# The value of expecting the unexpected: hazard awareness and the mitigation of tsunamis and megatsunamis in the absence of scientific consensus

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# A one-sided view of risk and decision-making: the risk equation as viewed by disaster science

Risk = hazard x vulnerability

Or

Risk = (hazard intensity-frequency function) x (vulnerability-hazard intensity function) x vulnerable exposure

# Why the differences to everyone else's view of risk? A valid reason and a dubious one I: the valid reason

- The hazard-causing phenomenon either:
  - Has no risk in its interaction with humanity (inanimate phenomena e.g. volcanic eruptions, tsunamis, landslides, hurricanes, fires)
  - Is unconscious of its risk (unconscious organisms e.g. diseases – smallpox was unaware of the risk of becoming extinct that was entailed by its interaction with humans)
- So, the distribution of risk and decision-making between the hazard phenomenon and humanity is extremely (entirely?) asymmetric or one-sided
- You can't win against these hazards in the sense of defeating them (except by exterminating them through attritional actions), in the case of disease organisms and other wild animals); you can only minimise your losses, maximise the gains from your risky behaviour, and avoid defeat* yourself

*Begged question: How can defeat (a term that is critical if not well understood in the context of conflicts between humans) be defined in the context of natural (and technological) disasters?

# II: the dubious reason

- Traditionally, the disaster (hazard) scientist or other disaster (hazard) professional is only listened to or called into action under a subset of the range of possible outcomes of a risk transaction
  - When the disaster has either happened or there are signs that it is about to happen, and the disaster management community is called into action
  - Usually by the ones who entered into the risk transaction (through, for example, development and land use decisions that put people in at- risk places) and are now demanding that its downside be minimized by some timely actions
- More recently, disaster scientists have also been called upon to limit (hedge) the range of possible negative risk outcomes by designing permanent mitigation measures or by setting up hazard monitoring and warning systems to enable responsive and anticipatory mitigation actions (at minimum cost to the positive risk outcomes, of course ……)
  - See Day & Fearnley (2015) for the definitions of permanent, responsive and anticipatory mitigation measures
- So, disaster (hazard) scientists have a very jaded view of risk …… we are usually only asked to address the downside of the one-sided risk transactions between humans and hazards

# The unfortunate consequences of this difference in ideas of risk

- Disaster scientists have problems when interacting with people who also see the upside of the risk transaction. Examples:
  - Farmers who persist in settling the flanks of volcanoes because of their fertile volcanic soils and reliable orographic rainfall
  - Fishermen who live on tsunami prone coasts, and the tourism industry that lives off the strange propensity of people to expose themselves to risks by lying around on beaches
- Disaster scientists rarely get credit for the avoidance of disasters that never happened because of their advice
  - and get blamed for spreading “unjustified” alarms about those possible disasters

“But there are even more mistreated heroes – the very sad category of those who were heroes, who saved our lives, who helped us avoid disasters …… we remember the martyrs who died for a cause that we knew about, never for those no less effective in their contribution but whose cause we were never aware of – precisely because they were successful”

Nassim Taleb, *The Black Swan*

# The value of expecting the unexpected

(Finally)

# Fatality percentages in tsunamis

- Fatality percentage (or ratio) in a tsunami: the proportion of the people who were in the inundation zone at the time of the tsunami who die
- Physical models of tsunami inundations and their effects indicate that as tsunami wave amplitude (intensity of hazard) increases, fatality percentage should also increase
  - The size of the "no escape zone", from which people who were there at the start of the event are physically unable to reach the limit of the inundation zone, increases as a proportion of the total inundation zone
  - The forces that the tsunami exerts on the human body increase with tsunami amplitude (flow depth and velocity), as do the intensities of other damaging effects (e.g. debris impacts, chances of drowning in flooded buildings)
- When we look at the fatality ratio distribution amongst uniform populations within individual tsunamis, the prediction of the dependence of fatality ratio upon tsunami intensity is broadly correct

Some example statistics on fatality percentages and wave amplitudes in tsunamis

[data from many studies, particularly by post-event tsunami survey teams in the case of recent events …… references on request]

# Ninigo Islands tsunami, Papua New Guinea, 1930

- Significant destruction on coasts up to 700 km from source
- Wave runups 5-24 m (measured by quantitative surveying of inundation limit points identified on the basis of eyewitness testimony in post event survey, 2005)
- Destroyed nearly every house in ~20 traditional coastal villages (estimated population ~3000, 150 per village living in ~20 houses)
- 12 people died (6 on atolls in the Ninigo Islands themselves, 6 at Sapara mission on the north coast of New Guinea)
- No fatalities at all in most villages where all the houses were destroyed
- **Fatality percentage ~0.4%**

# Solomon Islands (New Georgia) tsunami, 2007

- Tsunami wave runups 3-12 metres in damaged villages up to ~150 km from source
- ~6000 houses and other buildings destroyed or damaged (36000 people affected)
- 52 deaths, overall fatality percentage ~0.15%
- Fatality % in villages inhabited by Solomon Islands ethnic groups in the most-damaged area range 0% - 5%, with almost all < 1% (average ~0.3%)
- Fatality % in villages inhabited by Gilbertese migrants in same area range ~3-5 %, average 3.9%, despite only moderate tsunami runups in these villages
- Likelihood of a Gilbertese person dying in the tsunami >10 times greater than that of someone from one of the Solomon Islands ethnic group
  - Discrepancy even greater for children

# Other recent tsunamis in the SW Pacific

  - Santa Cruz Islands (Solomon Islands) 2013
  - Ambrym (Vanuatu) 1999
  - Samoa-Tonga 2009
- Similar patterns of extraordinarily low fatality percentages in traditional coastal villages
  - Despite non-existent or inoperative tsunami warning systems (only community-level and individual self warning)
- Sissano 1998, Papua New Guinea an (apparent?) exception:
  - ~2000 deaths
  - Fatality percentage on Sissano sandspit ~50%
  - Communities on the sandspit arrived there in preceding 100 years …… effectively, immigrants

# Sumatra (Indian Ocean) tsunami, 2004

- West coast of Aceh: 20-40 m tsunami runups ~30 minutes after source event, ~30-~100% fatality percentages in coastal communities
  - Arguably, physically inevitable given short time between earthquake and tsunami impact and great widths of “no escape zones”
- Thailand, Sri Lanka, SE India: 2-15 m tsunami runups, average fatality percentages 5-20%, locally up to nearly 100% (sandspits, again)
  - Tsunami runups comparable to SW Pacific examples, but fatality percentages one to two orders of magnitude higher
- Traditional coastal communities in the Andaman, Nicobar and Mentawai islands, with residence times of 100s to 1000s of years, suffered much lower fatality percentages than the more recent communities of the mainland coasts and the migrant and transient populations of tourist resorts

# Tohoku (Japan) tsunami, 2011

- Vast amount of data on both inundations and fatalities has been gathered and analysed (see especially work by Anawat Suppasri and colleagues at IRIDeS, Sendai), along with important evidence from survivor interviews (especially Ando et al., 2013)
- Overall pattern is of unexpectedly high fatality percentages despite huge investments in tsunami awareness education, tsunami warning system, tsunami evacuation shelters and permanent tsunami coastal defences

# Some trends in fatality percentages in the 2011 Tohoku tsunami:

- Long-established, small coastal communities that had experienced past tsunamis (most recent on the Sanriku coast: 1896, 1933) experienced fatality percentages 3-5 times lower than adjacent towns with historically recent growth and more immigrant and transient populations in the inundation zone
- Where tsunami defences were adequate and performed as designed, fatality percentages were comparable to those in the (unprotected) long-established small coastal communities
- Where tsunami defences failed, fatality percentages were amongst the highest of all at any given tsunami inundation height (even higher than in many communities without tsunami defences)
  - Interpreted in terms of a “false sense of security” …… but what does this mean and what processes are involved in creating increased vulnerability?

# Awareness and tsunami vulnerability: what is the strength of the connection?

- These recent events indicate that the small traditional communities of the SW Pacific, who experience frequent damaging tsunamis (as often as 1 / 50 years on any one stretch of coastline) have fatality ratios 1-2 orders of magnitude in individual tsunamis lower than those that occur in comparable tsunamis on coastlines that only experience such events with frequencies of 1 / 500 years or so
- **This means that the lifetime risk (probability) of dying in a tsunami for a person who lives on a coastline with tsunami frequency 1 / 500 years is more than that for a person who lives on a coastline where tsunami frequency is 1 / 50 years**

# The risk equation (of disaster science) is strongly non-linear

Risk = hazard x vulnerability

Or

Risk = (hazard intensity-frequency function) x (vulnerability-hazard intensity function) x vulnerable exposure

(e.g. high hazard reduces the strength of the vulnerability-hazard intensity function, or the size of the exposure, or both)

# Awareness and tsunami vulnerability: what is the mechanism of the connection?

- Note that in the SW Pacific and Andaman / Nicobar / Mentawai examples, only community self-warning operated on the time scales of the events – like the victims of the 2004 Indian Ocean tsunami, they did not have the benefit of tsunami warning systems
- Awareness of the hazard and of the actions for effective mitigation (rapid evacuation to high ground as a community) made the difference – but how?

# “Disaster Culture” in the SW Pacific

- Traditional knowledge of hazards and mitigation methods are passed from generation to generation by village elders (*Lapuns* in PNG) and other adults
- Beliefs (inductive knowledge) about hazards and their causes are embedded in culture
  - In the Schouten Islands in PNG, it was believed that tsunamis are summoned up by sorcerers’ spells, but that the spell is so powerful that it causes the ground to shake, so people are warned and the evil intents of the sorcerers are confounded
- This “disaster culture” is itself a part of a mindset of **“Constructive Paranoia”** (Jared Diamond, *The World Until Yesterday*) which means that people are ready to act on the slightest indication of danger, and insensitive to the costs of false alarms.