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Environmental and socioeconomic dynamics of the Indian Ocean tsunami in Penang, Malaysia

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This paper addresses some of the environmental and socioeconomic dimensions of the 2004 Indian Ocean tsunami on Penang, Malaysia. We aim to offer wide access to unique and perishable data, while at the same time providing insight to ongoing debates about hazards, vulnerability and social capital. Our social survey examines some of the dynamics that shaped the tsunami impact, response and recovery process. While in terms of lives lost Penang may not conform to arguments surrounding vulnerable environments, the recovery process is more marked by social disparities in terms of the ability to access resources. Our physical survey records local topography, flow depth and flow direction, and charts the differential impact of the tsunami. Yet measuring hazards is not a straightforward process, and relies on reflexive methodologies and eyewitness accounts.

Keywords: emergency response, Malaysia, tsunami, vulnerability, social capital

Introduction

At 0:59 GMT (08.59 Malaysian time) on 26 December 2004 a magnitude 9.3 earthquake occurred 160 km west of Sumatra and 900 km southwest of Penang, Malaysia (Figure 1). Since 1900 only the Great Chilean Earthquake of 1960 (magnitude 9.5) was larger. The 2004 earthquake was widely felt by communities in Penang (or Pinang) where many witnessed the ground move, vehicles sway, standing water become unsettled and doors and windows rattle. Few, however, connected the ground shaking with the likelihood of a tsunami.

The 2004 Indian Ocean tsunami provides access to unique and perishable data with which to construct and interpret trajectories of environmental and socioeconomic change and assess future risk (e.g. Adger *et al*., 2005). The purpose of this paper is to describe in detail the physical and social impacts of the Indian Ocean tsunami in Penang. We used a suite of research methods from the natural and social science to collect data from specific sites along the northern and western coast of Penang that display different physiographic conditions and vary in their nature and scale of social and physical impacts.

We made measurements of the tsunami wave, conducted interviews and assembled focus groups to obtain further information on the tsunami's characteristics and precursor warning signs from 'eyewitness interviews'. The social science field survey was guided by a core research question addressing the social patterns of impact and recovery. We were particularly interested in the social milieu in which livelihood impacts and

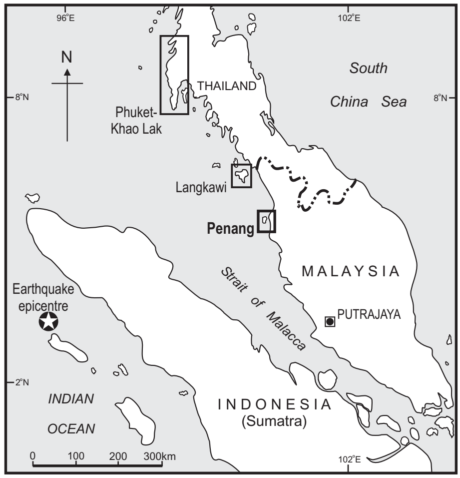

Figure 1. *Map showing the locations of Penang Island and those of the other similar National Science Foundation Small Grants for Exploratory Research (SGER) studies in Malaysia (Bird* et al.*, 2007) and in Thailand (Rigg* et al.*, 2005), and the epicentre of the 26 December 2004 magnitude 9.3 earthquake, the source of the 2004 Indian Ocean tsunami.*

patterns of local and institutional response by different groups took place (e.g. Davies *et al*., 2003; Dengler & Preuss, 1999; 2003; Stone, 2005). We therefore assessed the impact of the tsunami on people's actions, public services and communication, as well as the effectiveness of the response plans (Mileti & Sorensen, 1990; Mileti & O'Brien, 1992; Morrow *et al*., 1997; Covan *et al*., 2000; Rocha & Christoplos, 2001; Whitehead, 2002; Shaw & Goda, 2004; Thomalla & Schmuck, 2004; Buranakul *et al*., 2005). The data we collected allow us to discuss impacts, patterns of recovery and inequalities in support, but we also use the Penang tsunami to reflect on ongoing conversations about hazards, vulnerability and social capital (see, for example, Alexander, 1997; Hewitt, 1997; Pelling, 1998; Bankoff, 2001; Cutter, 2003; Cutter *et al*., 2003; Wisner *et al*., 2003; Pelling & High, 2005; Rigg *et al*., 2005).

Many social scientists now reject the popular terminology of 'natural disasters' and stress that while 'hazards' are natural, 'disasters' are not. A disaster occurs when an extreme event exceeds a community's ability to cope with that event (Lindell & Prater, 2003; Prater *et al*., 2004). To understand the process by which disasters produce community impacts, it is important to identify the pre-impact conditions that make communities vulnerable to disasters. Furthermore, information about the disaster impact process can be used to identify specific segments of each community that will be affected disproportionately (e.g. low-income households, or specific types of businesses and visitor/transient groups) and the event-specific conditions that determine the level of disaster impact. Ultimately, the understanding of disaster impact process allows planners to identify suitable emergency management interventions. But, as we discuss below, the impact in Penang does not 'neatly' conform to standard arguments surrounding vulnerable regions. The vast majority of fatalities were beach picnickers who were unaware of the impending wave. This is not to say that social dynamics are irrelevant; instead, we draw on related arguments that suggest it is the recovery process that is more marked by social disparities, especially in terms of ability to access resources. We suggest that social capital – here understood as the ability to mobilize prior and post-tsunami social networks – has been important in terms of recovery efforts.

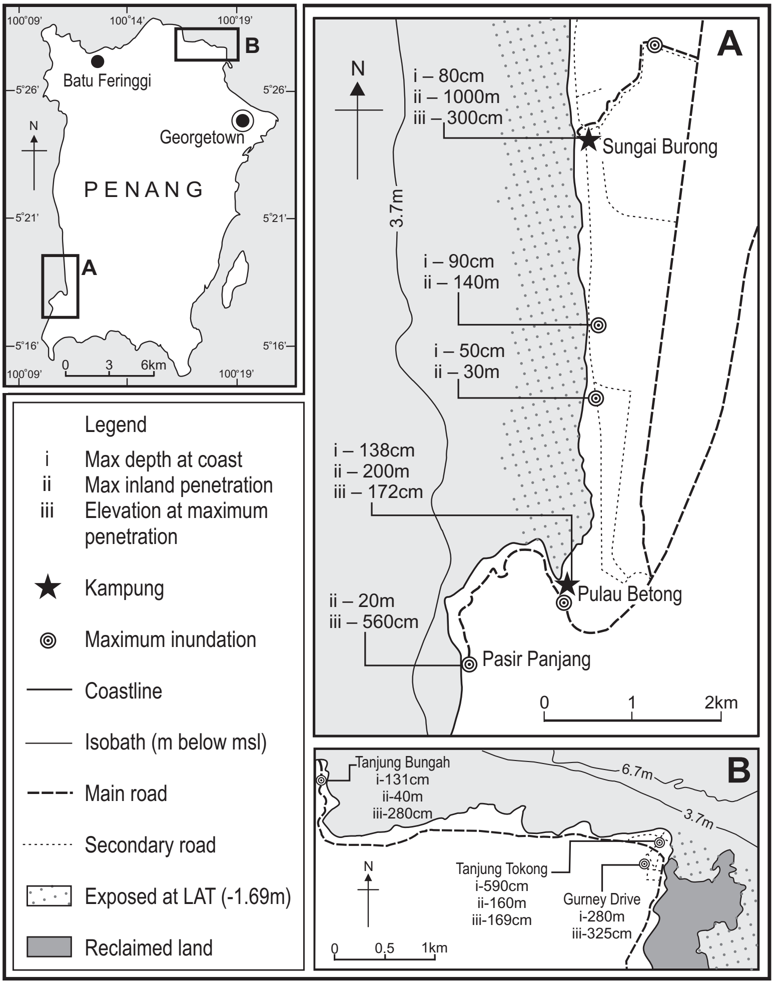

Figure 2. *Location map of Penang showing tsunami-affected study areas on the northern (B) and western (A) coastline, maximum depth at the coast (cm), inland penetration (km) and elevation of maximum penetration (cm) (LAT = lowest astronomical tide).*

Study area

Penang is an island off the northwest coast of Peninsular Malaysia (Figure 2). Penang is also the name of one of the states of Malaysia comprising the island and a strip on the mainland known as Province Wellesley or Seberang Perai.

Northern Penang

The northern coast of Penang (Figure 2B) is dominated by a series of rocky headlands separated by sandy beaches that trend north to south and east to west. The offshore area shelves gradually with the 2-m isobath on Admiralty Chart 1366 'Approaches to Pinang harbour' (~3.5 m below mean sea level (msl) 500–1000 m offshore). The region immediately inland of Tanjung Tokong is comparatively flat and 1.5–3 m above msl. The Chinese Taoist temple (Thai Pak Koong) and WWII-era fortifications occupy the headland itself, with a mix of highrise apartments and double-storey houses dominating the area between the coast and Gurney Drive (Persiaran Gurney). The area inland of Gurney Drive is occupied by high density single- and double-storey dwellings. The headland and coast to the east are protected by a rock and concrete revetment approximately 2.5 m high.

The beaches and headlands west of Tanjung Tokong are backed by steep slopes upon which multistorey apartments sit along with modern detached and semidetached double-storey residences, the Dalat International School, Penang Swimming Club and Chinese Swimming Club. There is also an important tourist industry along the coast, comprising several hotels and related services (restaurants, shops, etc.). Along these beaches, buildings and infrastructure have been built to within 20 m of the vegetation line, generally separated from the beach by a low concrete or brick fence.

At the western edge of this study site is Tanjung Bungah, a Malay kampung or settlement constructed on a north–south trending beach. The kampung is immediately north of a picturesque mosque, which is built entirely on cement pillars over the water (making it a popular tourist spot). The dwellings at Tanjung Bungah were not protected by coastal defences, which made this particular community vulnerable to the effects of the tsunami. Indeed, this was one of the worst affected communities on the island.

Western Penang

The west coast study area extends from the kampung at Sungai Burong in the north to the kampung at Pasir Panjang in the south (Figure 2A). In contrast to the northern study area, the coastline is north–south trending with a comparatively sparse population inhabiting single- and double-storey residential dwellings in both kampungs and isolated farmsteads. The area is a flat coastal plain, bounded 3 km to the east and on the coast at the southern end by steep bedrock hills. It was this steep onshore topography in the south that confined the wave and led to the death of many picnickers on the beach at Pasir Panjang. The very shallow offshore gradient is maintained seaward for several kilometres, and the 2-m isobath on Admiralty Chart 1366 (~3.5 m below msl) parallels the coast, approximately 2 km offshore.

Prior to recent residential and agricultural development, much of the coastal plain was vegetated with mangrove forest. A partly armoured bund (embankment) 3 m above msl now encloses much of what was previously the intertidal zone and the land has been cleared for the production of rice, coconuts and bananas. Inland of Pulau Betong, extensive areas have also been converted for aquaculture. The mangrove forest has been reduced to a thin strip seaward of the bund, less than 100 m wide, but coastal erosion in a number of locations has removed or reduced the mangrove fringe. Sluice gates on the rivers draining the area prevent the ingress of seawater during high tides and most of the area inland of the bunds is below local high tide level. The most damaging physical impact of the tsunami in this area was to property and agricultural lands.

Methods

The social and scientific sides of our research team were codependent. We worked alongside each other at each site, providing information to one another that was vital to connecting the different field components. The social and scientific sides of our research team were codependent. We worked alongside each other at each site, providing information to one another that was vital to connecting the different field components. We were able to bring together such a unique group of scientists to assess the impacts of the Indian Ocean tsunami through the National Science Foundation's Small Grants for Exploratory Research (SGER).[1] This enabled us to begin fieldwork immediately at five study areas within Malaysia and southern Thailand including Phuket, Khao Lak and Langkawi respectively (Figure 1). We were able to collect available and accessible, but perishable, social and physical data, which were being rapidly lost to fading memories and postdepositional change.

Social science field survey

Social science research methods can be loosely described as either positivist or interpretivist (e.g. Bryman, 1988; Brannen, 1992; Neuman, 1997), with the various approaches existing on a spectrum between the fully quantitative and the fully qualitative. Our research was carried out using interviews, an approach that lies closer to the interpretivist end of the spectrum and one that is typically used where there are specific research objectives but where flexibility is also required to enable exploration of unanticipated issues (Thomas, 2003).

Our interviews were conducted March–July 2005 with the aid of local representatives fluent in Malay and Penang Hokkien (the main Chinese dialect), as we needed to be sensitive to the emotional conditions and cultural practices of our interviewees. The interviews were audio taped and transcribed. In all, there were 30 key informants associated with the two main study sites in Penang including: government district and emergency officers; heads of fishing associations and fisherfolk; business owners/operators (e.g. restaurant and shop owners, fish wholesalers and floating cage farmers); kampung headmen (*penghulu*), farm labourers and coastal residents; as well as representatives from the Taiwan Tzu Chi Buddhist Foundation Malaysia, a nongovernment organisation (NGO) that provided assistance to those who suffered most in the immediate post-tsunami period. All informants were adults and from both Malay and Chinese communities, but the majority were male. It should be noted that this sample is not meant to be 'representative'; rather, we use these interviews to tease out some of the politics of the tsunami that merit further investigation.

Identification of informants was carried out using a bottom-up approach leading to referrals (snowballing). The fisherfolk of the kampung associated with the study sites congregated at beach shelters at times when they were not out at sea. We used these meeting places as an opportunity to talk informally. Some fisherfolk also agreed to be interviewed formally, and referred us to other key informants within the villages (such as the headmen). The headmen recommended others who had been most affected and/or who had a prominent role in the events following the tsunami.

Scientific field survey

We made measurements of local topography, flow depth and flow direction along cross-shore transects at Tanjung Tokong, Tanjung Bungah, Sungai Burong, Pulau Betong and Pasir Panjang (IOC, 1998; Tsunami Technical Review Committee, 2002). The height above mean sea level was determined by a Leica SR530 GPS system and local features mapped using a Trimble Geoxplorer XT. All measurements were fixed by GPS to a horizontal and vertical accuracy of ±5 m and ±0.15 m respectively.

Watermarks defined by a thin film of mud and organic debris on trees and electricity poles are taken as direct indicators of maximum wave height. The interpretation of watermarks on buildings is less straightforward (IOC, 1998); watermarks on the outside walls parallel to the direction of flow provide the most reliable estimates of maximum water depth.

The tsunami

The weather in Penang immediately prior to the tsunami was calm and clear. Although the tide was close to maximum for the day (0.29 m above msl), it was a neap tide and therefore 0.7 m below the mean highwater spring tide for Penang.

Eyewitness accounts

The eyewitness accounts of the Penang tsunami are similar to those in other tsunami studies (e.g. Dudley & Lee, 1998; Dengler & Preuss, 2003). Many people were knocked over by the first wave, and most survivors described three significant waves. The second wave was the largest and produced most of the damage, although some witnesses felt it was the third. Many who were caught up in the waves commented on the force of the water, claiming it took all their effort to hang on to whatever was secure (trees, posts, electricity poles, and the like). They also recalled a similar force as the waves retreated seaward. Those unable to hold on to something secure described a sense of being caught up in a 'washing machine' along with debris generated by the waves. Some were stripped of clothing, lost skin by sand abrasion and were battered hard by objects and others were cut by wood and metal. The fortunate were carried into the lagoon and were able to cling to floating debris. One small boy was carried over 50 m by the wave and found in the canopy of a palm tree at Sungai Burong. A restaurant owner from Tanjung Tokong, who was serving tables at the time, was swept off her feet and very badly injured. Those less fortunate were impaled, smashed into the rocky headlands, or buried under piles of logs and debris. Some who survived the initial impact were swept out to sea as the waters receded.

Although eyewitness accounts were useful in terms of reconstructing the tsunami event, descriptions varied considerably. This was likely the result of the general confusion that surrounded the tsunami but also reflects each person's unique experience of the event and their individual circumstances and memory errors (Neisser & Hyman, 2000; Dengler & Preuss, 2003). Some fisherfolk out at sea were completely unaware of the tsunami until they returned to find their jetty and fishing boats in disarray. Many of those on shore recalled strange events just prior to the tsunami: two of the fisherfolk interviewed knew that something 'strange' was happening and instinctively fled the jetty to higher ground. Some informants also commented on the sudden silence of animals and being aware of a general sense of nervous anticipation. Most notably, many eyewitnesses described a significant initial drawdown of the water surface, which at Pulau Betong exposed up to 1.5 km of the sea floor. As in many other tsunami disasters some people ignored this warning sign and went out onto the exposed platform to gather marine life (Dudley & Lee, 1998; Dengler & Preuss, 2003). The first wave was accompanied by extremely loud sounds, variously described as a jet plane, helicopter, train or bomb (Lander & Lockridge, 1989). Many went toward the beach to determine what the sounds were; they did not run away but stood and watched. Eyewitnesses described the tsunami as a broken wave or a bore that first appeared approximately 250 m from the shore. They also noted the colour of the water, with the first wave being clear and the subsequent waves heavily laden with mud. This ultimately left a heavy layer of mud being deposited inshore of the coastline.

Northern Penang

Digital photos from three locations around Tanjung Tokong suggest that a single initial wave front arrived from directly north at 13.34 Malaysian time. This wave arrived

4 hours 35 minutes after the earthquake and 1 hour and 15 minutes after the tsunami first struck Langkawi (Figure 1) Malaysia, 120 km to the north (Bird *et al.*, 2007). This implies an average velocity in the Straits of Malacca of 100 km/hr. The first wave caused minimal damage in the vicinity on the northern coast as it did not run in beyond the beach at most locations. A second, larger wave arrived from the north-northeast at 14.04 Malaysian time and caused most of the damage. Digital photos indicate that as this wave crossed the seawall at the Taoist temple on Tanjung Tokong, it reached a maximum height of 5.9 m above msl. Eyewitness accounts suggest that splash associated with the wave striking the seawall reached approximately 12 m above msl. This wave was followed by at least two distinct but smaller wave fronts arriving at 14.40 and 15.17 Malaysian time. The destructive power of the waves striking the headland was significantly diminished by a high stone and cement seawall (3.9 m above msl) that protects the coast. Nevertheless, the upper metre of the seawall, which serves as a safety barrier for pedestrians, was knocked over by the impact. Two wooden buildings immediately behind the seawall in the temple compound were completely destroyed and several concrete buildings in the compound sustained structural damage but did not collapse. Beyond 20 m from the seawall, no structural damage was sustained and water 0.25 m in depth flowed inland (and slightly downhill) for 160 m, with a maximum run-up occurring at 1.69 m above msl (Figure 2B).

Immediately east of Tanjung Tokong, the wave was funnelled up a narrow channel between the armoured coast to the west and ongoing land reclamation to the east. The jetty of the fisherfolk's co-operative near the mouth of this artificial embayment was completely removed. At the head of the embayment, water ran south-southwest over Gurney Drive, displacing concrete lane dividers (1 m in height and weighing approximately 1 ton) by 2 m. Twenty metres inland of Gurney Drive, water 0.45 m in depth caused significant structural damage to dense single- and double-storey dwellings, but little structural damage was sustained beyond this point. The water penetrated approximately 280 m inland and reached a maximum elevation of 3.25 m above msl (Figure 2B).

Video footage indicates that although the first two waves overtopped the revetment fronting Gurney Drive, most flooding was caused by the third wave that arrived from the east-northeast, having been reflected off the heavily armoured mainland 10–15 km distant. This wave struck the coast at an oblique angle such that water did not penetrate more than 100 m inland. This same wave continued west to strike Tanjung Tokong at 14.40 Malaysian time and travelled parallel to the east-west trending beaches between Tanjung Tokong and Tanjung Bungah. This wave may have struck the north–south trending coast Tanjung Bungah head-on. Indeed, the squatter community at this site was reported to be one of the worst affected communities on the north coast, largely because their homes were semipermanent structures of wood and concrete and were directly on the coast (several of these were constructed on stilts over the sea, on the leeward side of the settlement, as is common in many Southeast Asian fishing communities seeking shelter from monsoon-driven seas). Our measurements suggest that the maximum elevation of the waves at the coast was 3.24 m above msl (maximum water depth 1.31 m). As the community consists of tightly packed single-storey dwellings backed by steeply sloping land, the waves only penetrated 40 m inland and reached a maximum run-up elevation of 2.8 m above msl (Figure 2B).

Western Penang

We have no documentary or photographic records of the tsunami along the west coast of Penang, but detailed surveys between Sungai Burong and Pulau Betong allow a reconstruction of the maximum wave height and the area of inundation. At Sungai Burong, the northernmost site, watermarks were identified as high as 3.93 m above msl (maximum water depth 2.13 m). However, these were on walls facing the direction of flow and hence are considered to be higher than the average water depth. Watermarks on walls parallel to the direction of flow, and on electricity poles, suggest a maximum water depth of 0.8 m at the coast, rising to 1.1 m within 30 m of the coastal bund or river levees. Damaged fishing craft were found 250 m inland from the coastal bund, and 150 m north of Burong creek, indicating that the tsunami penetrated inland with significant force. The bitumen road which serves as a 3-m-high levee on the south side of Burong creek was only breached for 200 m upstream, while the northern levee (2.8 m above msl) was breached for 700 m upstream, suggesting that maximum run-up elevation was effectively 3 m above msl. In the creek itself, within the confines of the levees, the wave penetrated over 1 km upstream. Local informants indicated the location of rice fields that had been salt-effected, which were 1 km inland and 500 m north of Burong creek (Figure 2A).

The entrance to Burong creek may have served to focus the waves inland as 1.6 km further south, watermarks on a house 30 m inland from the coastal bund indicate that while water depths were similar, the maximum inundation was only 140 m from the coast. At this site, coastal erosion had left only a thin 20-m fringe of young mangroves which were completely flattened by the tsunami. A further 600 m south, the mangrove fringe seaward of the same bund is intact, mature and more than 50 m in width. Watermarks on trees 10 m inland of the bund indicate maximum water depths of 0.5 m, suggesting that the mangroves played a significant role in reducing the impact of the tsunami on the coast at this location. This finding supports previous research that argues human vulnerability to hazards is mediated by ecosystems (e.g. Moeller *et al.*, 1996) and some studies have clearly demonstrated increasing impacts because of degrading coastal habitats (Dixon & Weight, 1995). Mangrove forests dissipate the destructive forces of tsunami wave energy and erosive forces (Dahdouh-Guebas *et al.*, 2005; Kandasamy & Narayanasamy, 2005).

At the southernmost end of the study area, the kampung at Pulau Betong lies at the mouth of Betong creek and is backed by steeply sloping land to the south and west (Figure 2A). At the time of the tsunami, there was no bund, although one has since been constructed on the seaward side of the village. There was extensive damage to buildings in this kampung, likely because of the absence of coastal defences and the focusing at the southern end of a small north facing bay. Because many houses had been destroyed or substantially repaired, it was not possible to obtain measurements of water depth close to the coast. Nevertheless, watermarks at locations 50–100 m inland, some of which were protected by a 30-m-wide strip of mature mangrove, indicate maximum water depths of 1.38 m. Local informants indicated that the water reached, but did not cross, the intersection of the village road with the main coastal road. This indicates a maximum run-up of 200 m at 1.72 m above msl, but this was limited by steep slopes beyond this point to the south. The tsunami probably travelled a considerable distance up Betong Creek but this area was not surveyed for the current study.

Immediate impacts

The impact of the tsunami on Penang was a different order of magnitude compared to places like Aceh in Indonesia or Khao Lak in Thailand, and we would not want to

Table 1. Tsunami statistics for Penang.

(a) Overview

Deaths	Missing	Injured	Damage
52	5	205	521 houses 1430 boats

(b) Deaths by district

District	Site of casualties	Deaths
Northeast	Batu Feringgi/Tanjung Tokong	23
Southwest	Telok Bahang/Pulau Betong	27
Sungai Prai (Central)	Bukit Mertajam Hospital	0
Sungai Prai (North)	Jalan Padang Benggali/Teluk Air Tawar	2
	Overall Total	52

Sources: data compiled from the Malaysian Control Centre, Royal Malaysian Police Force Headquarters (NSDP, 2005) and various other sources.

combine Penang into a homogenous 'region of risk' (Bankoff, 2001). At the same time, the number of casualties and the amount of physical damage did have a significant impact on the island (Table 1). In terms of human impacts, 52 people lost their lives, another 5 still missing and 205 were injured. The casualties involved fisherfolk, picnickers and residents living in vulnerable coastal areas. The vast majority of deaths took place at Pasir Panjang, a popular leisure beach for Penang families. Many of those interviewed claimed the beach picnickers were killed because, upon seeing the shoreline recede, they chose to stay on the beach to see what was going on rather than vacating to higher ground. It was too late to flee when they realized the danger. No watermark information was available at Pasir Panjang but the government training complex 50 m behind the beach suffered structural damage and sections of the concrete fence 50 m long, separating the complex from the beach, were knocked down by the waves. Local informants suggested that the water reached the base of a telephone box 20 m from the coast at the north end of the beach. The base of this telephone box was determined to be 5.6 m above msl (Figure 2). A cliff 4-m high backs the beach at the northern end and this may have been a contributing factor in the death toll. In contrast, according to the chief emergency officer, the international tourist beaches on the north coast suffered no casualties because of alerts from Langkawi tourist operators via telephone and fax. Beach resort lifeguards instituted a red flag alert, which is thought to have saved many lives.

The human impact was combined with substantial destruction of property associated with the force of the waves. In terms of damage, most informants spoke of floodwater damage to the contents of their houses. Much of the concern was over electronic equipment such as televisions and DVD players because of the high costs of these items relative to family income. Mud was also regarded as a major problem; apart from seriously damaging the outboard motors of the fishing boats it permeated houses thus adding to floodwater damage. In addition to housing, local fishing jetties, which were small and built from poles and planks of wood, were destroyed. Fishing boats were tossed up and out of the jetties, with many swept far inland (up to 300 m). Another major impact was coastal flooding. Floodwater and mud smothered and killed newly planted rice in paddy fields up to 1 km from the coast.

Disaster recovery

Emergency response

It is fairly well documented that there was virtually no official warning of the impending tsunami before it hit Penang on the 26 December. This meant that the initial response happened in a bottom-up fashion, which is similar to many other disasters (Morrow, Gladwin, & Peacock, 1997; Covan *et al.*, 2000; Rocha & Christoplos, 2001; Whitehead, 2002; Shaw & Goda, 2004; Thomalla & Schmuck, 2004). This is exemplified by the experience of the Balik Pulau District Fire and Rescue Station, which serves the western coast of the island: the officer in charge received a call from 'someone in distress' in Pasir Panjang between 13.30 and 14.00, at which time he was still unaware there had been a tsunami. Shortly after the first call there were others, all from people in various states of distress at different locations along the coast. After sending crew to the first call, the officer responded to others, but it was not until he himself arrived on site, when it became evident there had been a 'serious incident', that he immediately informed his superiors at the Head Office in Penang. The director of the Fire and Rescue Service in Penang then contacted district officers who have responsibility for the coordination and administration of government activities at the district level. Their response was to immediately set up emergency management committees across the district. It is at this stage that disaster management became top-down. The committees immediately took responsibility for the coordination of search and rescue efforts as well as other major actors such as the police, St John's Ambulance, hospitals, Civil Defence, Malaysian Armed Forces and Social Welfare Department, as well as temporary relocation shelters. In total over 1000 people were involved (NSDP, 2005).

On the day of the tsunami the Balik Pulau Fire and Rescue Station had six officers on watch, but the officer in charge was able to call in another 24. The station had access to just one boat but was able to enlist a Malaysian Air Force unit to help search for survivors. By 27 December, their effort had increased to 50 people, one dive unit with 5 people onboard, one boat unit and a helicopter unit. On 28 December a jet-ski and speed boat units were also made available to help with the search and rescue operation. Civil Defence and the Armed Forces assisted with the search and rescue efforts during those first few days. The primary role of the police force in the first few days was to ensure the lines of communication (mainly roads) were kept clear of onlookers so as to secure the free movement of ambulances and rescue vehicles. Another important role was to ensure the security of vacated properties, which basically involved setting road blocks at appropriate locations and patrolling evacuated areas. However, according to district officers, looting did not become a serious problem.

Relief

The first and most important form of relief in the period immediately following a tsunami is the provision of basic needs (food, water, clothes and shelter) to those most seriously impacted. Altogether 2949 people had to be evacuated from their homes to temporary relocation centres – nine village halls, six schools and one fire station (NSDP, 2005). The Social Welfare Department was responsible for setting up temporary shelters, as well as coordinating the provision of food, water and clothing for the victims. However, other NGOs assisted with relief efforts, either in cooperation with the department or independently. Notable NGOs involved included the Malaysian Red Crescent Society, Mercy Malaysia, Tzu Chi Buddhist Foundation, corporate bodies such as Intel Corporation, and various private businesses and individuals. NGOs helped with 'on the ground' activities, such as distributing clothes, water and food, and cleaning up mud and debris from roads, as well as dispensing financial aid (charity donations).

While nearly 3000 people were located in these centres it is clear from interviews that there were many other victims that took shelter with friends and family. While evacuees at relocation centres were provided with food, water, bedding and clothes for as long as they stayed, many did not stay more than a few days as they were able to make their own longer-term housing arrangements, often with friends or relatives. Thus, informal networks of friends and family played an important role in the relief effort.

Recovery

Our research has identified three main groups of people economically affected by the tsunami: coastal residents, fisherfolk, and coastal business people. It was notable from the outset that none of our informants had any insurance coverage for disasters.

Recovery for coastal residents. To provide longer-term accommodation than the temporary shelters, the District of Penang built temporary housing at two locations in the northeast of the island – one at Batu Feringgi (phase 1) and the other, 5 km west, at Miami Beach (Pantai Miami) (phase 2). Together, these housing schemes encompassed 100 units and were built at a total cost of RM 1 226 369 (RM 1 then equivalent to almost USD 3.80) (NSDP, 2005). Those offered accommodation were coastal residents whose dwellings were either destroyed or badly damaged. Housing was also provided for those who lived in areas of the District of Penang now deemed unsuitable for future housing (i.e. vulnerable areas along the coast). This was especially notable for the squatter settlement at Tanjung Bungah, which was badly affected. In this sense the tsunami provided the state with a convenient opportunity to relocate this 'illegal' settlement. Not all residents of these housing schemes were happy about the arrangements, however, and many would have preferred to remain in their own homes. Temporary houses consist of one main room that serves as a living room-cum-kitchen, two bedrooms and a bathroom. All families, regardless of size, were accommodated within this same design. For many families this represented a much smaller and lower standard accommodation than their destroyed homes. Ultimately, it is the intention of the Penang state government to build new permanent housing for all families in temporary housing schemes, although those living in temporary housing suggest it will take many years before these are complete.

According to the NSDP (2005) 238 houses were destroyed by the tsunami, 8 were badly damaged and a further 275 received minor damage; most of these were concentrated at the Tanjung Bungah settlement. If the temporary housing schemes contained 100 houses, it is not clear is what happened to the occupants of remaining 138 destroyed houses that did not take up residence in temporary housing. Two temporary scheme informants suggested that some people went to live with family members. Perhaps this is part of the explanation, but also highlights the 'unofficial' recovery activities built through social capital. Regarding compensation, the data provided by the NSDP appears somewhat inconsistent with the figures for damaged houses. Apparently the owners of all 521 houses received some compensation but the amount varied, presumably, depending upon the extent of their losses: 323 owners received a sum less than RM 2000 and 198 received greater sums. Information received from the Social Welfare Department, which provided the compensation, suggests that this compensation was for the loss or damage to house contents not structures. However, further compensation was paid to those owners who carried out repairs to their houses. The eight owners who had 'badly' damaged houses received RM 5000 each and 258 owners of houses with 'minor' damage received RM 2000. This means that the other 17 owners with houses that exhibited 'minor' damage received no compensation at all. It is also clear from interviews that the amount of compensation paid to house owners fell short of what was needed to make full repairs and replace/repair damaged contents. Shortfalls were made up with loans and financial gifts provided by relatives, which points to the importance of kinship networks in the recovery effort. Despite these disparities, we detected no consistent pattern of inequality in support.

Recovery activities for fisherfolk. The financial impact on fisherfolk mainly resulted from boat damage and the loss of nets and other equipment. According to the Fisheries Development Authority of Malaysia or Lembaga Kemajuan Ikan Malaysia (LKIM), 1430 fishing boats were either badly damaged or destroyed (NSDP, 2005). The majority of affected boat owners (1333) received RM 1000 towards the cost of repairs; the remainder whose boats were destroyed received RM 3000 each. However, the amount of compensation reported by fisherfolk differed from the NSDP's (2005) figures. For example, one fisherman whose boat was completely destroyed reported receiving just RM 2000 from the government and NGOs combined. The chairman of the local fishing association at Sungai Burong said that the LKIM donated RM 1000 to each of his members regardless of whether they had to replace or repair their boats. Despite the apparent confusion over the amount of compensation paid, it seems that all fisherfolk received compensation within a month of the tsunami.

What is clear is that the amount of compensation was not sufficient to meet the full costs of boat repairs and/or losses. According to our informants, it cost approximately RM 5000 to replace a lost boat and RM 6000 to replace an outboard motor. This takes no account of the cost of nets, weights, or other essential equipment. Importantly, the fisherfolk affected were unable to fish while their boats were being repaired or replaced and in some cases waited up to four months for replacement outboard motors, delays that jeopardized livelihoods entirely reliant on fishing. Fortunately the support networks provided by relatives and friends meant that most were sustained during that time. LKIM did provide fisherfolk with technical assistance in repairing to outboard motors where repairs were all that was required. But most fisherfolk interviewed felt that the level of technical expertise provided was inadequate and many ended up paying for engine repairs anyway.

In the end, the financial shortfalls, which in some cases were very significant (RM 10 000 or more), had to be made up by loans. Government loans administered by LKIM were provided through local village headmen. The headman at Pulau Betong, for example, was able to provide RM 100 000 to 30 local fisherfolk. Where individual loans were greater than RM 2500 the fisherfolk were only required to repay 50 per cent, so there was in effect further compensation here. More often than not additional loans were also needed and the local fishing associations were able to provide these, but they had to be repaid in full. While all loans were provided interest-free most fisherfolk believe it will take five to six years to completely repay them.

It is notable that one of the local fish buyers in Pulau Betong effectively acted as a broker on behalf of the headman. He assessed each individual fisherman's needs and made a request to the headman for a loan on behalf of each. The loan must be paid by providing the buyer with fish, with the loan amount diminishing gradually as fish is supplied. This type of loan proved essential to the fisherfolk because, apart from the fishing association, there was no other means to borrow the funds needed (with no collateral, banks would refuse). However, there are potential problems with this system. The fisherfolk are effectively 'tied' to that particular buyer because only he has the appropriate connection to the headman to repay the loan. Most fisherfolk did not feel this situation would compromise them, but another fish buyer in the village (without financial connections to the headman) expressed concern because many of the fisherfolk that used to sell their fish to him no longer did. He claimed his business turnover had reduced by about two-thirds as a result. He also suggested the fisherfolk were not getting a 'fair' price for their fish because other buyers were no longer in a position to compete. These arrangements suggest fisherfolk and fish wholesalers might be experiencing an artificial cost price squeeze as a consequence. In this context of artificial price control, marginal fisherfolk become poorer while wealthier fish wholesalers (i.e. those with connections to the headmen) become wealthier. Indeed, one fisherman told how his relationship with the headman had affected his ability to obtain a loan. He felt disadvantaged because he had to obtain the funds he required from the fishing association which required full repayment of loans. Government loans were thus dependent on personal relationships between fisherfolk and headmen and, in Pulau Betong at least, relations between local fish buyers. This dynamic has been observed in many disaster sites, where hazards provide 'opportunities' for the dominant classes (Wisner *et al*., 2003; Bryant, 1998). In this sense the state and business unevenly support recovery efforts, with compensation not always reaching those most in need.

Recovery activities for businesses. The last broad group of affected residents can be generally classed as coastal business people. As one might expect, the level of impact varied enormously. International tourist hotels were largely unaffected, but small restaurants along the coast suffered severe damage. Those involved in offshore aquaculture lost boats, jetties, cages and other equipment, and some rice paddies in the southwest suffered salinity damage. We interviewed primarily restaurant owners and floating cage fish farmers, and what follows is a brief description of the experiences of one informant from both these businesses.

One oyster farmer, like all other floating cage farmers off the west and north coasts, told of how all his jetties were completely destroyed by the waves. He was only able to recover 5000 out of the 200 000 oysters he had before the tsunami hit and was thus unable to supply his customers for three months while he rebuilt his jetties and reestablished his stock. This oyster farmer also had an employee who was paid throughout the period when the business had no income. He estimated that the total financial impact was approximately RM 20 000. However, because the government regarded such business people as financially robust, they received very little compensation. This particular owner/operator received just RM 1000 two months after the tsunami, so the major part of the costs associated with rebuilding his business had to be met from his personal savings.

The owner/operator of an open-air restaurant in Tanjung Tokong recounted a similar situation. She described how the largest of three waves knocked her off her feet and carried her and several staff and customers through to the back of the seating area. She received significant injuries and had to be treated in hospital, at a cost of RM 20 000. The restaurant also sustained significant damage and while she was supplied some building materials free of charge from the government, she still had to spend RM 60 000 of her own savings on rebuilding work. Fortunately her labour costs were kept low because she received considerable help from the local community. Like the oyster farmer, she continued to pay all six of her staff while the restaurant was unable to trade (a period of three weeks). She also donated RM 1000 to each of her staff, again from her own savings, to compensate them for trauma and losses. Her only compensation was RM 200 from the Social Welfare Department on the day and another RM 100 from the Penang Foundation (an NGO). It seems that state efforts to support displaced residential communities and fisherfolk was at the expense of financial assistance for coastal businesses.

Reduction of vulnerability

The models proposed by Lindell & Prater (2003); and Prater *et al.* (2004) suggest the effects of a disaster can be determined by hazard exposure, physical vulnerability and social vulnerability. There also are three event-specific conditions – hazard event characteristics, improvised disaster responses and improvised disaster recovery – that mediate disaster effects. Of these, hazard event characteristics and improvised disaster responses combine with pre-impact conditions to shape a disaster's physical impacts. The physical impacts, in turn, combine with improvised disaster recovery to produce the disaster's social impacts. In this complex grid of vulnerability, communities can engage in three types of emergency management interventions to ameliorate disaster impacts (Prater & Lindell, 2000; Lindell & Perry, 2004; Tang, 2006; Prater *et al.*, 2006). Physical impacts can be reduced by hazard mitigation practices and by emergency preparedness practices while social impacts can be reduced by recovery preparedness practices. A subsequent earthquake on 28 March 2005 provided an ideal opportunity to examine these sorts of responses and impacts, as well as any reductions in vulnerability.

The 28 March earthquake event also occurred near Sumatra and measured magnitude 8.7. Nearly all the people interviewed were aware of, and felt, the earthquake. While some informants did evacuate in an orderly way to higher ground, most remained at their homes or businesses. Some said they moved furniture and electrical equipment to higher positions as a precaution. Others sought information and guidance on the need to evacuate. One of our informants who had access to the internet investigated the possibility of a tsunami for herself and felt satisfied she did not need to evacuate. Still others contacted Fire and Rescue Services (as well as the police) for information. The officer in charge contacted the headquarters of the Malaysian Fire and Rescue Department and the Meteorological Department for information and was told that there would probably not be a tsunami but to be 'on alert'. This information was passed on to the villagers and they were apparently satisfied that there was no need to evacuate to higher ground. Both Fire and Rescue and the police said they felt more confident about handling a tsunami because of their previous experience.

In Penang relocation has been site-specific in that only villagers from Tanjung Bungah have been moved away from the coast. If their relocation remains permanent, it will reduce losses of life and property in future tsunamis. The memory of the tsunami and ongoing education programmes should also keep hazard awareness high, at least among this generation of coastal zone villagers (Hanson, 2005). Outside of the tsunami-impacted area, it is unclear what long-term tsunami hazard reduction measures have been instituted. There are ongoing tsunami education programmes and tsunamis are now included in government plans and briefs of committees, but there are no plans for drawing up tsunami fact sheets or evacuation plans. Furthermore, research shows that public response to tsunami warning messages is complicated by numerous factors (Lindell & Perry, 1992; 2004; Baker, 1995; Atwater *et al.*, 1999; Sorensen, 2000). Mileti

& O'Brien (1992) showed that responses to post-impact earthquake warnings are psychologically different from responses to pre-impact warnings. The rarity of warning events also means that people often look to others to clarify what may be perceived as an ambiguous situation (Latane & Darley, 1976). Official warning messages require effective public education, so tsunami warnings are both technological and social concerns (Lazarus *et al.*, 2002). In Hawaii, Lachman *et al.* (1961) showed that only about 5 per cent of those affected by the tsunami disaster in 1960 reacted appropriately to the official sirens used to alert the people, although most connected the siren to the idea that a tsunami was expected. This inference is supported in Penang where most people remained at their homes or businesses in response to the March 2005 earthquake.

It should be noted that the 2004 Indian Ocean tsunami produced indirect psychological and political impacts in other countries that also have tsunami hazard exposure through the high profile media attention (Prater *et al.*, 2006). Connor's (2005) evaluation of a tsunami hazard awareness programme in Oregon, USA was able to document significant increases in coastal residents' knowledge about tsunami behaviour and appropriate protective actions attributable to news media coverage of the 2004 tsunami.

Concluding discussion

The scientific survey of the northern and western coasts of Penang revealed that the maximum water depth was 5.9 m above msl at Tanjung Tokong, and eyewitness accounts suggest that splash was approximately 12 m above msl. The impact of the waves along the coastline was mainly limited to the immediate coastal locations, but this varied with construction materials and methods, physiographic conditions and the existence of mangrove habitats.

Our social survey revealed that initial response to the tsunami happened in a bottom-up fashion. In the first few days after the tsunami, following standard protocol, the priority was to ensure that lines of communication were kept clear and to ensure the security of vacated properties. The Social Welfare Department was primarily responsible for providing basic needs (food, water, shelter and clothing), but also received assistance from NGOs. The evacuees were initially housed in relocation centres, but longer-term accommodation is being provided for those whose houses were destroyed. The Social Welfare Department also provided compensation to most owners of destroyed or damaged houses, but this was insufficient to meet the costs of repairs and to replace lost or damaged goods.

Two commercial groups economically affected by the tsunami, fisherfolk and coastal businesses, lacked insurance coverage for disasters and the government compensation was not sufficient to meet the full costs of repairs and/or losses. While all owners received some compensation there were discrepancies regarding amounts. Like many householders, it is clear that fisherfolk had to sustain significant financial shortfalls. To meet these shortfalls LKIM offered interest-free loans (through village headmen) that only required 50 per cent repayment. However, these loans were dependent on personal relationships between fisherfolk, fish wholesalers and headmen. This supports findings that suggest that the ability for individuals and communities to recover from the tsunami is affected by social capital, thus producing different 'geographies' of adaptability (Pelling, 1998). It also supports research that suggests the dominant classes are able to find opportunities that forestall the worst financial impacts of hazardous events (Bryant, 1998).

Even within business communities, however, the level of economic impact varies enormously, with little government compensation. The perceived 'robustness' of these small-scale businesses was in reality achieved though considerable assistance from local communities. Indeed, across the sometimes overlapping groups of coastal residents, fisherfolk and business owners/operators, social capital plays a crucial role in response and recovery activities (see also Putnam, 1996; Moore *et al*., 2004).

Our research revealed that of 52 tsunami casualties, most were located in our two field sites. In western Penang, the vast majority were curious beach picnickers blocked in by a bedrock cliff. This group is not 'vulnerable' in the same way as 'marginal' groups typically represented in the hazards literature (Wisner *et al*., 2003; Bryant, 1998). In other words, beach picnickers are not a social group made vulnerable by particular social, political or economic process. This is not to propose that social dynamics did not play an important role in reducing casualties at some sites. Many people were on Penang beaches that day, but those at international tourist resorts received unofficial warning from the business networks of international tour operators. Conversely, in northern Penang many casualties were from the squatter settlement at Tanjung Bungah. Here illegal tenure fostered the use of semipermanent wood and concrete construction materials, making this community particularly vulnerable to loss of life and property.

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Endnote

1 The SGER used research methods drawn from both the natural (Hawkes *et al*., 2007a; 2007b) and social sciences (Buranakul *et al*., 2005; Rigg *et al*., 2005; Bird *et al*., 2007) to elucidate the immediate pre- and post-tsunami trajectory of events and impacts associated with the 2004 tsunami along the west coast of the Malay Thai Peninsula. The research also involved undergraduate and graduate students from Malaysia, Thailand, UK and USA, which produced two senior theses, two Masters theses and one PhD dissertation. This SGER helped set up a successful grant application to NSF to search for historic and prehistoric records of tsunamis in Indonesia.

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