9]
5. Lost any family	70	42	73	67	5.8*	41	43	-1.7*
					[2.1]			[1.4]
6. Damage to the home	58	23	61	56	5.2	25	22	2.2
					[2.6]			[0.9]
7. Received housing assistance by 2009	54	14	56	51	5.0*	14	13	1
					[2.3]			[1]
Sample size (for survivors)	1,514	7,002	754	760		3,213	3,789	

Notes: Sample size is for outcomes of survivors (in rows 2 through 7). Sample size including those who died (row 1) is product of number of survivors and (1/[1-fraction who died reported in row 1]). All estimates are weighted. Standard errors take into account clustering at the primary sampling unit. * indicates significance at 5%.

Table 2 : Percentage living in a home owned by a family member

Damage	1. Males							2. Females						
	Pre-	Post-tsunami			Changes			Pre-	Post-tsunami			Changes		
	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004
1. Age 25-69														
Heavy	80.6	59.6	72.0	85.2	-21.0	25.6	4.6	82.4	63.5	72.2	86.2	-18.9	22.8	3.9
Other	93.1	88.5	90.2	93.0	-4.6	4.5	-0.1	93.8	90.2	91.4	94.0	-3.6	3.9	0.3
Difference	-12.5*	-28.9*	-18.2*	-7.8*	-16.4*	21.1*	4.7	-11.4*	-26.7*	-19.2*	-7.8*	-15.3*	18.9*	3.6
[se]	[3.0]	[3.9]	[3.1]	[2.5]	[4.6]	[4.3]	[2.9]	[3.3]	[4.3]	[3.6]	[2.7]	[4.4]	[4.4]	[2.6]
2. Age 25-34														
Heavy	75.1	56.2	65.0	80.8	-19.0	24.6	5.6	79.2	55.8	61.4	81.5	-23.4	25.7	2.3
Other	90.5	83.7	84.8	87.9	-6.8	4.1	-2.7	91.1	85.6	85.7	90.3	-5.5	4.7	-0.8
Difference	-15.4*	-27.5*	-19.8*	-7.1*	-12.2	20.5*	8.3*	-11.9*	-29.8*	-24.3*	-8.8*	-17.9*	21.0*	3.1
[se]	[4.2]	[4.8]	[4.3]	[3.5]	[6.3]	[5.5]	[4.2]	[3.6]	[5.0]	[4.5]	[3.7]	[6.0]	[5.9]	[3.9]
3. Age 35-44														
Heavy	78.7	50.7	66.3	84.0	-27.9	33.4	5.4	79.1	63.9	75.5	89.7	-15.2	25.7	10.5
Other	91.6	85.7	89.8	92.7	-5.9	7.1	1.2	93.4	89.7	93.4	96.1	-3.7	6.3	2.7
Difference	-12.9*	-35.0*	-23.5*	-8.7*	-22.0*	26.3*	4.2	-14.3*	-25.8*	-17.9*	-6.4*	-11.5*	19.4*	7.8*
[se]	[3.9]	[5.4]	[4.9]	[4.3]	[6.5]	[6.5]	[5.1]	[4.6]	[5.0]	[4.2]	[3.1]	[5.5]	[5.2]	[3.1]
4. Age 45-54														
Heavy	88.4	71.1	84.5	92.5	-17.3	21.4	4.2	87.9	71.8	81.5	88.1	-16.0	16.3	0.2
Other	95.6	93.6	94.4	96.3	-1.9	2.7	0.8	96.4	94.1	95.2	94.8	-2.2	0.7	-1.6
Difference	-7.2	-22.5*	-9.9*	-3.8	-15.4*	18.7*	3.4	-8.5*	-22.3*	-13.7*	-6.7	-13.8*	15.6*	1.8
[se]	[4.2]	[6.0]	[4.3]	[3.1]	[5.4]	[5.0]	[2.7]	[4.2]	[6.0]	[5.3]	[4.3]	[5.2]	[5.3]	[3.6]
5. Age 55-69														
Heavy	87.8	72.4	84.5	88.1	-15.4	15.8	0.3	91.6	75.6	87.3	91.9	-16.1	16.4	0.2
Other	97.1	94.8	94.7	98.0	-2.3	3.2	0.9	97.4	96.6	96.3	98.2	-0.8	1.6	0.7
Difference	-9.3	-22.4*	-10.2*	-9.9	-13.1*	12.6	-0.6	-5.8	-21.0*	-9.0	-6.3	-15.3*	14.8*	-0.5
[se]	[5.3]	[6.0]	[4.8]	[5.3]	[6.4]	[6.7]	[5.2]	[3.6]	[6.3]	[4.6]	[3.7]	[5.5]	[4.8]	[2.9]

Notes: Standard errors [se] take into account geographic clustering of respondents at the primary sampling unit. * indicates difference is significant at 5%.

Table 3 : Percentage working in week before interview by gender, age and year

	1. Males							2. Females						
	Pre-	Post-tsunami			Changes			Pre-	Post-tsunami			Changes		
Damage	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004
1. Age 25-69														
Heavy	87.4	84.4	88.5	89.4	-3.1	5.0	1.9	38.7	45.4	48.6	50.1	6.7	4.7	11.4
Other	94.2	88.9	89.8	89.0	-5.4	0.1	-5.3	48.3	42.8	46.8	55.0	-5.5	12.2	6.7
Difference	-6.8*	-4.5*	-1.3	0.4	2.3	4.9*	7.2*	-9.6	2.6	1.8	-4.9	12.2*	-7.5	4.7
[se]	[2.2]	[1.8]	[1.7]	[1.6]	[2.4]	[2.2]	[2.5]	[5.5]	[3.8]	[2.6]	[3.4]	[4.7]	[3.9]	[4.4]
2. Age 25-34														
Heavy	74.5	87.6	89.0	94.8	13.1	7.3	20.4	31.9	43.8	50.8	51.6	11.9	7.7	19.6
Other	89.5	89.2	91.9	92.9	-0.3	3.7	3.4	40.9	36.5	39.0	55.2	-4.4	18.7	14.3
Difference	-15.0*	-1.6	-2.9	1.9	13.4*	3.6	17.0*	-9.0	7.3	11.8*	-3.6	16.3*	-11.0*	5.3
[se]	[5.0]	[2.8]	[2.7]	[2.1]	[4.5]	[2.8]	[4.5]	[5.4]	[4.1]	[4.0]	[4.3]	[5.4]	[4.4]	[5.6]
3. Age 35-44														
Heavy	97.0	87.8	95.9	95.1	-9.1	7.4	-1.7	45.1	52.3	54.3	56.1	7.1	3.9	11.0
Other	98.3	93.8	94.5	94.6	-4.5	0.9	-3.6	52.3	51.2	56.1	61.5	-1.1	10.3	9.2
Difference	-1.3	-6.0*	1.4	0.5	-4.6	6.5	1.9	-7.2	1.1	-1.8	-5.4	8.2	-6.4	1.8
[se]	[1.8]	[2.9]	[1.7]	[2.0]	[3.4]	[3.6]	[2.9]	[6.6]	[5.8]	[4.9]	[5.2]	[6.1]	[5.6]	[5.2]
4. Age 45-54														
Heavy	98.8	88.0	87.4	84.7	-10.8	-3.2	-14.0	45.3	44.7	44.1	48.3	-0.6	3.6	3.0
Other	97.5	92.5	91.1	92.3	-5.0	-0.2	-5.2	54.9	46.7	52.6	57.0	-8.2	10.3	2.1
Difference	1.3	-4.5	-3.7	-7.6*	-5.8	-3.0	-8.8*	-9.6	-2.0	-8.5	-8.7	7.6	-6.7	0.9
[se]	[1.1]	[3.3]	[5.5]	[3.6]	[3.6]	[4.3]	[3.9]	[6.0]	[5.3]	[6.0]	[5.8]	[6.1]	[6.9]	[6.2]
5. Age 55-69														
Heavy	80.0	62.3	71.0	68.4	-17.8	6.2	-11.6	37.3	36.0	35.6	34.2	-1.4	-1.7	-3.1
Other	90.7	74.4	75.8	67.2	-16.3	-7.2	-23.5	49.1	35.4	38.8	37.9	-13.7	2.6	-11.2
Difference	-10.7*	-12.1	-4.8	1.2	-1.5	13.4	11.9	-11.8	0.6	-3.2	-3.7	12.3	-4.3	8.1
[se]	[4.6]	[6.2]	[5.9]	[6.3]	[7.5]	[7.2]	[7.8]	[8.7]	[7.0]	[6.3]	[7.1]	[9.0]	[8.8]	[10.8]

Notes: Standard errors [se] take into account geographic clustering of respondents at the primary sampling unit. * indicates difference is significant at 5%.

Table 4 : Percentage widowed by gender, age and year

	1. Males							2. Females						
	Pre-	Post-tsunami			Changes			Pre-	Post-tsunami			Changes		
Damage	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004	A. 2004	B. 2005	C. 2006	D. 2009	E. 2005 - 2004	F. 2009 - 2005	G. 2009 - 2004
1. Age 25-69														
Heavy	1.1	6.4	3.6	3.9	5.1	-2.5	2.7	10.7	14.6	15.5	18.7	3.9	4.1	8.0
Other	1.3	1.6	1.6	2.7	0.2	1.1	1.3	11.8	14.1	15.1	18.7	2.3	4.6	6.9
Difference	-0.2	4.8*	2.0*	1.2	4.9*	-3.6*	1.4	-1.1	0.5	0.4	0.0	1.6	-0.5	1.1
[se]	[0.5]	[1.1]	[0.8]	[0.8]	[1.1]	[1.1]	[0.8]	[2.1]	[2.1]	[2.0]	[1.9]	[1.3]	[1.2]	[1.4]
2. Age 25-34														
Heavy	0.1	2.6	2.4	2.9	2.5	0.3	2.9	2.6	3.4	3.7	3.9	0.8	0.5	1.3
Other	0.1	0.2	0.2	1.3	0.1	1.1	1.2	1.8	1.8	2.1	2.5	0.0	0.7	0.7
Difference	0.0	2.4	2.2	1.6	2.4	-0.8	1.7	0.8	1.6	1.6	1.4	0.8	-0.2	0.6
[se]	[0.1]	[1.3]	[1.2]	[1.3]	[1.3]	[1.4]	[1.3]	[1.2]	[1.1]	[1.2]	[1.3]	[1.5]	[1.5]	[1.7]
3. Age 35-44														
Heavy	0.9	5.7	2.9	1.1	4.7	-4.6	0.2	4.1	12.3	11.2	14.1	8.2	1.7	10.0
Other	1.3	0.7	0.5	1.0	-0.7	0.3	-0.3	7.7	8.6	9.3	12.5	0.9	3.9	4.8
Difference	-0.4	5.0*	2.4*	0.1	5.4*	-4.9*	0.5	-3.6	3.7	1.9	1.6	7.3*	-2.2	5.2
[se]	[0.8]	[1.6]	[1.1]	[0.7]	[1.8]	[1.8]	[0.6]	[1.8]	[3.3]	[2.7]	[2.9]	[3.1]	[2.3]	[2.7]
4. Age 45-54														
Heavy	2.4	11.2	5.0	4.6	8.8	-6.6	2.2	13.0	18.0	19.8	26.9	5.1	8.8	13.9
Other	1.6	2.0	1.4	1.9	0.4	-0.1	0.3	16.7	19.9	21.6	26.8	3.2	6.9	10.1
Difference	0.8	9.2*	3.6	2.7	8.4*	-6.5	1.9	-3.7	-1.9	-1.8	0.1	1.9	1.9	3.8
[se]	[1.8]	[3.7]	[2.3]	[2.0]	[3.3]	[3.4]	[2.3]	[5.9]	[5.1]	[5.3]	[5.3]	[4.1]	[2.9]	[5.0]
5. Age 55-69														
Heavy	2.5	9.9	6.2	11.8	7.5	1.9	9.3	48.5	51.2	57.4	65.1	2.7	14.0	16.6
Other	3.1	5.0	6.5	9.2	1.9	4.2	6.0	38.0	47.6	50.1	59.7	9.6	12.1	21.7
Difference	-0.6	4.9	-0.3	2.6	5.6*	-2.3	3.3	10.5	3.6	7.3	5.4	-6.9	1.9	-5.1
[se]	[2.0]	[3.3]	[2.9]	[4.1]	[2.8]	[3.4]	[3.8]	[6.1]	[7.7]	[6.8]	[6.4]	[5.9]	[3.9]	[5.0]

Notes: Standard errors [se] take into account geographic clustering of respondents at the primary sampling unit. * indicates difference is significant at 5%.