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Timothy H. Dixon
Excerpt
More Information

1 Black and White Swans, Communication, Evolution, and Markets

"What we've got here is failure to communicate."

Dialogue from the 1967 American film "Cool Hand Luke"

Japan's nuclear disaster of 2011 caused huge economic losses, not only for Japan, but for the world economy. While the earthquake and accompanying tsunami that caused problems at the Fukushima-Daiichi nuclear complex were unavoidable, the accompanying nuclear and financial meltdowns were not. Many geologists were aware of the possibility of large tsunamis in this part of coastal Japan, but engineers and government regulators did not consider the possibility of such high water or factor it into the plant's design. Backup power systems failed in the accompanying flood, leading to the overheating of fuel rods and a nuclear plant operator's worst nightmare, a core meltdown. The miscommunication between scientists and plant managers contributed significantly to the problems at the power plant, the resulting nationwide power interruptions, and the consequent factory closings and supply chain disruptions around the world. Although it is difficult to separate total losses from the earthquake and those due only to the nuclear plant, it is likely that the latter caused Japanese and global losses exceeding US $100 billion (all dollar amounts are in US currency unless otherwise indicated). In an increasingly complex and interdependent world economy, we can no longer afford such easily avoidable mistakes.

In 2007, Nassim Taleb published an influential book called *The Black Swan*. Taleb's basic premise is that in many human endeavors, we seek to manage risk by preparing for a range of possible bad events. These hypothetical "worst case" scenarios may be based on past experience, or expert predictions. While this approach works most of the time, every once in a while things go spectacularly wrong; the worst case event envisioned by planners was not nearly bad enough. Such events are sufficiently rare that they are difficult or impossible to predict, hence difficult or impossible to prepare for. Taleb refers to such events as "black swans," since most swans are white, and we come to expect the latter color. Many recent catastrophes – from the financial meltdown in 2008–2009 to Japan's earthquake, tsunami, and nuclear meltdown in 2011 – have been called black swans.

While some disasters may exemplify Taleb's black swans, I argue that many, at least the natural ones, should have been foreseen. While we can't stop an earthquake or a hurricane, we ought to at least be able to mitigate their worst effects through basic planning and better building. Earthquakes, tsunamis, and hurricanes usually occur in well-defined places for well-understood reasons. Some of the problems in New Orleans in 2005 and at Japan's Fukushima nuclear plant in 2011 have strikingly similar causes. Critical facilities in New Orleans lost power because backup generators or their control functions were in the basement or ground floor, easily knocked out by floodwaters. Similarly, backup power and certain control functions at the Fukushima power plant were sited at low elevations, susceptible to flooding. In both cases, many experts knew that flooding at these locations was possible.

If most swans are indeed white, we should be able to plan accordingly. Why we don't has a number of explanations, but two important ones relate to communication. First, while scientists have a pretty good understanding of the key processes that produce natural disasters, we are not always very good at communicating that understanding to the public and to policy makers. Our writing and speaking styles can be long-winded and verbose. We often violate Rule # 1 of *Elements of Style*, Strunk and White's classic treatise on clear writing. (Rule # 1 is "Use fewer words.") Second, government and policy experts, business, and the media are not particularly good at listening to scientists. As a result, scientific understanding of risk often fails to translate into effective government, business, or personal preparation. There are too many barriers between scientific knowledge and appropriate action.

One reason that it's hard to get the attention of the public and policy makers is that scientific understanding of process does not necessarily translate into predictive capability. It's tough to get everyone's attention if you can't come up with a clear "do something by this date" statement. Scientists could not predict the timing of the 2011 earthquake and tsunami in Japan or the strikingly similar events in 2004 in Sumatra. Scientists knew that large earthquakes and tsunamis were possible at these locations, but they could not say when they would occur. Given human nature, it is easier to act on threats perceived as immediate; long-term threats are often ignored. Being told that a major earthquake is likely within the next 50 years gives policy makers sufficient time to change building codes and the construction industry time to strengthen buildings, but often that knowledge does not translate into action. Political cycles are short, and next year's budget problems usually trump longer-term considerations. The same considerations often apply in business. The tenure of company CEOs has been getting shorter as investors demand quick profits. Better to leave those boring but costly infrastructure upgrades to one's successor.

In terms of the public's ability to listen, many natural phenomena (my preferred term for natural disasters) occur on time scales that are long when compared to typical human experience; they are off the radar screen for most people, even many scientists. A colleague trained in astronomy expressed surprise when I explained to him that he was involved in a project to build an astronomical observatory on a mountain in Mexico that was part of an active volcano. Although it had not erupted in several hundred years, there was no guarantee that it would not erupt again within the next 50 years, the lifetime of the instrument being designed.

To some extent, this lack of appreciation for long time scales reflects our evolutionary heritage. This means that two themes of this book are closely related: The less than superb communication skills of many scientists, combined with the innate human characteristic of focusing on short-term issues, means that non-scientists tend not to listen to our message, especially when that message involves long-term trends and long-term risks.

LONG-TERM RISK, LISTENING SKILLS, AND EVOLUTION

Most people know that it is not healthy to smoke too many cigarettes or eat too much junk food (foods high in sugar, salt, or fat). Too much smoking leads to lung cancer, while eating too much junk food can lead to obesity, diabetes, stroke, and heart attack. Both practices can lead to premature death. Yet businesses make huge profits every year selling cigarettes, junk food, and sugary drinks. They know that people can be relied upon to choose short-term pleasure despite long-term risk. We have a built-in "present bias."

Why do people discount or ignore long-term risk? There are a number of explanations, but I'm going to focus on one that I think is important, at least when applied to discussion and understanding of longer time scale Earth processes: human nature, bequeathed to us by millions of years of evolution. For most species, including our ancestors, survival depended on sensitivity to immediate surroundings and events. Even today, most of us are hardwired to be sensitive to things happening around us; we are not hardwired to be sensitive to change on longer time scales. As with any inherited trait, this reflects two sorts of selection pressures that influence evolution: survival selection and sexual selection. In terms of survival, when our ancestors wandered in the wilderness, hunting and gathering, they had to be acutely aware of their immediate surroundings and *changes* to their surroundings – survival depended on it. But not changes on time scales of decades or centuries. Changes on time scales of days or seconds were the things that mattered. Even when our ancestors turned to farming several thousand years ago, they mainly had to be sensitive to seasonal changes; longer-term processes were simply not important when life spans were shorter than 30 or 40 years. For most species, there is little survival advantage bestowed upon individuals who are sensitive to changes on decade or longer time scales – it just doesn't matter. To this day, a geologist talking about time scales of hundreds or millions of years to a room full of non-geologists is sure to be met with glazed eyeballs. In terms of sexual selection, let's be honest: The successful hunter of 100,000 years ago had a better chance of getting the girl than the guy who waxed eloquent about a volcanic eruption flattening the village years in the future.

We all have a tendency to focus on disasters – they are immediate, and more interesting. The media and the audience are unlikely to focus on examples of earthquakes and hurricanes where planning and well-designed buildings did their job of minimizing casualties and economic disruption; such events are not considered newsworthy. "If it bleeds, it leads" is the newsroom rule. The low- to no-impact examples are, nevertheless, important for us to consider, demonstrating that we can build smarter. Moderate to large earthquakes happen frequently in Japan, New Zealand, California, and Chile, and the well-designed and well-built infrastructure in these locations usually performs quite well. When things do go wrong, we can study the failure and improve things, whether it's the basic design, construction practice, or management. This is essentially the focus of this book. Many studies suggest that relatively modest changes in design and construction can improve survivability of infrastructure. I'll try to identify this "low-hanging fruit" in subsequent chapters.

On September 5, 2012, a magnitude 7.6 earthquake struck northwestern Costa Rica. Although this was a large earthquake, damage was not significant, and there were no fatalities (one person had a heart attack near the time of the earthquake, which may or may not have been earthquake-related). Part of the explanation for the lack of damage and minimal loss of life was that this earthquake was expected, at least in a general sense. Beginning in the 1990s, Costa

Rican seismologist Dr. Marino Protti began to publicize the fact that, given the past history of large earthquakes in this area, the probability of a similar event in the future was high. Although he did not predict an earthquake in any given year, he worked tirelessly to warn the public and government officials about the likelihood of large earthquakes and the importance of adequate building codes and preparation. The activist approach by Protti and his colleagues to earthquake preparedness had a significant impact on disaster mitigation in the region and is an indicator that it is possible to do better, even with limited resources.

Prior to catastrophe, it is difficult to get the attention of the media on natural hazards in the crush of other more immediate events. Science in general, and natural hazard planning in particular, are perceived to be less important than military or national security issues, not as exciting as the next sports match, not as sexy as the latest celebrity scandal. A geologist using public funds to dig trenches is more likely to be fodder for late night comics than a media darling, even if that trench contains clues to the last earthquake or tsunami, information that could save many lives and billions of dollars in avoided damage.

BOX 1.1 Digging trenches and studying dirt: The principle of superposition

How do geologists get information on past disasters if the events are too old to be described in history books? It turns out that nature leaves clues in the top few meters (10 to 15 feet) of the Earth's surface. By doing some detective work and studying surficial soil and sediments (the "dirt"), we can often piece together a sequence of events from the clues left behind. For example, geologists studying past tsunamis may dig a trench to look in cross section at layers of sediment that were deposited by the tsunami. The basic principle is "superposition," first enunciated by Danish scientist Nicolas Steno in the 17th century. This simple idea states that sediments on the

BOX 1.1 **(cont.)**

top are usually younger than sediments buried more deeply. By dating material lodged within a given disturbed layer with radio-carbon or other technique, it is possible to estimate the age of the last tsunami and, if several events are visible, get an idea of the frequency of these events. This is an incredibly valuable tool for hazard assessment and is one reason why geologists are so enamored of long time scales and digging trenches, as described in the next few chapters and Figure 4.1

COST OF DISASTERS AND THE ROLE OF MARKETS

If communication is part of our problem concerning natural disasters, how important is it to fix it? Experience shows it is hugely important. Consider losses associated with Japan's 2011 nuclear disaster. Total costs from the earthquake and tsunami will probably exceed $200 billion. Some of these costs were unavoidable, but costs associated with the nuclear accident (the avoidable part) will probably exceed $100 billion. These include the direct costs associated with cleanup, lost power and its replacement cost, and lost production in industries reliant on that power, as well as indirect costs related to future lawsuits or payments to individuals and businesses damaged in the disaster, lost economic opportunity associated with abandonment of the irradiated zone, lost economic opportunity by industries forced to close or reduce output after the disaster, and worldwide economic disruption. (In today's global economy, many factories around the world rely on products produced in Japan.) The accident affected the nuclear industry worldwide, making it more difficult to gain approval for new nuclear power plants, a blow to the reduced carbon energy strategy in some countries (Chapter 6). Germany decided to phase out nuclear power as a direct result of the Japanese accident. Natural disasters are expensive, not only in terms of injury and loss of life but also in damaged or destroyed infrastructure, lost business, and reduction in future economic growth. In a world experiencing increasing fiscal problems, we cannot afford to waste such large sums of money on preventable disasters.

Disasters are getting more expensive with time. Does this reflect increased disaster frequency (Figure 1.1), or are other factors at play? One factor contributing to the increased cost and frequency is population growth. In other words, even if disasters are occurring at the same rate, there are now more people in harm's way. Figure 1.2 shows US costs from natural disasters over the same period as Figure 1.1. Cost increased more than fivefold since 1980, during a period when US population increased by only about 35 percent. The difference reflects several factors, including the increasing percentage of population concentrated in vulnerable coastal areas

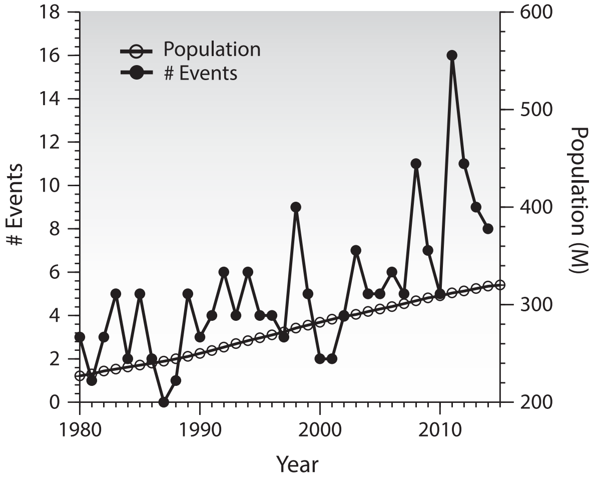

FIGURE 1.1 Number of weather-related disasters in the US whose cost exceeded $1 billion (left-hand scale), compared to the US population in millions (right-hand scale). The horizontal scale shows time for the years 1980 to 2014, the period when good data on disaster costs are available. Costs adjusted for inflation to 2015 dollars. Disaster data from National Atmosphere and Ocean Administration (http://www.ncdc.noaa.gov/billions/). Population data from World Bank.

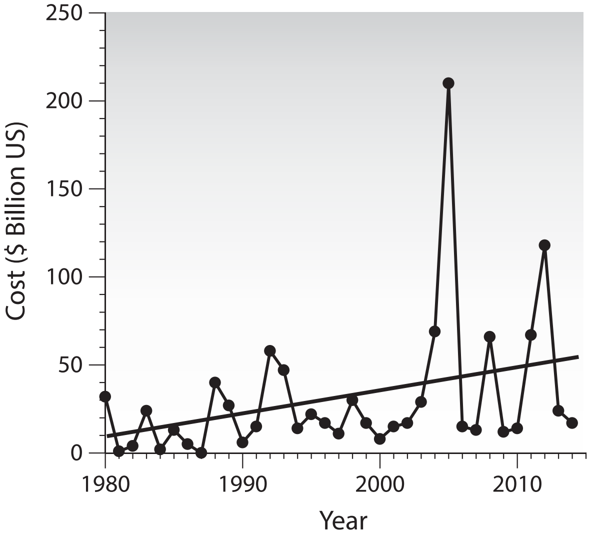

FIGURE 1.2 Cost of natural disasters in the US plotted against time (years from 1980 to 2104, the same period as Figure 1.1), adjusted to 2015 dollars. A best-fit line through the data is also shown. Data from NOAA.

that are susceptible to storm-induced flooding and tsunamis, often the costliest disasters. The value of coastal real estate and other coastal infrastructure has also increased significantly over this period. The intensity of storms may also be increasing (likely a consequence of global warming), which in turn increases the damage from a given storm (Chapters 7 and 8).

Different countries may have very different costs due to population growth trajectories (how fast their population is increasing) and their geography (for example, the amount of vulnerable coastline). The Philippines is especially susceptible to flooding from storm surge – it lies in the tropical typhoon belt and, being an island nation, has lots of coastline. It also has a rapidly growing population, with a large percentage living in vulnerable coastal areas.

Many low-lying coastal countries will be increasingly affected by sea-level rise and hurricane-related storm surge, so costs associated with these events are likely to continue rising. In the US, populations vulnerable to hurricanes and flooding include areas along the Gulf of Mexico and the Eastern Seaboard. In the tectonically active west coast of the US, large urban areas such as Los Angeles, San Francisco, and Seattle lie on or near earthquake-prone fault zones. Disasters in any one of these regions have the potential to deal a devastating blow to the US and global economy.

To illustrate the increasing cost with time, consider the recent US experience. In 2011, a record-breaking 16 disasters that exceeded the billion dollar cost threshold occurred, breaking the previous record (11 in 2008). NOAA estimates that the US experienced approximately $67 billion in damages from weather-related events in 2011 and nearly 1,000 fatalities from nine severe weather or tornado incidents, two flood events on the Mississippi and Missouri Rivers, one drought/heat wave, one winter blizzard, one wildfire, and two tropical storms and hurricanes, including Hurricane Irene. Munich Re, a global re-insurance firm that insures the insurance companies in the event of large losses, estimated 2011 costs in the US at $77 billion. This counts insured plus uninsured costs, and uses a slightly broader definition of disaster compared to the NOAA estimate. The year 2005 continues to hold the US record for total cost: approximately $200 billion according to NOAA. Damages from Hurricane Katrina alone exceeded $100 billion (Lott and Ross, 2006). Costs for 2012, totaling approximately $118 billion, include significant costs from a summer drought and heat wave (mainly agricultural losses and wildfires), and storm and flood damage from Hurricane Sandy in October. The biggest wildfire season on record occurred in 2015. Total costs since 1980 exceed $1 trillion.

If present trends continue, by 2050 the US can expect to incur an average annual cost of about $150 billion from weather-related disasters, with the occasional (possibly once per decade; the exact frequency cannot be known) loss of half a trillion dollars. To paraphrase