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Inadequate warning system left Asia at the mercy of tsunami

Emma Marris, Washington

When two tectonic plates beneath the Indian Ocean cracked past each other at 0:59 GMT on 26 December 2004, the sea floor was forced upwards by some 10 metres. This displaced in the region of a trillion tonnes of water, driving it towards southeast Asia's coastline in a long, low-amplitude wave travelling at up to 900 kilometres per hour.

When the wave reached shallower water near the coast, it shortened, slowed and gathered into surges that killed at least 150,000 people across a dozen countries. In the aftermath of the disaster, casualties continue to mount at a ferocious pace.

Seismologists knew about the magnitude 9 earthquake within minutes (see 'Triple slip of tectonic plates caused seafloor surge', below), but the absence of monitoring equipment in the ocean itself meant that they didn't know for sure that a tsunami had occurred. Those who suspected as much were unsure how to get the word out to the regions most at risk.

Although the small global community of tsunami researchers had expressed some concerns about the risk of such an event, little had been done to plan for it. "It is

D. ALANGKARA/AP

Devastated: the shattered remains of Meulaboh in Indonesia, largely destroyed by the tsunami.

Triple slip of tectonic plates caused seafloor surge

In the aftermath of the tsunami that devastated coastlines around the Indian Ocean, experts are piecing together details of the seismic slip that sparked the waves. The earthquake, the world's biggest for more than 40 years and the fourth largest since 1900, has literally redrawn the map, moving some islands by up to 20 metres.

The destruction, which claimed as many as 150,000 lives, was unleashed by a 'megathrust' — a sudden juddering movement beneath the sea floor. A build-up of pressure caused the floor of the Indian Ocean to lurch some 15 metres towards Indonesia, burrowing under a tectonic plate and triggering the ferocious swells that smashed into surrounding shores.

The earthquake followed almost two centuries of tension during which the India plate pressed against the Burma microplate, which carries the tip of Sumatra as well as the Andaman and Nicobar Islands. The plates move against one another at an average rate of about 6 centimetres a year, but this movement does not occur smoothly. There has not been a very large quake along this fault since 1833 — a fact that may have contributed to the huge force of this one. The India plate's jarring slide released the tension on the Burma microplate, causing it to spring violently upwards.

Quakes of this type, called subduction earthquakes, are commonplace throughout the world, but rarely strike with such force, says Roger Musson of the British Geological Survey in Edinburgh. "This is the largest earthquake I've seen in my career as a seismologist," he says. "The length of the rupture was 1,200 kilometres — I could hardly believe it."

The earthquake, measured at magnitude 9.0, actually consisted of three events that occurred within seconds of each other, Musson explains. The initial slip, which happened to the west of Sumatra's northern tip, triggered two further slips to the north. The total force released was enough to jolt the entire planet.

The seafloor bulge unleashed a wave that surged through the Indian Ocean. Initially, the energy of such a wave is distributed throughout the water column, and surface perturbation is small. Only when the water grows shallow, near the coast, does the wave emerge on the surface as a tsunami — the name is Japanese for 'harbour wave'. In this case, the wave hit Indonesia and Thailand within an hour, and then Sri Lanka and India, ultimately reaching as far as eastern Africa.

Michael Hopkin

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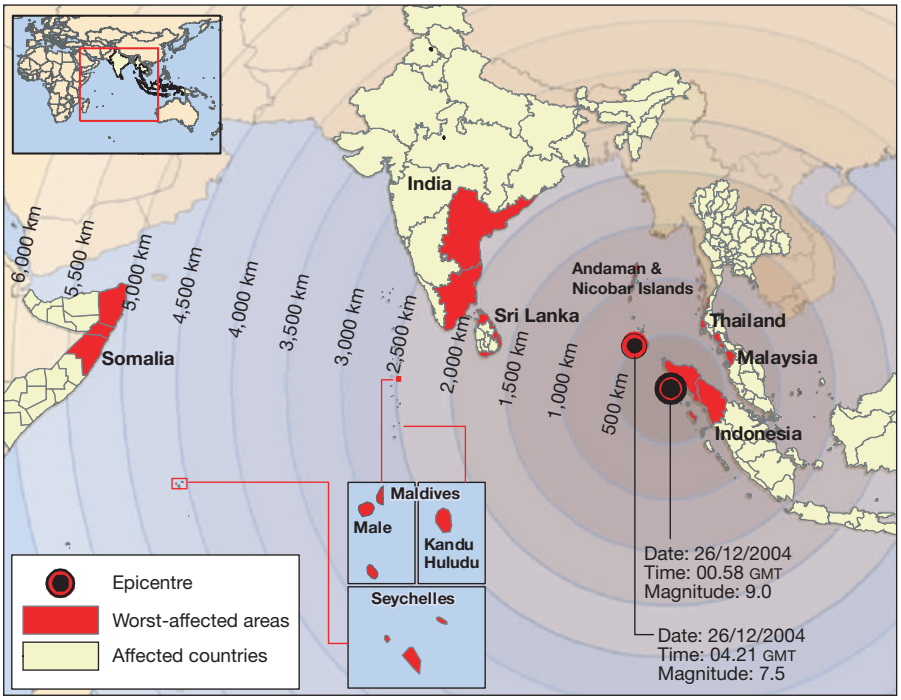

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The tsunami driven by an oceanic earthquake caused widespread destruction, as shown by these views of Banda Aceh, Indonesia, before and after the disaster.

always on the agenda," says Vasily Titov, a tsunami researcher at the Pacific Marine Environmental Laboratory in Seattle, Washington. But he says that it has been difficult to raise the money for a monitoring system. "Only two weeks ago it would have sounded crazy," he says. "But it sounds very reasonable now. The millions of dollars needed would have saved thousands and thousands of lives."

The most recent comparable event in the region took place in 1883 (see 'Tsunamis: a long-term threat', right). In contrast, earthquakes in Chile in 1960 and Alaska in 1964 led to the creation of a reasonably sophisticated tsunami warning system in the Pacific Ocean. Two international tsunami warning bodies exist under UNESCO's Intergovernmental Oceanographic Commission (IOC): the International Coordination Group for the Tsunami Warning System in the Pacific, known as ITSU, and the International Tsunami Information Center based in Hawaii. They get by on annual budgets from the IOC of about US$40,000 and $80,000, respectively, which are supplemented by grants from nations on the Pacific rim.

Displacement data

To predict a tsunami with any useful time advantage, researchers say, data on small changes in sea level and pressure have to be collected directly from the floor and surface of the ocean. The strength of the event depends on the displacement of the ocean floor, not on the strength of the earthquake.

Some buoys that could provide such data are already in place in the Indian Ocean. And only a few weeks before the tsunami struck, members of ITSU were talking about how these could be adapted for use in a tsunami-warning system, says Peter Pissierssens, head of ocean services at the IOC.

Within 20 minutes of the earthquake, at least three monitoring stations in the United States had detected it, initially estimating its magnitude to be around 8. The United States Geological Survey (USGS) circulated the information to about 100 people, mostly its own researchers and senior officials, within 16 minutes, and sent a more detailed bulletin to a list of external contacts, including the US Department of State, after an hour. The USGS has no responsibility for tsunami monitoring and its statement did not mention the risk of such an event.

The Hawaii-based Pacific Tsunami Warning Center (PTWC), meanwhile, sent out a bulletin to its regular circulation list, noting that the event presented no tsunami risk in the Pacific. According to Laura Kong, director of the International Tsunami Information Center, "let's keep an eye on it" was the prevalent attitude that night. "At that point, none of us expected anything like what we have seen," says Charles McCreery, director of the PTWC and deputy chair of

Tsunamis: a long-term threat

Last month's tsunami tragedy, shocking as it was, had ample historical precedent. On 1 November 1755, for example, a fire following an earthquake destroyed two-thirds of Lisbon, Portugal. In panic, the population sought shelter near the shoreline, only to be hit by waves said to be as high as houses. More than 60,000 people died.

Devastating tsunamis are known in historical times to have affected the populated coasts of Papua New Guinea, Japan, Hawaii, Crete, Sicily and the Crimea — to name just a few. In the Pacific region, where 80% of all tsunamis occur, a 1947 analysis indicated that seismic sea waves higher than 7.5 metres occur on average every 15 years[1]. Records going back to 684 BC refer to four Pacific tsunamis higher than 30 metres.

Outside the Pacific, tsunami frequencies have been studied in some detail only for the Aegean and Black Sea regions. Records there reveal that the coastal and surrounding areas of Turkey have been affected by more than 90 tsunamis over the past 3,000 years[2].

For most other areas, information concerning the return periods of tsunamis is scarce. A rough comparison of tsunami frequencies in different parts of the globe was done in 2000 by the London-based Benfield Hazard Research Centre, as part of its Tsunami Risks Project. The resulting risk analysis estimates the return periods of 10-metre waves to be about 1,000 years for the North Atlantic and Indian oceans, southern Japan and the Caribbean, 500 years for the Philippines and the Mediterranean Sea, 250 years for Alaska, South America and Kamchatka in eastern Siberia, and less than 200 years for Hawaii and the southwest Pacific.

The south Asian disaster will have a "huge effect" on instigating more thorough risk assessments, predicts Bill McGuire, a volcanologist and director of the London research centre, as well as encouraging preventive measures in threatened regions.

Quirin Schiermeier

www.nerc-bas.ac.uk/tsunami-risks

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India pledges to fund alert system in wake of disaster

India's government and scientific establishment have been heavily criticized for failing to provide warning of a tsunami that drowned at least 12,000 people on the nation's eastern coast.

Newspapers and opposition spokesmen have asked why a country with India's scientific resources couldn't better prepare for such an event. Ministers immediately pledged up to US$29 million to build a tsunami-monitoring system, and promised to seek more cooperation with the Pacific Tsunami Warning Center in Hawaii.

"This is not a knee-jerk reaction. We are very serious," science and technology secretary Valangiman Ramamurthi told *Nature*. "We are going to have a brain-storming meeting this month to decide how we should proceed and we have invited experts from the United States," he said. In response to criticism, he added: "We cannot join a Pacific network as India is not in that region. And you do not make heavy investment to warn against something that happens once in a century."

The ocean development secretary, Harsh Gupta, told a press conference in New Delhi that there was no record of a tsunami ever hitting the Indian coastline, even as other government ministers acknowledged such events in 1833 and 1883.

G. OSAN/AP

Relief centres in India have been inundated with people in need of food and aid.

"No government thought of it," says science minister Kapil Sibal. "The last recorded tsunami was in 1883. It was not in the horizon of our thoughts." India now plans to install a network of 10 to 12 seafloor pressure sensors to be imported from the United States, as well as several floating sensors on ocean buoys, linked to an Indian geostationary satellite.

Critics say that the tragedy exposed a major weakness in the current system, which authorizes only the Indian Meteorological Department to put out hazard alerts. "Data were pouring into our lab but we cannot issue alerts even if we can analyse the data for tsunami potential," says one researcher at the National Geophysical Research Institute in Hyderabad.

They also want to know why the Indian air force, whose base in Car Nicobar Island was submerged by tides an hour before the waves hit the mainland, failed to provide any public warning.

The tsunami spared India's main rocket launch site at Sriharikota Island, 80 kilometres north of Chennai. But it damaged cooling water pumps at a nuclear power station at Kalpakkam, leaving staff with very little time to shut down the plant safely. "The tsunami factor was not taken into account," says Anil Kakodkar, chairman of the Atomic Energy Commission. "From now on, it will be factored in."

K. S. Jayaraman, New Delhi

ITSU. "We expected a local tsunami at most."

At 2:04 GMT, the PTWC put out another bulletin revising the quake up to magnitude 8.5. Because there was no information about sea levels in the area, the existence of a tsunami was merely hypothetical, but staff were worried enough to begin looking for numbers to call in Asia.

Communication breakdown

According to Kong, the team tried and failed to reach colleagues in Indonesia. Australia was contacted, although to little avail, as that country experienced only half-metre waves. It was not until 3:30 that the team in Hawaii saw news reports on the Internet of casualties in Sri Lanka. The wave had already crossed the ocean, to devastating effect.

Kong says that without a predetermined communication plan, warning efforts were doomed from the start. But she adds that the PTWC will in future directly contact the US state department, which can communicate risks to any nation, at any time.

Indonesian seismologists initially underestimated the strength of the earthquake, according to local news reports. And although officials there had very little time in which to act, an instrument that could have helped warn them of the approaching wave was transmitting its information to a dead phone line, according to a senior Indonesian seismologist (see *news@nature.com* doi:10.1038/news041229-4; 2004).

Efforts over the years to get an Indian Ocean warning system in place have made little progress in the face of national governments' reluctance to invest in them. In 2003, a working group on the Tsunami Warning System in the Southwest Pacific and Indian Ocean was established within ITSU. But Pissierssens says that the first chair of the group, a representative from Indonesia, left soon after his appointment and that the group then split into two according to region.

Phil Cummins a seismologist at Geoscience Australia in Canberra agreed to write a position paper for the group on tsunami risk in the Indian Ocean. "I am still in the process of writing that paper," he says. "No one else was 100% convinced that we should worry and that included me, I've got to admit."

According to Pissierssens, UNESCO will now make an observation system in the Indian Ocean a priority. "The first thing we will do is send out a survey team in January or February," he says, "and then we want to set up a conference in the area." Needless to say, there is little reluctance now to accept the need for the system. The UN International Strategy for Disaster Reduction has also said that one should be built within a year. And the Indian government, under intense domestic pressure for its failure to warn people on its eastern coast, said it would spend up to US$29 million to build a system itself (see 'India pledges to fund alert system in wake of disaster', above).

Nicole Rencoret, spokeswoman for the UN's disaster-reduction branch, notes that early warning systems could watch for other natural disaster risks, as well as tsunamis. "There has been an enormous amount of focus on tsunamis, but we need to take a multihazard approach," she says. ■

DIGITALGLOBE

Turning tide: the waters of the Indian Ocean tsunami recede after battering the coast of Sri Lanka.