What was the deadliest natural catastrophe?

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Intro

Knowing what kind of catastrophes humanity has suffered in the past may provide us with some insight into how likely we are to experience them in the future. Unfortunately, existing work on the frequency and severity of past catastrophes is scattered across multiple sources which vary in reliability. In this document, I review the existing evidence on how many people were killed by three past historical events–the Black Death, the Plague of Justinian, and the Spanish Flu–as well as two, unknown pre-historic events. I compare these figures to estimates of global population to suggest which event killed the largest proportion of humanity at the time.

Contenders

In order to arrive at a preliminary list of contenders, I used Wikipedia's List of natural disasters by death toll (Wikipedia, 2022). From each sub-list, I collected natural events that were listed as having caused more than one million deaths. Since I'm interested in finding the event that killed the largest proportion of the population at the time, I divided the highest estimate of the death toll for each event by world population at the time. Population data came from Our World in Data (Our World in Data, 2022). The ten deadliest events by this measure are listed in the table below.

Event	Years	% world killed (Wikipedia's highest)	% world killed (best estimate)
Black Death	1346-1353	44%	10%
Plague of Justinian	541-542	24%	0.6-4.4%

Spanish Flu	1918-1920	10%	0.9%
Great European Famine	1315-1317	1.9%	
Chinese famine	1906-1907	1.45%	
Chalisa famine	1783-1784	1.35%	
Antioch earthquake	526	0.4%	
China floods	1931	0.2%	
Shaanxi earthquake	1556	0.18%	
Yellow River flood	1887	0.12%	

In the rest of this post, I focus on just the top 3 disasters from table X. Only those three affected the entire world, or a large region of it. I have found that Wikipedia estimates of the death tolls tend to be too high, rather than too low, so I'll use the numbers above as rough upper bounds. These tend to be almost one order of magnitude higher than the best estimates available, as I explain below. Since the Wikipedia estimates of the death tolls of the remaining catastrophes are significantly lower than my best estimates for the death tolls of the top three, it seems safe to exclude them from the rest of my analysis.

Black Death

Between 1346 to 1353, it's estimated that somewhere between a quarter and two-thirds of all Europeans died from the bubonic infection of the bacteria *Yersinia pestis* (Benedictow, 2021, p. 875; Byrne, 2012, p. 108; Hays, 2005, p. 43; Ziegler, 2013, p. 231). That is a wide range. Unfortunately, it is hard to be more specific. A classical source on the subject summarises the uncertainty: "To maintain that one European in three died during the period of the Black Death can never be proved but, equally, cannot be wildly far from the truth. Further than that, in the present state of knowledge, one cannot go" (Ziegler, 2013, p. 231).[1]

The global death toll is even more uncertain, but something around 10% is a reasonable guess. Wikipedia's upper bound of 44% seems nearly impossible. A third of all Europeans was 5.5% of the world population at the time (Byrne, 2012, p. 108; Goldewijk et al., 2017). But records are scarce for the Middle East and North Africa, and nearly absent for Asia. One expert estimates one-third of Syria and Egypt died (Dols, 2019, pp.

[1] Recent estimates tend to be on the higher end of the a quarter to two-thirds range. Benedictow's two-thirds attracted some controversy initially but it has come to be regarded as one of the most well-researched estimates, with a very minute analysis of a plethora of direct historical sources listing death tolls.

218–223). If we assume all of the Middle East and North Africa experienced the same mortality rate, then we can add an additional 1.5% of the world population to the death toll (Goldewijk et al., 2017).

Although we have few records of the plague in Asia (Sussman, 2011), the consensus is that that's where it originated. It seems likely then that Asia, which had over half of the world population at the time, was also hit hard. For example, if China alone experienced the Black Death and had a death rate half as bad as Europe's, another 3% of the world would have died (Goldewijk et al., 2017). Thus, this relatively conservative estimate adds up to 10% of the world population. The actual toll is probably slightly higher or lower than this, of course. Luke Muehlhauser's literature review on the subject arrived at an estimated global death rate of 5-15% (Muehlhauser, 2017).[2]

The Plague of Justinian and the First Plague Pandemic

Wikipedia lists three sources for its Plague of Justinian's death tolls. Each is a secondary source and counts deaths over a period longer than the years 541-542.[3] It's somewhat difficult to know how exactly to define a 'catastrophe' in this case. The Plague of Justinian was actually just phase one of the First Plague Pandemic, which started in 541, likely peaked a year later in Constantinople, and ended in 750. Although it seems unlikely that it could rival the Black Death's mortality rate, Wikipedia's estimate of 24% worldwide mortality is high enough to make this plague a contender. I looked into an unlikely, worst-case scenario by assuming that every area affected by the First Plague Pandemic was affected equally badly. My rough estimate, detailed below, assumes the plague had a 20% mortality rate and affected 20% of the world population, suggesting a global mortality rate of 4%. This estimate–which again, is almost certainly too high–is still lower than Muehlhauser's lowest estimate for the Black Death's death rate of 5%.

The historical consensus is that the hardest-hit place during the Plague of Justinian was Constantinople in 542 (Hays, 2005, p. 23; Rosen, 2010, p. 17; Stathakopoulos, 2008, 2017). However, actual mortality figures are highly uncertain: official records were lost and most anecdotal accounts seem exaggerated. One leading expert's best guess, after correcting a previous erroneous model, is that there were "about 80,000 victims (or 20 percent of the population and roughly about 880 victims a day)" (Stathakopoulos, 2017,

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[2] His low estimate assumes no deaths in Asia, which seems unlikely to me.

[3] For instance, of the three listed sources one states: "By the time Justinian's plague had run its course in AD 590, it had killed as many as 100 million people" (Maugh, 2002); and a second: "the Plague of Justinian, to give both pandemic and emperor their names, killed at least twenty-five million people; depopulated entire cities; and depressed birth rates for generations" (Rosen, 2010, p. 3). But it couldn't have depopulated several cities and have a generational effect just within two years as it doesn't spread that fast. Rosen (2007) later states "the range of deaths during the critical three months of 542 can be calculated at anywhere from sixty thousand to two hundred thousand." (p. 210).

p. 140).[4] He states that the plague eventually spread everywhere across Europe, North Africa and the Middle East, though reports of its effects outside the Byzantine Empire are even less reliable.

To estimate the total number of deaths caused by this plague, we can multiply its estimated mortality rate by the total number of lives it affected over time in the areas it spread. The 500 AD total population of Europe, North Africa, and the Middle East was 54 million; about 21% of the world population.[5] The Population Reference Bureau's demographic model suggests that 26.59 billion births took place globally between the years 1 AD and 1200 AD period (Kaneda & Haub, 2021). Population was mostly steady in these regions (barring Western Europe, where population doubled) during this time. Plus, most plague deaths likely occurred within the first half-century. Therefore, I will make the simplifying assumption that 21% of these births were in the affected regions.

The pandemic lasted for about 17% of the 1-1200 AD period, so it could have affected slightly under 1 billion lives. Still, even if we make the further unrealistic assumption that the plague was in full force throughout these regions, and we ignore high early childhood mortality, this Plague would have killed 200 million people out of the 4.5 billion born within that period.[6] That suggests a global mortality rate of 4.4%.

But, given all our assumptions, this is surely too high. If we instead use Wikipedia's death toll of 30-50 million we get just 0.6-1% worldwide mortality. On the whole, it seems unlikely that the Plague of Justinian is a strong contender for the title of deadliest natural catastrophe.

Spanish Flu

The latest expert estimate of the Spanish Flu's death toll is that it killed 17.5 million people between 1918 and 1919, corresponding to only 0.92% of the 1918 world population (Spreeuwenberg et al., 2018). The highest death toll in the literature is 100 million, which suggests a 5.26% worldwide mortality (Johnson & Mueller, 2002). Methodological decisions such as which reference year to use and whether to use age-specific mortality explain some of the variation in these estimates. However, this latest study demonstrates that anything above 25 million would require implausible assumptions. For instance, it would require that mortality was highest among children, which is contrary to empirical data everywhere outside India (Spreeuwenberg et al., 2018, p. 2565), and that censuses around the world failed to register the population

[4] A good overview of past erroneous figures can be found in Rosen (2007, pp. 209-210).
[5] N. Africa: 7,970,300; W. Europe: 20,642,314; C. Europe: 5,199,620; Turkey: 5,500,012; Middle East: 14,590,841; World: 253,237,587 (Goldewijk et al., 2017).
[6] Even in the worst-hit Byzantine Empire the pandemic was not at full force everywhere (Mordechai et al., 2019).

decline implied by such figures (Spreeuwenberg et al., 2019; Spreeuwenberg, personal correspondence, August 18, 2021). Moreover, 100 million was the upper end of a huge *ad hoc* upwards adjustment to previous research that actually estimated a death toll of 50 million (Johnson & Mueller, 2002).[7]

Pre-historic population bottlenecks

Recorded history provides no plausible contender for the Black Death. I will now look into plausible pre-historical population bottlenecks from genetic studies. Although none of these events could have caused as many deaths as the Black Death, they may rival it in proportional terms because the global population was so much smaller.

But first, a bit of background on the methods used by these studies.[8]

Suppose you have an urn with ten balls, eight red and two blue. To simulate random selection, you pull one random ball, note its colour, put it back in the urn and select another ball. You repeat this until you've drawn ten balls total. The colours you've drawn are used to set the colour distribution of the next generation. For each draw, there is an 8 in 10 chance the ball is red. The cumulative chance the next generation will be entirely red, given by multiplying the chance of red in all ten draws, is slightly over 1 in 10. But suppose there was a sudden drop in population, such that the next generation consists of only five balls. The chance of an entirely red generation is now almost 1 in 3. Moreover, if there were many different colours, the distribution will shift towards a single colour over many generations even without a population drop, but will do so at a slower rate. (See also this didactic simulation from the University of Arizona.)

Certain genes are not subject to strong selective pressures and fluctuate randomly in the population, just like the successive generations of blue and red balls. Suppose there are two possible variants of one gene. As in our urn example, when a population undergoes a drastic size reduction, there's an increased probability that one variant will be lost because most population members will have no offspring (Charlesworth, 2009; Husemann et al., 2016; Plutynski, 2007; Wang et al., 2016). As we will see, genetic studies reveal that human populations have much less genetic diversity than would be expected if we had simply had constant growth since the first humans evolved. In other

[7] After compiling death tolls across the globe totalling close to 50 million, the article's last paragraph states: "Global mortality from the influenza pandemic appears to have been of the order of 50 million. However, even this vast figure may be substantially lower than the real toll [...] the real pandemic mortality may fall in the range of 50 to 100 million" (Johnson & Mueller, 2002, p. 115). No justification was given for the 100 million upper bound.

[8] This field is particularly technical and complex. I will present simplified explanations. I will not address the biases and their corrections involved in these methods. For instance, some methods will produce skewed results as they get close to the first human generation because simulations often make a few simplifying assumptions such as having only one couple at first and a sharp cut-off point between other hominids and *Homo Sapiens*. One may simply ignore these results as statistical artefacts.

words, there were probably large reductions in population size at some point in our history.

Geneticists use several other methods to infer past demographic changes. For instance, the number of generations it would take with a constant mutation rate for current allele diversity to have evolved from a homogenous population is known as the coalescence time (Charlesworth, 2009). Coalescence time is also highly sensitive to changes in population size, decreasing drastically after a bottleneck.

In all such models, only the population that contributes to genes in the next generation is considered; this population is called the *effective population size* and is generally smaller than the actual census population (Allaby, 2020; Frankham, 1995; Yu et al., 2004). It remains the case that a drop in the effective population size will cause a decline in the population contributing to genes in succeeding generations.

Although still uncertain, there is high-quality recent genetic evidence, and modest consensus among researchers, that a large population bottleneck happened tens of thousands of years ago. It may have reduced the effective human population size by 40-90% outside Africa (Marth et al., 2004; Osipov et al., 2021; Voight et al., 2005; Weaver & Roseman, 2008; Williams, 2012).[9] The Toba supervolcanic eruption, which happened 74,000 years ago, has been proposed as the cause. While that theory is considered plausible, it's far from a certainty.[10] I found only one very recent study against the Toba hypothesis. That paper concedes that a population bottleneck very likely occurred, but argues its timing doesn't coincide with the Toba supervolcano (Yost et al., 2018).[11] In any case, while the bottleneck's exact date is uncertain and it occurred across hundreds of generations, it would still be the closest we ever came to extinction. And even if it wasn't the Toga supervolcano, its cause was almost surely natural.

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[9] It's worth noting that the existence of a bottleneck has been disputed by some studies (Gathorne-Hardy & Harcourt-Smith, 2003; Hawks et al., 2000; Weaver & Roseman, 2008), but it is supported by the weight of the evidence.

On dating the bottleneck, a review says "about 50,000 years ago" (Weaver & Roseman, 2008). The most comprehensive study I could find considers a wide-range of parameters, with scenarios that range from 20,000 to 120,000 years ago. Their two best-fitting models start at 90,000 and 87,500 years ago (Voight et al., 2005). A range of 20,000-120,000 correctly reflects the high uncertainty in these models and might suggest a 70,000 central figure, but few possible parameters were compatible with the extreme ends of this range.

[10] For dating see Chesner et al. (1991) and Roberts et al. (2013). See my larger compilation of sources for and against the Toba bottleneck hypothesis here: Quick assessment of a ~Toba population bottleneck hypothesis

[11] This paper also seems to suffer with several issues, see additional comments here.

There is one other contender for the most deadly pre-historic catastrophe. At least four recent genetic studies, so far unopposed, indicate the existence of a second population collapse: a male-only population bottleneck at around 10,000 BC (Batini et al., 2015; Karmin et al., 2015; Poznik et al., 2016; Zeng et al., 2018). The initial study found a reduction of 60-80% in the global male effective population size (Karmin et al., 2015, fig. S4B), which suggests a 20-25% reduction in the overall effective population size. That's higher than the highest estimate of the Black Death's mortality rate of 17%. However, the main tentatively proposed cause was anthropogenic: endemic wars between early settlements.[12] Moreover, these studies have not yet been closely scrutinised by sceptics. And, without a similar reduction in the female population, it's unlikely we risked extinction even with a 90% fall in the male population.

Still, this event would constitute a larger percentage death toll than the Black Death, and it *might* have had natural causes.

Conclusion

With the caveat that the two prehistoric examples are highly uncertain, the best candidates for the top five deadliest natural catastrophes in the natural history of our species are listed below. I've also added mortality rates for the COVID-19 pandemic, as of April 2022, for comparison.

Event	Years	Est. % world killed
Likely the Toba supervolcanic eruption	88,000-48,000 BC	40-90%
?????	10,000-7,000 BC	Up to 20-25%
Black Death	1346-1353	10%
First Plague Pandemic	541-750	0.6-4.4%
Spanish Flu	1918-1920	0.9%
COVID-19 Pandemic	2019-2022	0.08-0.26%[13]

[12] Sexual selection from surviving females mating with winning males playing as much of a role as war deaths. Interestingly, the regional onset of this bottleneck tracks the onset of intensive agriculture which enabled large permanent settlements (compare Karmin et al., 2015, fig. S4B; Stephens et al., 2019, fig. S2). Intensive agriculture, as opposed to early extensive agriculture, is characterised by the use of domesticated animal and plant species, specialised agricultural tools such as the plough and sickle, and techniques such as irrigation

[13] Using the 14 April 2022 total reported and estimated from excess deaths (Economist, 2022).

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