Tsunami Warning and Response
Lessons Learned

Laura Kong
Director, International Tsunami Information Center

Charles McCreery
Director, Pacific Tsunami Warning Center
No Common Sense for Tsunamis

- Tsunamis are Not Common - Often 1\textsuperscript{st} Time
  - For individuals at risk
  - For government officials that must respond (incl. TWCs)

- Tsunamis Can Be Learned From
  - Tsunami wave characteristics from physics / models
  - Human response behavior from social science

- Each Tsunami is Unique

  - What situations might occur?
  - How to prepare/respond based on best science?
  - Procedures recorded in SOPs

- Learn from the Past to Improve Future Response
September 1992 Nicaragua Tsunami

- Ms=7 earthquake off the coast of Nicaragua
- Very little shaking along the coast
- Little or no tsunami expected, but
- Large tsunami struck – 116 lives lost

Lessons Learned

- Slow Earthquake
- Use Mw, not Ms
- Use slow discriminant
- Not always shaking
- Not that uncommon – 06 Java, 10 Mentawai
New Guinea Tsunami - Jul 1998

- Mw 7.1 earthquake – no tsunami expected, but
- Large tsunami impact – 2200 lives lost
- Probable cause was undersea landslide triggered by the earthquake

**Lessons Learned**

- Tsunami possibility after any large earthquake
- Roar from the sea may be only real warning
Sumatra Tsunami - Dec 2004

- Mw 9.2 earthquake – size not known for 4 hours
- Rupture direction and extent only known later
- Unrecognized hazard – nothing like this expected
- End-to-end alerting not possible

**Lessons Learned**

- Use new methods to measure huge quakes
- Techniques to quickly gauge rupture area
- Expect 1000-yr event
- Use forecast models
- End-to-end alerts
Japan Tsunami – Mar 2011

- Mw 9.0 earthquake – that big was not expected
- First alert in 3 min, but earthquake size and forecast tsunami impacts too small
- Human behavior – some did not evacuate

Lessons Learned

- Expect 1000-yr event
- Conservative first alert message
- Study/address how to motivate right actions
Earthquakes and Tsunamis

Death
• Earthquakes – building collapse, fire
• Tsunamis – drowning, most older (65% > 60 yrs)

For 2011 Japan, only ~5% of exposed population died
1923 Kanto EQ
Total deaths: 105,385
Fire: 87.1%
Collapsed house: 10.5%
In the factory: 1.4%
Flow out or buried: 1.0%

Cause of Death - Past earthquakes
Cause of Death - Past earthquakes

1995 Kobe (Hanshin Awaji)
Death: 6,434
Missing: 3
Crushed: 83.3%
Fire: 12.8%
Unknown: 3.9%
11 March 2011
Cause of Death

92.4%: Drowning
4.4%: Crushed
1.1%: Fire
2%: Unknown
11 March 2011
Age of Death

Death (left, %) vs population (right, age)

Iwate, Miyagi, Fukushima prefecture

e.g.,
65 % > 60 years old
Earthquake and Tsunami
Local and Indigenous Knowledge
In Indonesia

Ardito M. Kodijat
Programme Officer
Indian Ocean Tsunami Info Centre – UNESCO/IOC
Disaster Risk Reduction / Tsunami Info Unit UNESCO Jakarta Office
a.kodijat@unesco.org

Irina Rafliana
Indonesian Institute of Sciences (LIPI)
Coordinator - Public Education & Community Preparedness
(COMPRESS) Program
LOCAL TSUNAMI

Aceh – Nias 2004, Mag. 9, EQ
166,000 casualties

Biak 1996
Mag. 8.1 EQ
167 casualties

Pangandaran 2006
Mag. 6.8 EQ
500 casualties

Mentawai 2010 Mag. 6.8 EQ
400 casualties

Banyuwangi 1994
Mag. 7.5 EQ
250 casualties

Flores 1992, Mag. 7.5 EQ 2000

Source: BMKG
Local and Indigenous Knowledge in DRR

Indigenous knowledge:
- Methods and practices by group of people with advanced understanding of local environment
- Formed over generations of habitation.

Local and Indigenous knowledge and DRR: Through knowledge-sharing over generations, communities prepared to respond / recover from disaster.

Preparedness in cultural practices:
- Folklore, legends, stories and songs
- Building Structure
Smong: “When you feel the ground shake, the sea water receded, big wave may follows”

Simeulue Island, Indonesia

• In 2004 tsunami arrived in about 10 minutes after the earthquake;
• No knowledge of word “Tsunami” prior 2004;
• In 2004 only 7 people died out of approximately 78,000 people living in the island. 95% Living in coastal area;
• People living in island experience similar tsunami in 1907 and develop local and indigenous knowledge: Smong;
• Knowledge passed from generation through stories and remains of 1907 tsunami such as displaced coral etc;
Mentawai Islands, Indonesia

Earthquake and Tsunami 2010

- In 2004 tsunami arrived in about 7-10 minutes after the earthquake;
- Tsunami drills in several areas in Mentawai prior to 2010;
- In 2010, ~ 500 people died from EQ & Tsunami;
- Experienced EQ and tsunami in 1861
- Community has Indigenous song called Teteu that (assumed) to reminds people of earthquakes. Teteu: a word that has two meaning “earthquake” and “grandfather”

Teteu

Teteu amusiat loga
Teteu katinambu leleu
Teteu girisit nyau’nyau’
Amagolu’ teteu tae pelebuk
Arotadeake baikona
Kuilak pai-pai gou’gou’
Lei-lei gou’gou’
Barasita teteu
Lalaklak paguru sailet

Grandfather (earthquake), the squirrel is chattering
Grandfather (earthquake), noise comes from the hills
Grandfather (earthquake), land is sliding
Angry our grandfather (earthquake) seashell
The Baiko tree is cut
The Kuilak bird flaps its tail like a chicken
The chickens run away
Here comes Grandfather (earthquake)
Rumbling sound people hiding

The translation is based on the northern island verses of the song
Folklore, legends, stories and songs

<table>
<thead>
<tr>
<th>Smong</th>
<th>Teteu</th>
</tr>
</thead>
<tbody>
<tr>
<td>The meaning of <strong>the word “Smong”</strong> gives instruction: <strong>“When you feel the ground shake, the sea water receded, big wave may follows”</strong> and therefore the people moved to the hills.</td>
<td>The song does not gives any instruction only as reminder (assumed) to the people of an event (earthquake) that happened in the past.</td>
</tr>
<tr>
<td>The word become a part of a story that was told from generations, referencing to some remains of the 1907 tsunami.</td>
<td>The event (earthquake) were told as a part of a song that describes natural phenomena (assumed).</td>
</tr>
<tr>
<td>The telling of the Smong (story) was diminishing and was not told to children again before 2004.</td>
<td>Continue to be sung however, the word of Teteu was more toward the meaning of “grandfather” than “earthquake”.</td>
</tr>
<tr>
<td>In-depth study has been done on Smong.</td>
<td>No in-depth study was done on Teteu.</td>
</tr>
</tbody>
</table>

Photos by Eko Yulianto
Local Tsunamis: Lessons Learned

- **Know Natural Warnings.** Self-Evacuate - Don't wait. Walk, do not drive (stuck in traffic). Evacuate Vertically if there is no time.

- **Prepare before** the event – hazard zones, evacuation maps, signage, exercises, awareness

- **Long-term knowledge of traditional people** can be powerful in preparedness (e.g., Indonesia)

- Plan especially for essential for **Critical Facilities and Special Needs Populations - Hospitals, Tourists/Transient populations, Elderly, Schools**

- **Build hard countermeasures conservatively** - sea walls and water gates, vertical refuges
Local Tsunamis: Lessons Learned

- If local warning wanted, dense data network required. Network must be robust and/or redundant (broken instruments disable monitoring).
- The 1st Tsunami Warning is most important and should not underestimate. Possible later problems in transmission and understanding. Important to note trade-off between time and accuracy (fastest forecasts are least accurate).
- Expect at least 1 or more communication methods to go down. To ensure message receipt, implement redundant communications at all levels and between all stakeholders.
Lessons Learned - SCIENCE


- Slow earthquakes are possible, but currently not 100% diagnosible by TWC (e.g., 1992 Nicaragua, 2006 Java, 2012 El Salvador).

- Gigantic earthquakes are the most catastrophic, but where unknown and recurrence interval long (~100s-1000s years). Paleotsunami studies provide informative constraints.
Thank You

Laura Kong
Director, International Tsunami Information Center

Charles McCreery
Director, Pacific Tsunami Warning Center