

CASE STUDY OF COASTAL FLOODING: THE JAPANESE TSUNAMI OF MARCH 2011 – IMPACTS, RECOVERY, ENVIRONMENTAL AND ECONOMIC REPERCUSSIONS

The triple hazards of earthquake, tsunami and nuclear accident that struck Japan in March 2011 had a traumatic effect on the country. The short- and long-term impacts have been profound, reaching to the very heart of Japan's national identity and changing the lives of many of its people irrevocably. For a detailed account and explanation of these events and their immediate aftermath, see *Geofile* 654 (January 2012) 'Japan 2011: Earthquake, Tsunami, Nuclear Crisis...' which explores the longer-term impact of this hazard event.

Impacts

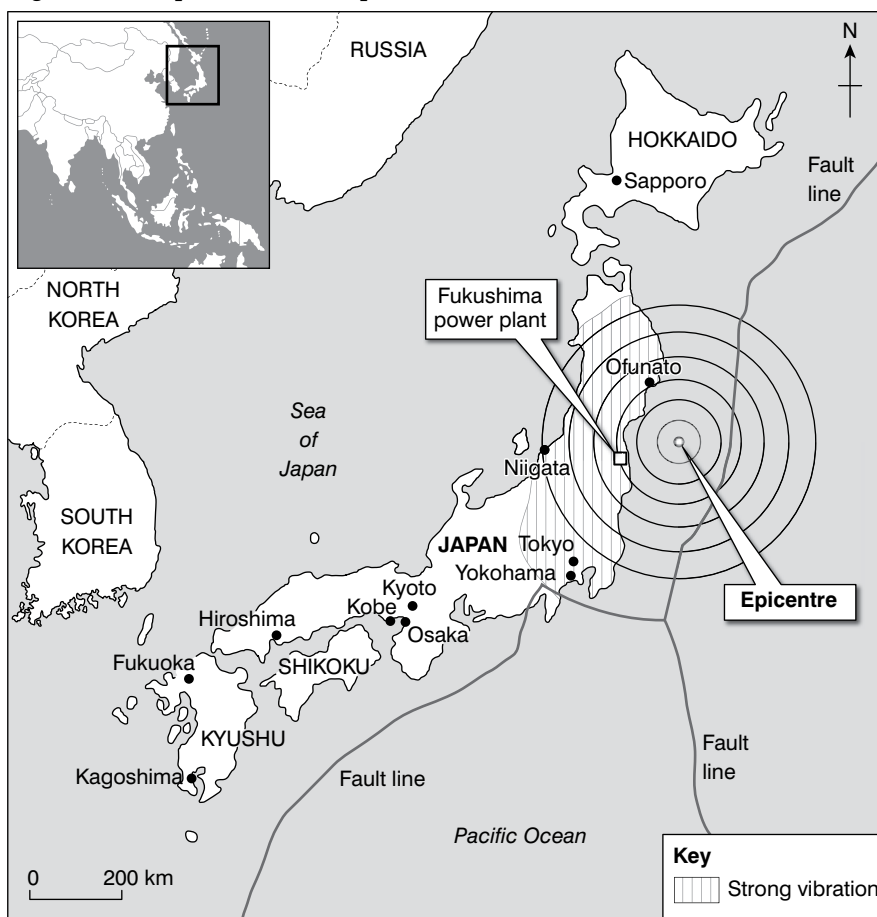
The earthquake itself

The earthquake of 11 March 2011 was the most powerful to have struck Japan in over a thousand years. With a magnitude of 9 on the Richter scale, it ranked as the fifth-strongest ever recorded globally. Its focus was located 25 km below the Pacific Ocean, 100 km off the Japanese coast, close to the fault line where the denser oceanic crust of the Pacific plate is subducted below the continental Eurasian plate (Figure 1). Shaking from the earthquake waves affected the entire northern half of Honshu, Japan's main island, reaching the Tokyo conurbation in just 100 seconds. The most severe tremors were felt in the Tohoku region of the north-east coast. Automatic warnings were immediately triggered on television and mobile phones, giving people time to take shelter, and Japan's stringent building regulations proved effective in preventing any major damage in the capital. Japan's regular earthquake drills helped people to protect themselves and minimised casualties. In the week that followed the main earthquake there were over 500 aftershocks measuring between 5 and 7 on the Richter scale. These indicated new stresses which could be transferred elsewhere along the fault, increasing fears of a future threat to Tokyo, where 30 million people live within 2 metres of sea level.

The tsunami

Powerful as the earthquake's immediate impact was, its

Figure 1: Earthquake location map

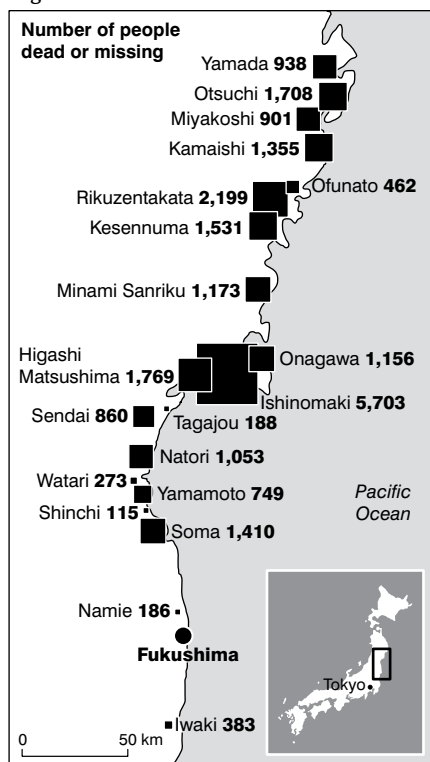


Source: Adapted from *The Guardian*, 12 March 2011

overwhelming effect was the creation of a devastating tsunami on Japan's north-east coast. A six metre upward surge of the seabed at the epicentre set up a wave that travelled at 800 km/h across the Pacific and westwards to Japan. As it approached Japan, the shallower depth slowed the ocean swell and piled up the water into a breaking wave over 10 m high. Scientists estimate that 10 billion tonnes of water hit north east Japan. In spite of sirens warning people to evacuate, it seems that the scale and speed of the coastal flooding were completely unexpected. Within an hour of the earthquake, towns and villages along a 300-km stretch of coast had been inundated by the tsunami. Defensive seawalls and levees were overtopped by the floodwaters, swamping the low-lying urban areas and carrying a destructive tide of debris up to 10 km inland. This

advanced up river valleys and across the coastal plain like a bulldozer, flattening houses, industrial areas, public buildings, transport links and farmland. Many unfortunate residents and workers had no time to reach higher ground: of nearly 16,000 people who died and over 3,000 who are still officially missing, 90% were killed by the tsunami (Figure 2). In the days that followed, more victims would be claimed by injuries, shock, exposure and fires that broke out in the wrecked settlements. A significant proportion of the victims were elderly: 56% of the deaths were among those over 65, and 75% of those missing were over 60. The tsunami was blamed for the decline in Japanese life expectancy in 2011. The average lifespan of women fell 0.4 years to 85.9 years, while for men there was a slight fall to 79.4 years.

Figure 2: Tsunami casualties

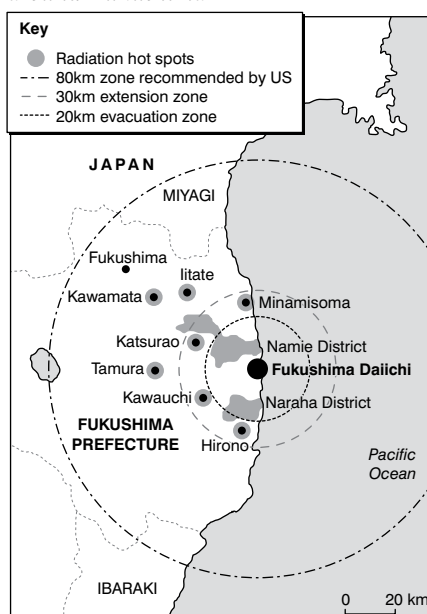


Source: Adapted from *The Guardian*, 12 May 2011

Nuclear crisis

At the ageing Fukushima-Daiichi nuclear power plant, opened in 1971, the earthquake led to an automatic shutdown of the three reactors (out of six) that were operating at the time. Emergency back-up generators restored the system to cool the reactor cores and used fuel stores, but were then put out of action when a 14-m high tsunami struck soon afterwards. It later became clear that the plant's operators had severely underestimated the potential risks from earthquakes and tsunamis. The reactors began to overheat, causing a series of explosions which released radioactivity into the air and led to the designation of a 20-km evacuation zone around the plant. Over the next two days 80,000 residents left their homes to move in with relatives and friends elsewhere, or to emergency refugee shelters in public buildings. A further 136,000 people, living 20 to 30 km from the plant, were told to stay indoors. There was also a constant leak of radiation into the sea from the basement of the reactor buildings which were flooded with 60,000 tonnes of radioactive water (Figure 4). In late April a 20-km exclusion zone was declared around the plant, and the evacuation zone extended to 30 km (Figure 3). 250 workers inside Fukushima-Daiichi were struggling to contain the leaks, and facing serious illness due to the harsh conditions. By mid-May it was acknowledged that the three most

Figure 3: Exclusion zone imposed around Fukushima



Source: Adapted from *The Guardian*, 13 April 2011 and *Graphic News*, ASR

damaged nuclear reactors were likely to have melted down. Over the next six months as many as 3000 people were involved in work at the site, until in December it was announced that 'cold shutdown' had been achieved. This meant that the reactors were no longer emitting radiation above official limits for the public. The Fukushima-Daiichi disaster was graded 7, a 'major accident', and the highest level on the international scale of severity. Only the 1986 meltdown of the Chernobyl reactor in the Ukraine had previously been graded 7, although 10 times more radiation was released in that incident.

Recovery

In the aftermath of the tsunami there was widespread criticism of the government's speed of response to the disaster. Many survivors said they were left to fend for themselves in the chaotic conditions and harsh weather that followed. The government countered that 50,000 personnel from Japan's self defence forces, safety agencies and national police were mobilised in the first two days, and that a total of 160,000 were in operation two months later. Nevertheless, it cited severe damage to transport and communications infrastructure as the main reason for difficulties in bringing relief to the beleaguered residents. The major highway through the Tohoku region was reopened after a fortnight and the 'shinkansen' (bullet train) line to Tokyo was fully operational by the end of April.

Figure 4: Radioactive water plume on 9 April 2011



Source: Adapted from *The Guardian*, 13 April 2011

One month after the earthquake and tsunami struck, Japanese and US troops were still engaged in the search for bodies. At this stage, fewer than two-thirds of the final toll of nearly 20,000 victims had been found. More than 150,000 survivors were living in evacuation centres. The following week the US Secretary of State, Hillary Clinton, visited Tokyo to pledge support for Japan and the two countries announced the formation of a public-private partnership to lead reconstruction. In May, as the operation to clear rubble began along the north-east coast, the World Bank estimated the cost of recovery at £144 billion. The government calculated that it would take three years to scrap, burn or recycle the 25 million tonnes of debris created by the destruction of 16 towns, 125,000 buildings, 23 railway stations and hundreds of miles of roads, rail tracks and sea defences. 60,000 acres of agricultural land had been contaminated through inundation by the tsunami. 70,000 temporary houses were needed to accommodate the 300,000 people who had lost their homes. Japan, previously one of the world's biggest aid donors, became the leading destination for international charity. The Japanese Red Cross received £1.5 billion in foreign donations. In November 2012 a scandal hit the Japanese government when an audit revealed that a quarter of its £91 billion reconstruction fund was spent on projects unrelated to the disaster. It was also discovered that red tape and indecision about rebuilding plans meant that about half the budget had yet to be distributed.

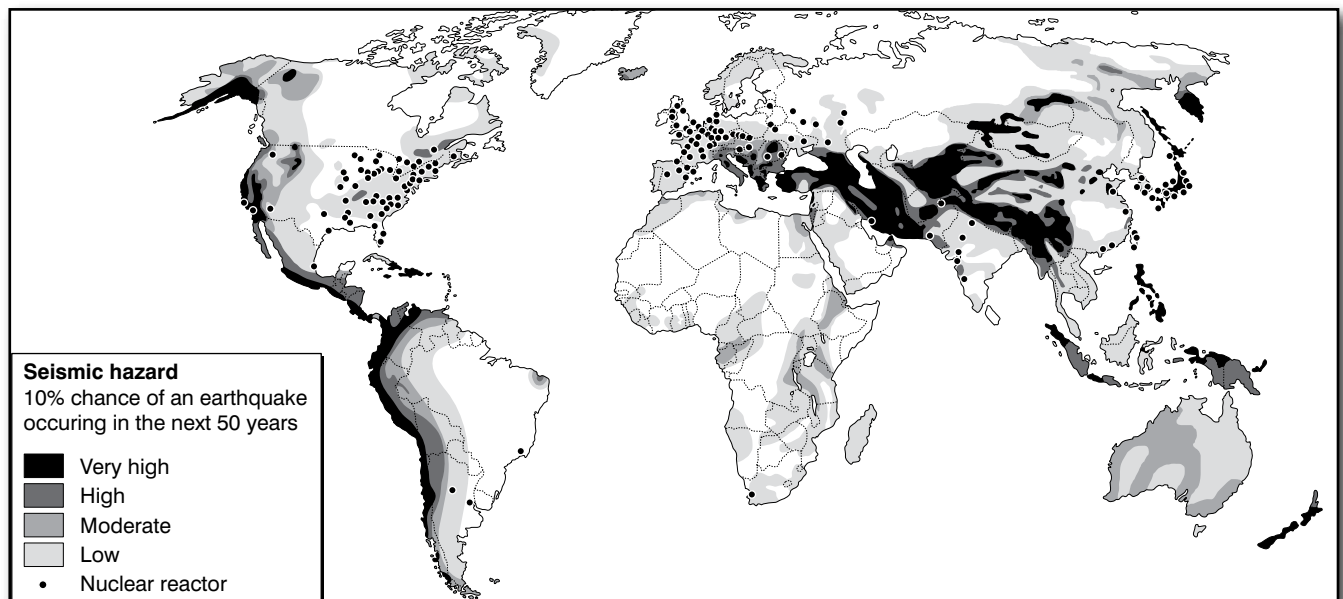
Environmental repercussions

Radiation

(a) Direct impacts on people

By far the most menacing legacy of the meltdown at Fukushima-Daiichi is the long-term threat to public health posed by exposure to increased radiation. In the residential areas

Figure 5: Nuclear reactors and areas of earthquake risk



Source: Adapted from *The Guardian*, 15 March 2011, IAEA, *Washington Post* reports, *Graphic News*, Reuters

of eastern Fukushima prefecture, radiation levels are 15 times higher than before the tsunami. Parents are particularly concerned about the vulnerability of their children, who are more susceptible to the effects of radiation than adults. Every child is required to wear a small dosimeter, which measures their exposure to radiation. The public are suspicious of official safety levels, and many have bought Geiger counters or dosimeters of their own. Children habitually wear masks and hats for protection when outside, and parents often strictly limit their play time in the open air. At Fukushima, 15% of the locations tested were above the level considered as contaminated at Chernobyl. Radiation 'hot spots' have also been detected around Tokyo, 200 km away.

(b) Impacts on the food supply

Residents of eastern Fukushima, numbering close to two million, also have fears arising from the contamination of food and water supplies. Most people will only drink bottled water, and generally avoid local produce. Cases of tainted beef and rice crops have raised questions over food screening measures and have eroded public confidence, leading to a lack of trust in government safety standards. Some farmers' groups have resorted to testing the radiation levels of their produce and voluntarily destroying any crops or animal products that might be hazardous. Fishing co-operatives in Fukushima prefecture adopted a voluntary embargo on operating in local waters, fearing the effect of radiation leaks on seafood. In summer 2012 the first catches of

octopus (which trap fewer radiation particles) were permitted, but research suggests that larger and bottom-dwelling species, such as cod, halibut, pollock, flounder and sole, may be inedible for the next 10 years. Only five months after the meltdown, traces of radiation were detected in blue fin tuna caught off the coast of California.

Nuclear energy policy

(a) Japan

In May 2012 the last reactors still operating were turned off and Japan was without nuclear power for the first time in 40 years. In July a report on Fukushima-Daiichi from an independent panel blamed the meltdown on 'a multitude of errors and wilful negligence' by the government, safety officials and the operating company. Other observers pointed to the complex entanglement of political, bureaucratic and financial interests in Japan's nuclear industry, suggesting that the relationship between regulators and regulated was too close, allowing power firms to influence official policy. In September the Japanese government announced that it would close all 50 functioning nuclear reactors by 2040 and increase renewable sources to 30% of the energy mix, as well as developing sustainable use of fossil fuels. This decision also accepted an increase in the country's heavy dependence on oil and natural gas, with serious implications for its carbon emissions targets. Just one week later, the 2040 deadline was abandoned after pressure from business leaders who said the move would harm the economy by forcing firms to shift production

overseas due to the high cost of imported oil and gas.

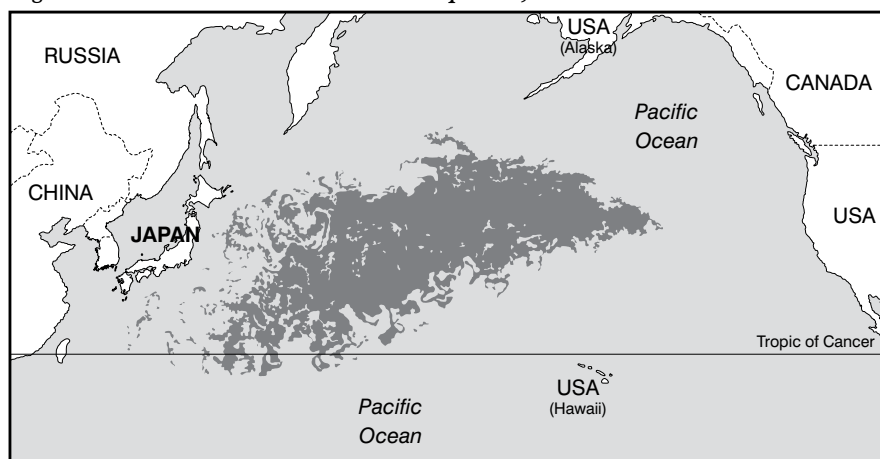
(b) World

The Fukushima accident has affected attitudes to nuclear power outside Japan in markedly different ways. Within weeks, public protests in Germany were followed by a government confirmation that it would accelerate its retreat from nuclear power, with the final reactor being shut down by 2022. This would require a doubling of its renewables supply, from 17% to 35%, and would make Germany a net importer of energy as early as 2012. However, apart from Germany and Japan, such negative reactions have largely been limited to Italy, Israel and Indonesia. Indonesia's location on the Pacific 'Ring of Fire' and its experience of the devastating tsunami in 2004 make its antipathy understandable (Figure 5). Elsewhere, the US, UK and France remain committed to nuclear power as an important part of their energy strategies, while India and China are pressing ahead with their nuclear plans, albeit with greater focus on safety considerations. Most surprisingly, some environmentalists have actually strengthened their belief in the nuclear option as a way of reducing carbon emissions and combating global warming.

Ocean debris

The tsunami swept an estimated 5 million tonnes of debris into the Pacific Ocean, dumping as much in one day as would normally happen in a whole year. According to NASA satellite data, the heaviest 70% sank

Figure 6: Areas where tsunami debris was present, six weeks later



Source: Adapted from *The Guardian*, 2 May 2011 and IPRC

to the seafloor, leaving 1.5 million tonnes to drift slowly eastwards across the Pacific. After a year the debris stretched across 4000 nautical miles of the ocean, though by then it was very sparse and dispersed (Figure 6). 95% of the flotsam is expected to join the permanent accumulation of non-biodegradable rubbish known as the 'North Pacific Garbage Patch', while the remainder will eventually come ashore along North America's Pacific coastline. Fears of radioactive contamination have so far proved unfounded, but the debris poses threats to marine life and is a hazard to navigation.

Economic repercussions

The most direct economic effect of the disaster was felt by the operators of the Fukushima-Daiichi nuclear plant, the Tokyo Electric Power Company (TEPCO). Within a month of the explosions at its reactors, TEPCO had lost more than four-fifths of its stock market value. The company had made £1 billion profit in 2010 but, following the nuclear accident, it faced a compensation bill of £37 billion over the next two years. These huge costs would arise from the provision of replacement power, the construction of new generation capacity and the decommissioning of the Fukushima-Daiichi reactors. In addition, the firm had suffered a humiliating loss of reputation, especially when it was revealed that it had falsified nuclear safety data hundreds of times since 2000. In May 2011 TEPCO announced a £9.5 billion loss, the largest ever recorded in Japan outside the financial sector. By December, when the plant had been stabilised, TEPCO had received massive financial support from the

government, regarded by many as a 'de facto' nationalisation of the company. Even so, TEPCO reported a £6 billion financial loss in May 2012. It was not until October 2012 that the company finally admitted blame for the disaster, publicly acknowledging that it had known more extensive safety measures were needed but had failed to implement them.

In general the Japanese economy suffered a severe blow, and in 2011 the country reported its first annual trade deficit for 30 years, to which the disaster was a chief contributory factor. Japanese manufacturing industry suffered serious disruption, through energy shortages, damage to infrastructure and breaks in the supply chain from the country's numerous small manufacturing enterprises, to which major firms subcontract production of components. Toyota shut all 18 of its domestic factories for 20 days, losing over a quarter of a million vehicles. Similar steps were taken at its plants in North America, France, Poland and Turkey. In the UK, all three Japanese car-makers, Honda, Toyota and Nissan, had to scale back production for months due to delayed imports of parts from Japan. The Nissan plant at Sunderland, for

example, normally ships in 20% of its components from Japan.

The insurance industry was hit hard by claims arising from all aspects of the disaster, with the total bill estimated at £20 billion, even though many of the buildings destroyed in Japan had not been insured. Most of the losses were absorbed by Japanese insurers, of which 40% had been reinsured with European firms. Lloyd's of London took a £1.2 billion hit from Japan, to which was added £1.4 billion in losses arising from the Thai floods of October 2011. In Thailand 80% of the damage involved buildings owned by Japanese technology companies, many of which had transferred production there after the March disaster.

FOCUS QUESTIONS

1. Why is Japan still vulnerable to the effects of earthquakes or a tsunami, in spite of the elaborate defence measures and civilian protection programmes it has put in place?
2. Consider the arguments for and against the development of new nuclear power stations in the United Kingdom.
3. Refer to Figure 5. Describe a) the pattern of earthquake hazard globally, b) the world distribution of nuclear reactors. What conclusions can you draw from the relationship between the two?