Measuring the Mortality Impacts of Climate-related Disasters

Counting Cases and Estimating Excess Deaths

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Ideal vs. observed information

Ideal vs. observed information

"All the business of war, and indeed all the business of life, is to endeavor to find out what you don't know by what you do; that's what I called 'guess what was at the other side of the hill'."

–Attributed to the Duke of Wellington

Role of epidemiology in disasters

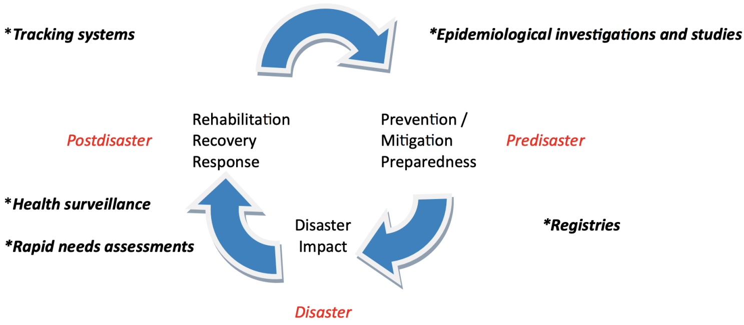


FIGURE 2—Disaster epidemiology actions and the disaster management cycle.

Source: Malilay et al., 2014, "The Role of Applied Epidemiology Methods in the Disaster Management Cycle", *American Journal of Public Health*

A disaster's mortality impact

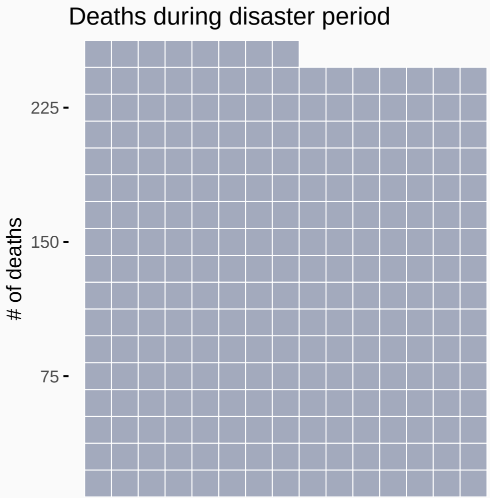
Following a disaster, we are interested in determining the number of deaths that occurred in the disaster-affected area that would not have occurred **but for** the disaster.

4. If this disaster had **NOT** occurred, would this decedent still be alive?	
If yes --->	Return to question #1 to re-evaluate.
If no, this death is **NOT** disaster-related.	If, after re-evaluation, status of this case is still uncertain, set it aside as a death that is ***possibly*** related to the disaster. Do **NOT** include this case on the Classification and Coding Matrix.

Last question on a flow chart for determining and classifying disaster-related deaths.

Source: Combs et al., 1999, "Assessing disaster-attributed mortality: Development and application of a definition and classification matrix", *International Journal of Epidemiology*

Mortality information from a disaster

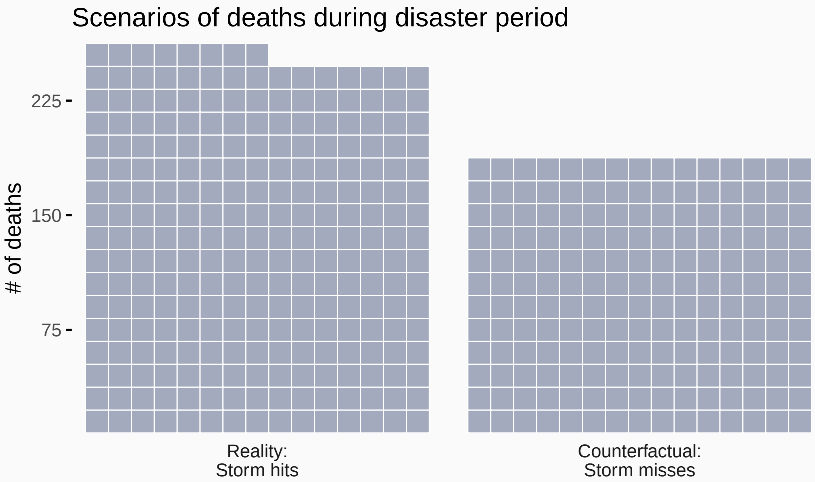


Each square represents a death during the disaster period in a disaster-affected community.

A disaster's mortality impact

Source: AccuWeather

Ideal information



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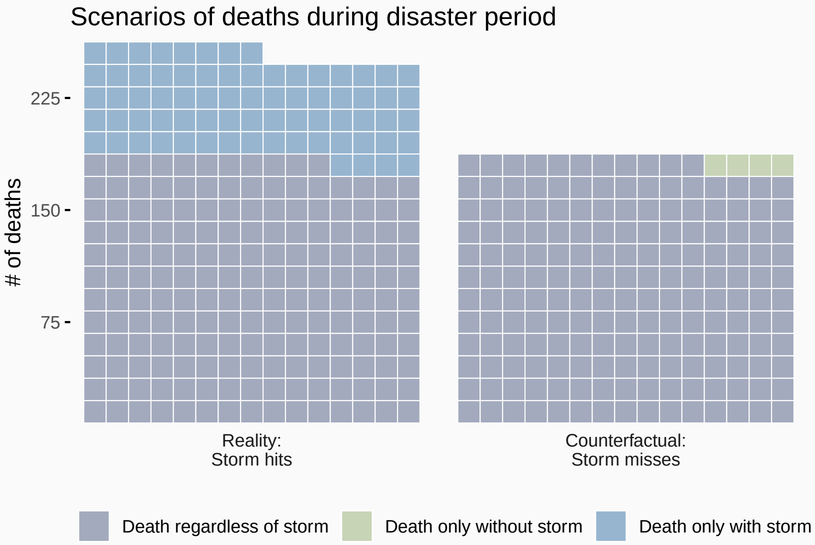

Figuring out what you don't know from what you do

"All the business of war, and indeed all the business of life, is to endeavor to find out what you don't know by what you do; that's what I called 'guess what was at the other side of the hill'."
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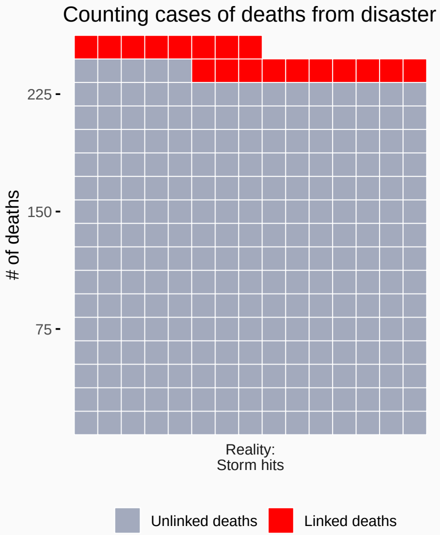
1. **Counting cases** of disaster-attributable mortality
2. **Estimating excess** community-wide mortality during the disaster period compared to the counterfactual that the disaster didn't happen

Counting cases

Counting cases



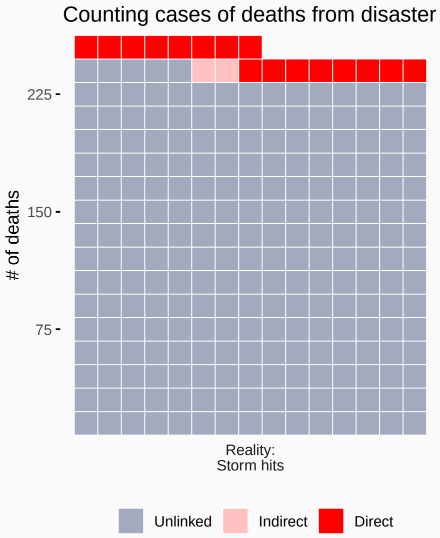
Investigate each death, case-by-case. Use information from the death certificate and other sources to determined if that specific death can be linked to the disaster.

Direct and indirect deaths

- **Direct deaths:** "Caused by environmental forces of the hurricane and direct consequences of these forces."
- **Indirect deaths:** "Caused by unsafe or unhealthy conditions because of loss or disruption of usual services, personal loss, or lifestyle disruption."

Source: Issa et al., 2018, "Deaths Related to Hurricane Irma — Florida, Georgia, and North Carolina, September 4–October 10, 2017", *Morbidity and Mortality Weekly Report*

Direct and indirect deaths



Investigations of each case can help determine if the death was directly or indirectly attributable to the disaster.

US CDC Morbidity and Mortality Weekly Report

For many American disasters, results from this approach are reported in the US CDC's Morbidity and Mortality Weekly Report (MMWR).

CENTERS FOR DISEASE CONTROL

July 3, 1981 / Vol. 30 / No. 25

MMWR

MORBIDITY AND MORTALITY WEEKLY REPORT

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Epidemiologic Notes and Reports

Kaposi's Sarcoma and *Pneumocystis* Pneumonia Among Homosexual Men – New York City and California

During the past 30 months, Kaposi's sarcoma (KS), an uncommonly reported malignancy in the United States, has been diagnosed in 26 homosexual men (20 in New York City [NYC]; 6 in California). The 26 patients range in age from 26-51 years (mean 39 years). Eight of these patients died (7 in NYC, 1 in California)—all 8 within 24 months after KS was diagnosed. The diagnoses in all 26 cases were based on histopathological examination of skin lesions, lymph nodes, or tumor in other organs. Twenty-five of the 26 patients were white, 1 was black. Presenting complaints from 20 of these patients are shown in Table 1.

Skin or mucous membrane lesions, often dark blue to violaceous plaques or nodules, were present in most of the patients on their initial physician visit. However, these lesions were not always present and often were considered benign by the patient and his physician.

A review of the New York University Coordinated Cancer Registry for KS in men under age 50 revealed no cases from 1970-1979 at Bellevue Hospital and 3 cases in this age group at the New York University Hospital from 1961-1979.

Seven KS patients had serious infections diagnosed after their initial physician visit. Six patients had pneumonia (4 biopsy confirmed as due to *Pneumocystis carinii* [PC]), and one had necrotizing toxoplasmosis of the central nervous system. One of the patients with *Pneumocystis* pneumonia also experienced severe, recurrent, herpes simplex infection; extensive candidiasis; and cryptococcal meningitis. The results of tests for cytomegalovirus (CMV) infection were available for 12 patients. All 12 had serological evidence of past or present CMV infection. In 3 patients for whom culture results were available, CMV was isolated from blood, urine and/or lung of all 3. Past infections with amebiasis and hepatitis were commonly reported.

TABLE 1. Presenting complaints in 20 patients with Kaposi's sarcoma

Presenting complaint	Number (percentage) of patients
Skin lesion(s) only	10 (50%)
Skin lesions plus lymphadenopathy	4 (20%)
Oral mucosal lesion only	1 (5%)
Inguinal adenopathy plus perirectal abscess	1 (5%)
Weight loss and fever	2 (10%)
Weight loss, fever, and pneumonia (one due to *Pneumocystis carinii*)	2 (10%)

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES / PUBLIC HEALTH SERVICE

Hurricane Floyd, 1999

In September 1999, Hurricane Floyd caused extensive damage—especially from widespread flooding—in eastern North Carolina.

Source: US Army Corps of Engineers

Hurricane Floyd, 1999

in May 2000, a report on the storm's health impacts in North Carolina, including attributable mortality, was published in the CDC's MMWR.

TABLE 1. Deaths related to Hurricane Floyd, by cause of death — North Carolina, 1999

Cause of death	Number*	(%)
Drowning	36	(69)
In motor vehicle	*24*	
In boat	*7*	
As pedestrian	*4*	
In house	*1*	
Motor-vehicle crash (excluding drowning)	7	(13)
Myocardial infarction	4	(8)
Fire (burns and trauma from escape attempts)	2	(4)
Hypothermia	1	(2)
Electrocution	1	(2)
Fall	1	(2)

*n=52.

Source: US CDC, 2000, "Morbidity and Mortality Associated With Hurricane Floyd—North Carolina, September–October 1999", *Morbidity and Mortality Weekly Report*

Hurricane Floyd, 1999

> *"The medical examiner determined that 52 deaths were associated directly with the storm. Decedents ranged in age from 1 to 96 years (median: 43 years); 38 (73%) were males. . . . Seven deaths occurred during transport by boat; flotation devices were not worn by any of the decedents."*

Source: US CDC, 2000, "Morbidity and Mortality Associated With Hurricane Floyd—North Carolina, September–October 1999", *Morbidity and Mortality Weekly Report*

Hurricane Katrina, 2005

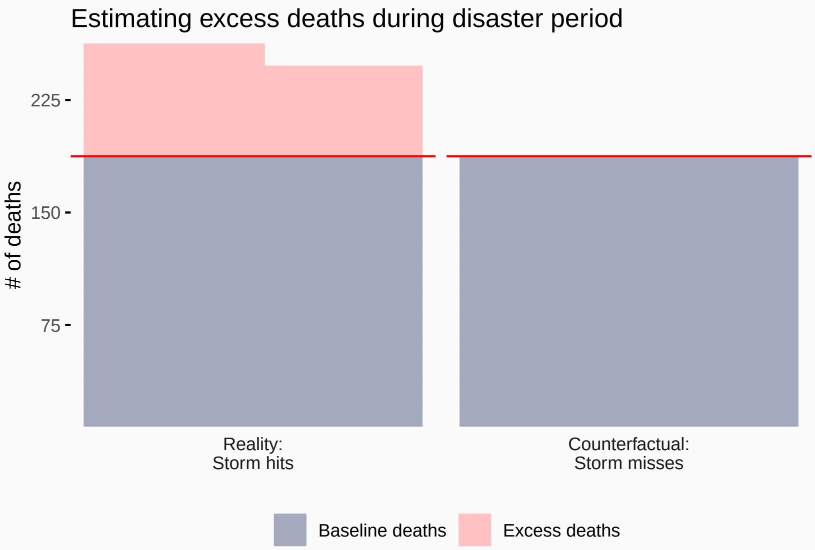
TABLE. Number of deaths directly, indirectly, or possibly related to Hurricane Katrina, by cause of death — selected counties,* Florida and Alabama, August–October 2005

	Florida					Alabama			
Cause of death	Direct	Indirect	Possible	Total	(%)	Indirect	Possible	Total	(%)
Drowning	3			3	(21)	1		1	(4)
Car collision		3†		3	(21)	1		1	(4)
Hit by falling tree limb	2	2		4	(29)				
Carbon monoxide poisoning		2		2	(14)				
Fall from ladder		1		1	(7)				
ASCVD§						6	3	9	(38)
Chronic alcoholism						1		1	(4)
Sepsis						1		1	(4)
Seizure						1		1	(4)
Other CNS¶ disease						1		1	(4)
Traumatic brain injury						1	1	2	(8)
Homicide (gunshot wound)							3	3	(13)
Suicide						1	1	2	(8)
Asphyxia						1		1	(4)
Undetermined			1	1	(7)		1	1	(4)
Total	**5**	**8**	**1**	**14**		**15**	**9**	**24**	

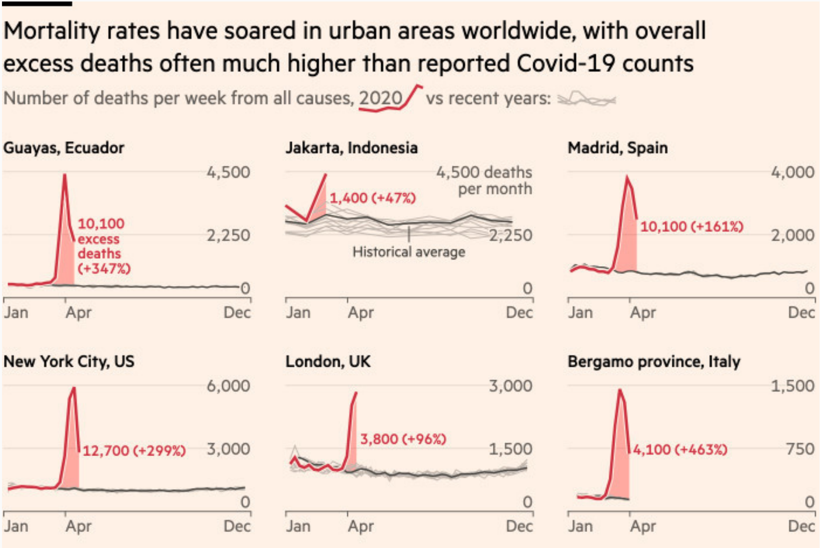
Source: US CDC, 2006, "Mortality Associated with Hurricane Katrina — Florida and Alabama, August–October 2005", *Morbidity and Mortality Weekly Report*

Estimating excess mortality

Estimating excess mortality

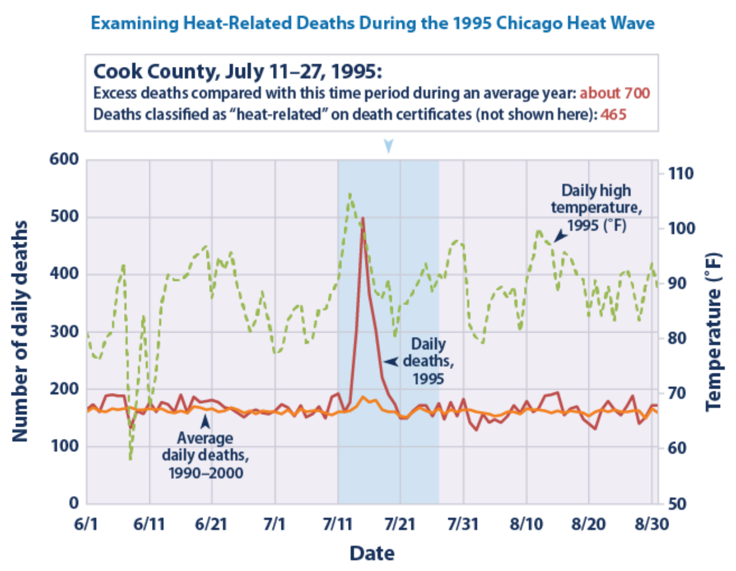


Covid-19



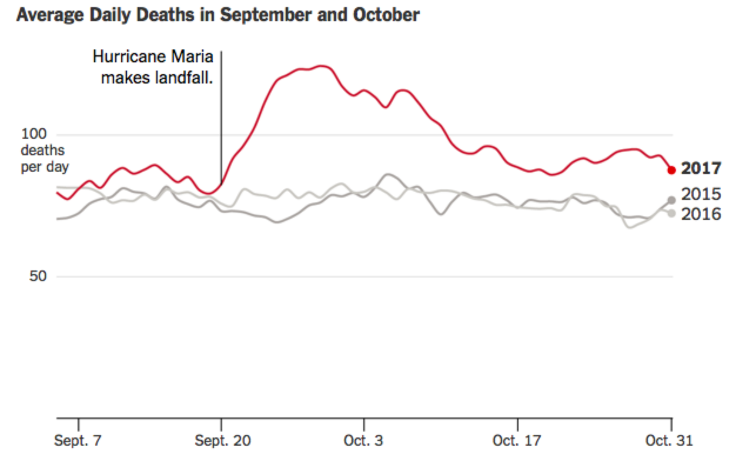
Source: Financial Times

1995 Chicago heat wave



Source: US EPA, "Climate Change Indicators in the United States: Heat-Related Deaths"

Hurricane Maria, 2017



Source: New York Times

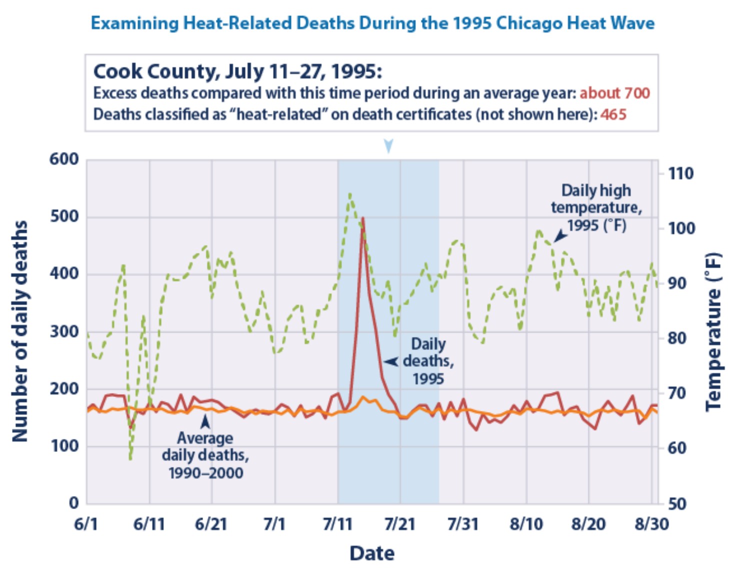
2012 Beijing flood

"We compared community-wide mortality rates on the peak flood day and the four following days to seasonally matched nonflood days in previous years (2008–2011), controlling for potential confounders, to estimate the relative risks (RRs) of daily mortality among Beijing residents associated with this flood."

Sources: Yan et al., 2020, "Community-wide Mortality Rates in Beijing, China, During the July 2012 Flood Compared with Unexposed Periods," *Epidemiology*; CNN

Comparing measurements from the two methods

1995 Chicago heatwave



Source: US EPA, "Climate Change Indicators in the United States: Heat-Related Deaths"

2012 Beijing flood

> *"For the flood period of 21–22 July 2012, we estimated a total of 79 excess deaths among Beijing residents; by contrast, only 34 deaths were reported among Beijing residents in a study using a traditional surveillance approach."*

Source: Yan et al., 2020, "Community-wide Mortality Rates in Beijing, China, During the July 2012 Flood Compared with Unexposed Periods," *Epidemiology*

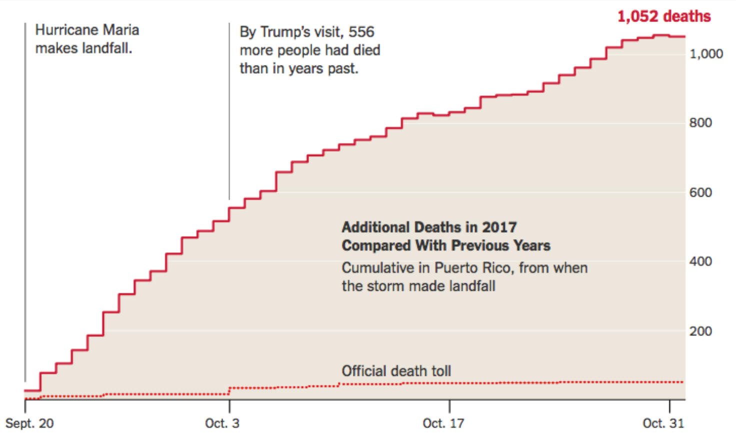
2004 Florida hurricane season

Comparison of observed storm-dependent mortality and official mortality for the 2004 hurricane season in Florida

	Charley	Ivan	Frances/Jeanne
Period of increased mortality (days)	62	47	59
Average deaths/day during 2004	36.3	12.5	70.5
Expected deaths per day	32.5	10.3	63.7
Deaths above expected	133	90	401
Official death count	37	39	68
% explained by official death count	28	40	17

Source: McKinney et al., 2011, "Direct and indirect mortality in Florida during the 2004 hurricane season," *International Journal of Biometeorology*

Hurricane Maria, 2017



Source: New York Times

Comparing measurements

A protest in Puerto Rico in June 2018 highlights one estimated death toll for Hurricane Maria.

XAVIER GARCIA/BLOOMBERG/GETTY

DEATH COUNTERS

When scientists tallied how many people perished in Hurricane Maria and other crises, they battled statistical, political and physical hurdles. But new methods are in the works.

BY CARRIE ARNOLD

In the pale predawn hours of Old San Juan last February, Neysha Burgos-Nieves and Hector Rosado loaded a battered black car with everything they might need for a few days — from bottled water and protein bars to flashlights and a change of clothes. Their first stop was more than two hours away, high in Puerto Rico's isolated central mountains. Although it had been more than four months since Hurricane Maria had slammed into the island in September 2017, much of the US territory remained without electricity, water or mobile-phone service. If Burgos-Nieves and Rosado ran into trouble once they left the relative safety of San Juan, the two research assistants would be on their own.

Their goal was simple, if ambitious: calculate the excess mortality from Hurricane Maria. In other words, determine how many people perished in the months following the storm and subtract the number of people who, on average, probably would have died anyway. Burgos-Nieves, Rosado and their adviser Domingo Marqués, a clinical psychologist at Carlos Albizu University in San Juan, had no idea what that estimate might be. But anyone who had spent time in Puerto Rico knew that the excess deaths were much higher than the government's official count of 64.

It was gruelling work. Many of the researchers in Marqués's team had lost electricity, water and, in some cases, their homes. Nearly all admit to breaking down in tears at least once. "Every day, you would hear more stories of suffering. It was exhausting," Rosado says.

But the project held a deeper meaning than simply counting those who had died. "We were giving light where there was a lot of darkness. We gave light to the truth," Burgos-Nieves says.

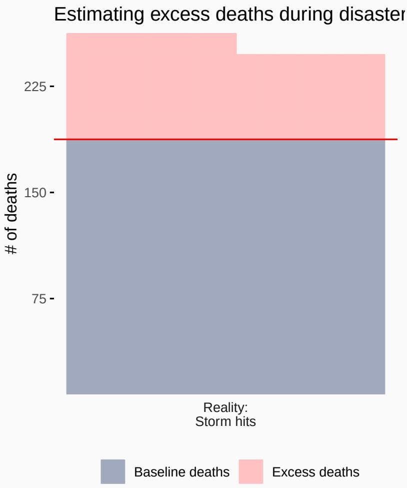
Throughout history, humanity has lurched from one disaster to the next. Some are born of nature's capriciousness; others arise from

Normally, mortality counts are the function of governments, which collect death certificates and keep the public informed. A death toll should theoretically be as straightforward as tallying those who have perished. Nothing about disasters, however, is simple.

Source: Arnold, 2019, "Death Counters," *Nature*

Complementary approaches

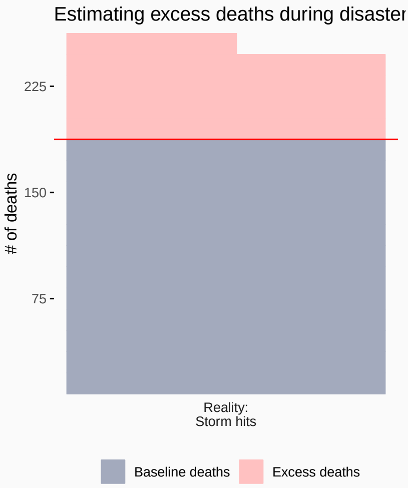
Estimating excess—methodological objective



Strength:

Minimize *error* in estimating number of excess deaths.

Estimating excess—methodological objective



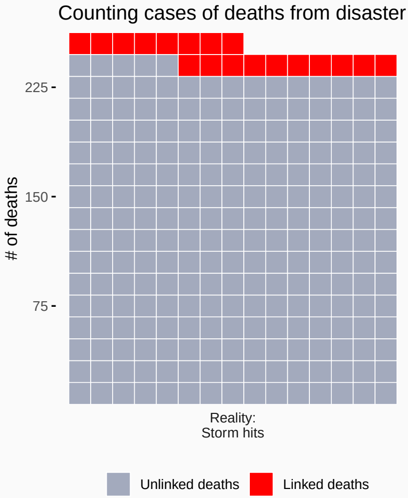
Strength:

Minimize *error* in estimating number of excess deaths.

Compromise:

- Excess deaths are estimated with some uncertainty (variance) because number of baseline deaths is estimated with some uncertainty.
- Individual deaths aren't identified as linked or unlinked.

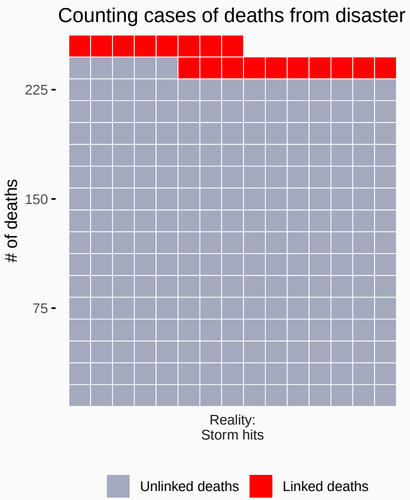
Counting cases—methodological objective



Strength:

Maximize *sensitivity*—the probability that if a death is classified as "linked", it really would not have happened without the disaster.

Counting cases—methodological objective



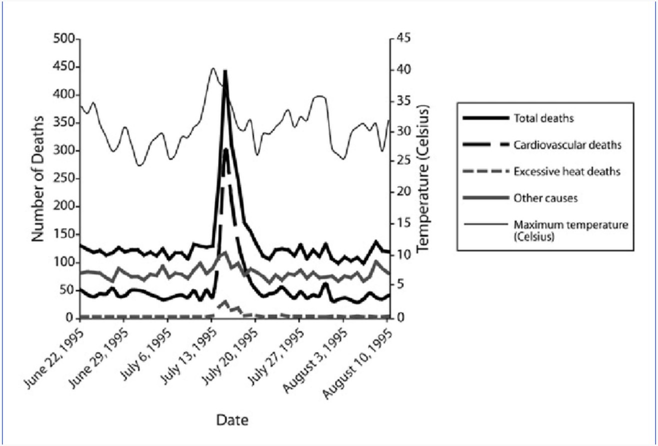
Strength:

Maximize *sensitivity*—the probability that if a death is classified as "linked", it really would not have happened without the disaster.

Compromise:

- Maximizing *sensitivity* may decrease *specificity*—the probability that if a death is classified as "unlinked", it really would still have happened without the disaster.

Chicago, 1995



Source: Kaiser et al., 2007, "The Effect of the 1995 Heat Wave in Chicago on All-Cause and Cause-Specific Mortality", *American Journal of Public Health*

Hurricane Irma, 2017

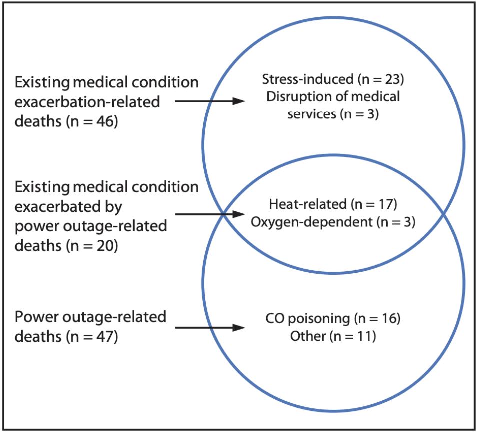
TABLE. Circumstances of confirmed deaths* related to Hurricane Irma — Florida, Georgia, and North Carolina, September 4–October 10, 2017†

Circumstance of death	No. of deaths	% of total deaths§
Directly hurricane-related¶	**11**	**8.5**
Accident	11	8.5
Drowning related to flooding	7	5.4
Tree-related injuries	4	3.1
Indirectly hurricane-related¶	**115**	**89.1**
Natural	48	37.2
Existing medical condition exacerbation	46	35.7
Stress-related cardiac disease	23	17.8
Heat-related	17	13.2
Oxygen-dependent disease	3	2.3
Disruption of emergency medical services	3	2.3
Floodwater infection	2	1.6
Accident	67	51.9
Carbon monoxide poisoning	16	12.4
Preparation/Repair injury	15	11.6
Motor vehicle crash	13	10.1
Falls from standing height**	13	10.1
Other††	12	9.3
Possibly hurricane-related¶	**3**	**2.3**
Homicide	1	0.8
Suicide	1	0.8
Undetermined	1	0.8

Source: Issa et al., 2018, "Deaths Related to Hurricane Irma — Florida, Georgia, and North Carolina, September 4–October 10, 2017," *Morbidity and Mortality Weekly Report*

Hurricane Irma, 2017

FIGURE. Overlapping circumstances of deaths associated with existing medical condition exacerbation and power outages caused by Hurricane Irma — Florida, Georgia, and North Carolina, September 4–October 10, 2017*,†



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XAVIER GARCIA/BLOOMBERG/GETTY

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