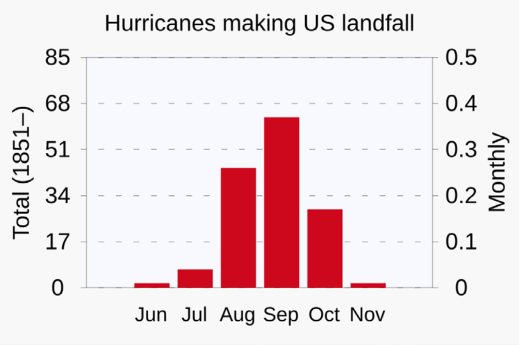

HURRICANES AND FLOODS:
IMPACT WITH A FOCUS ON INFECTIOUS DISEASES

David J. Weber, MD, MPH, FIDSA, FSHEA, FRSM (London)
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Disclosures: Consultancy-Pfizer, GSK, PDI, BD, Germitec; Speaker's Bureau-Pfizer, Merck, BD, GAMA

LECTURE TOPICS

- Impact of climate changes
- Deaths from natural disasters and weather events
- Impact of tropical cyclones: Focus on US
- Impact of climate change on tropical cyclones: Frequency, severity, microbial risks
- Impact of tropical cyclones and flooding: Focus on infectious diseases
  - Disaster management overview
  - Non-infectious diseases associated with tropical cyclones and flooding
  - Infectious diseases associated with tropical cyclones and flooding
- Mitigating infectious disease risks associated with tropical cyclones and/or flooding

Potential Health Impacts of Climate Variability and Change for the United States

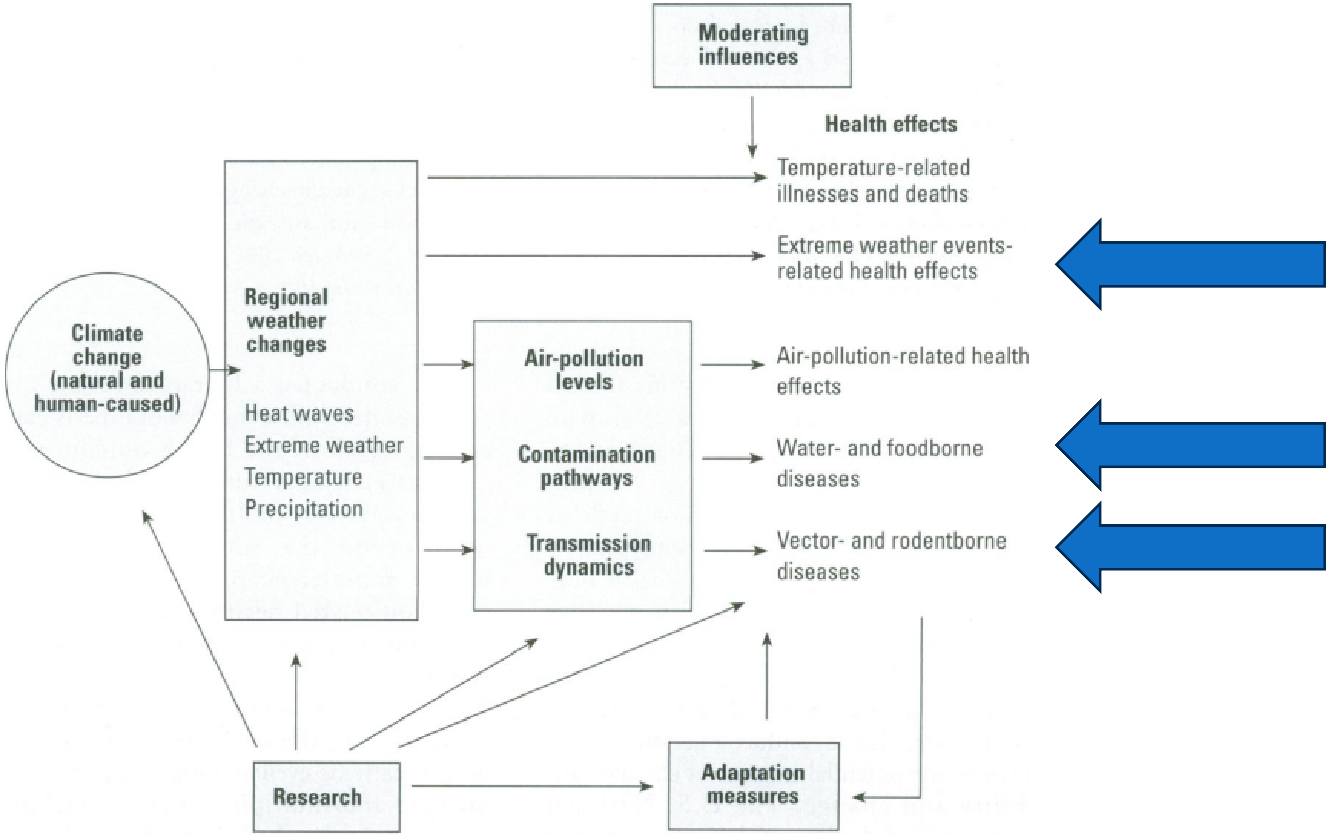
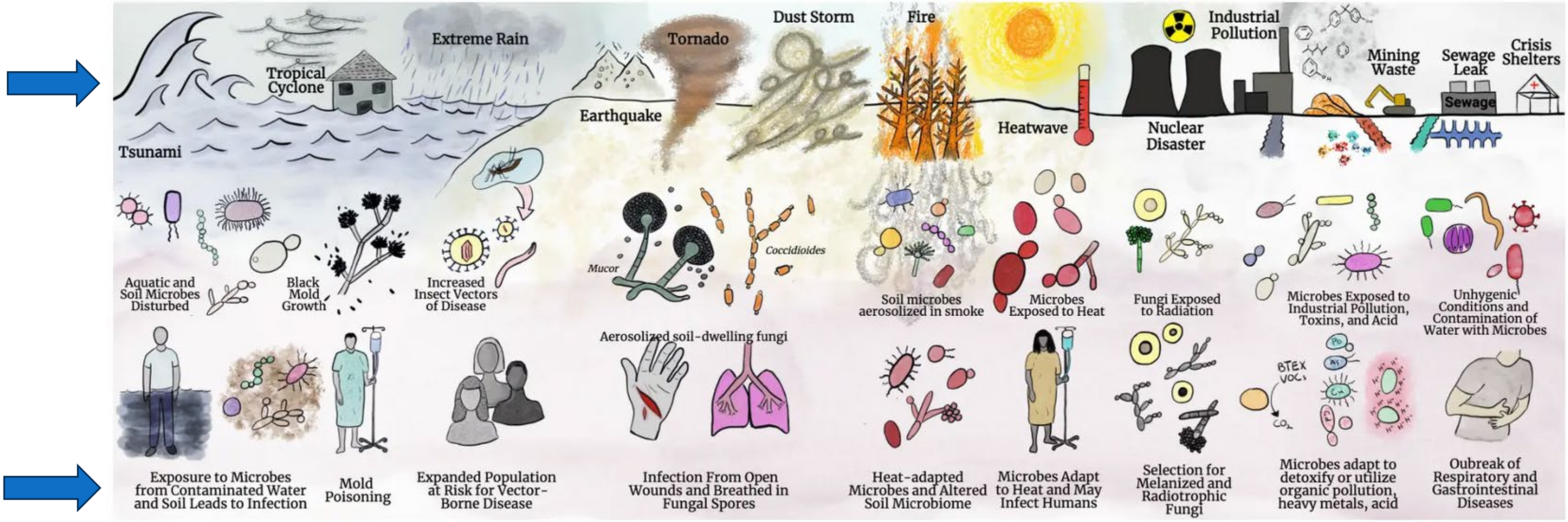


Figure 1. Potential health effects of climate variability and change. Moderating influences include nonclimate factors that affect climate-related health outcomes, such as population growth and demographic change, standards of living, access to health care, improvements in health care, and public health infrastructure. Adaptation measures include actions to reduce risks of adverse health outcomes, such as vaccination programs, disease surveillance, monitoring, use of protective technologies (e.g., air conditioning, pesticides, water filtration/treatment), use of climate forecasts and development of weather warning systems, emergency management and disaster preparedness programs, and public education.

Patz JA, et al. Environ Health Perspect 2000;108:367-76



https://www.contagionlive.com/view/in-the-aftermath-post-hurricane-infections

NATURAL DISASTERS

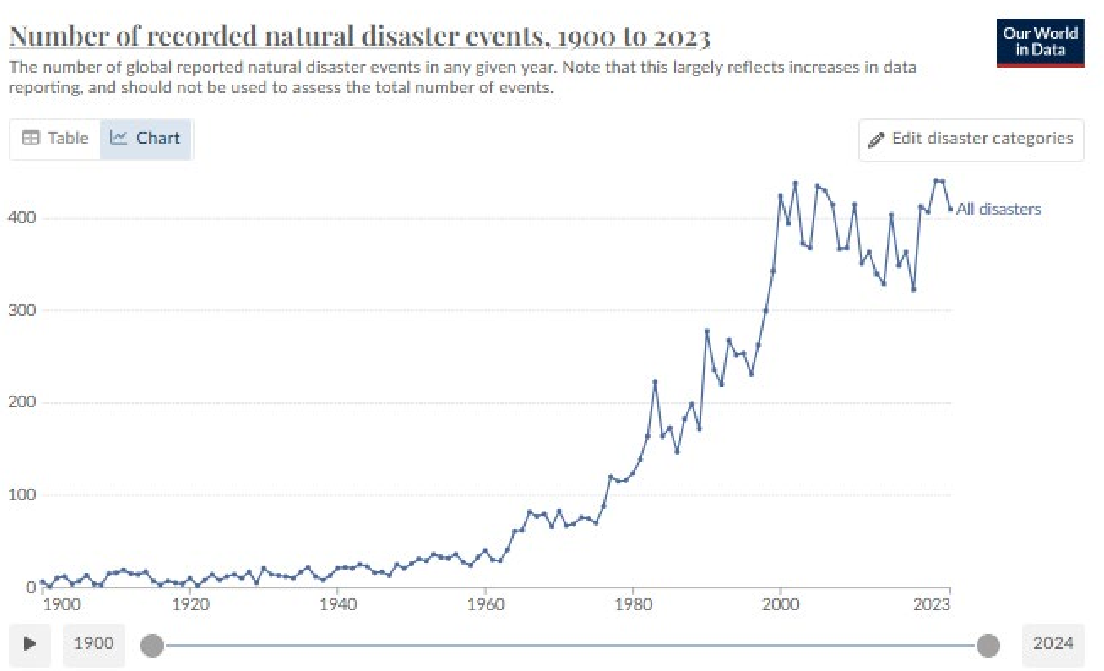
Disasters – from earthquakes and storms to floods and droughts – kill approximately 40,000 to 50,000 people per year. This is the average over the last few decades.

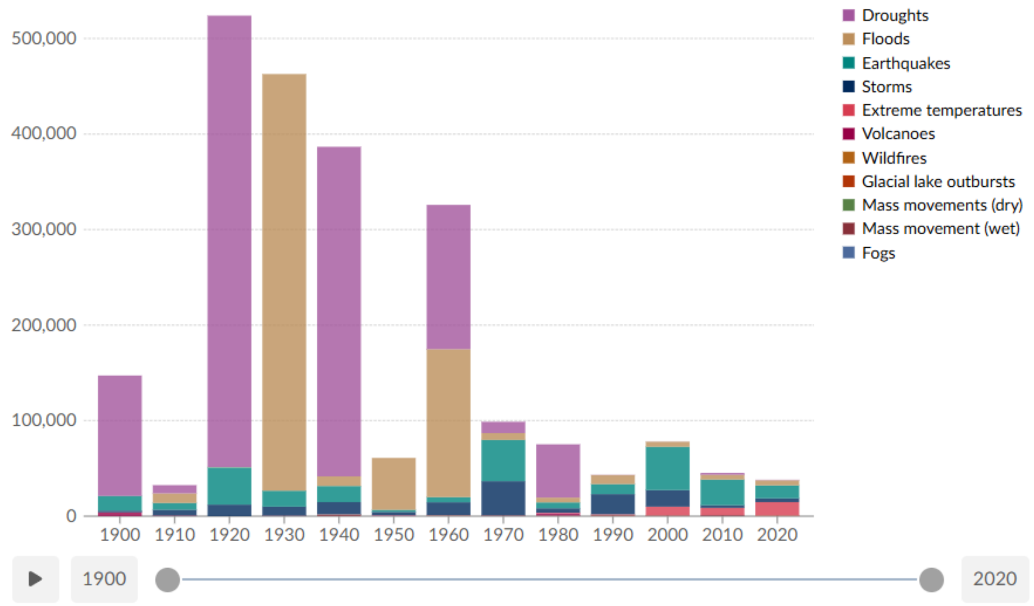
While that's a relatively small fraction of all deaths globally, disasters can have much larger impacts on specific populations. Single extreme events can kill tens to hundreds of thousands of people. In the 20th century, more than a million deaths per year were not uncommon.

Disasters have other large impacts, too. Millions of people are displaced – some left homeless – by them each year. And the economic costs of extreme events can be severe, and hard to recover from. This is particularly true in lower-income countries.

We are not defenseless against disasters: deaths from disasters have fallen significantly over the last century as a result of early warning systems, better infrastructure, more productive agriculture, and coordinated responses.

As climate change increases the risks of more extreme events, making societies even more resilient will be crucial to prevent our recent progress from reversing. To do so, we need to understand how disaster events are changing, who is most vulnerable, and what can be done to protect them.





https://ourworldindata.org/natural-disasters

DEATHS FROM NATURAL DISASTERS, US

Deaths	Year	Event	Type	Location
6,000-12,000	1900	Hurricane	Tropical cyclone	Galveston, TX
5,000	1936	Heat wave	Heat wave	United States
4,000	1862	Great flood	Flood	Western US
3,389	1899	Hurricane	Tropical cyclone	Puerto Rico, East Coast US
3,000+	1906	San Francisco Earthquake	Earthquake	San Francisco, US
2,982 (est.)	2982	Hurricane Maria	Tropical cyclone	Puerto Rico, East Coast US
2,823	1928	Okeechobee hurricane	Tropical cyclone	Puerto Rico, Florida US1893
2,209	1889	Johnston Flood	Dam failure	Pennsylvania, US
2,000	1893	Cheniere Caminada hurricane	Tropical cyclone	Louisiana, US
1,700	1980	Heat wave	Heat wave	Central and Southern US
1,500-2,500	1871	Peshtigo fire	Wildfire	Wisconsin and Michigan US
1,500	1896	Heat wave	Heat wave	Northeast and Midwest US
1,392	2005	Hurricane Katrina	Tropical cyclone	FL, LA, MS, AL, GA, KY, OH

US deaths from pandemics: 1918-19 flu, 675,000; AIDS, ~700,000 by 2018; COVID-19, >1,219,000

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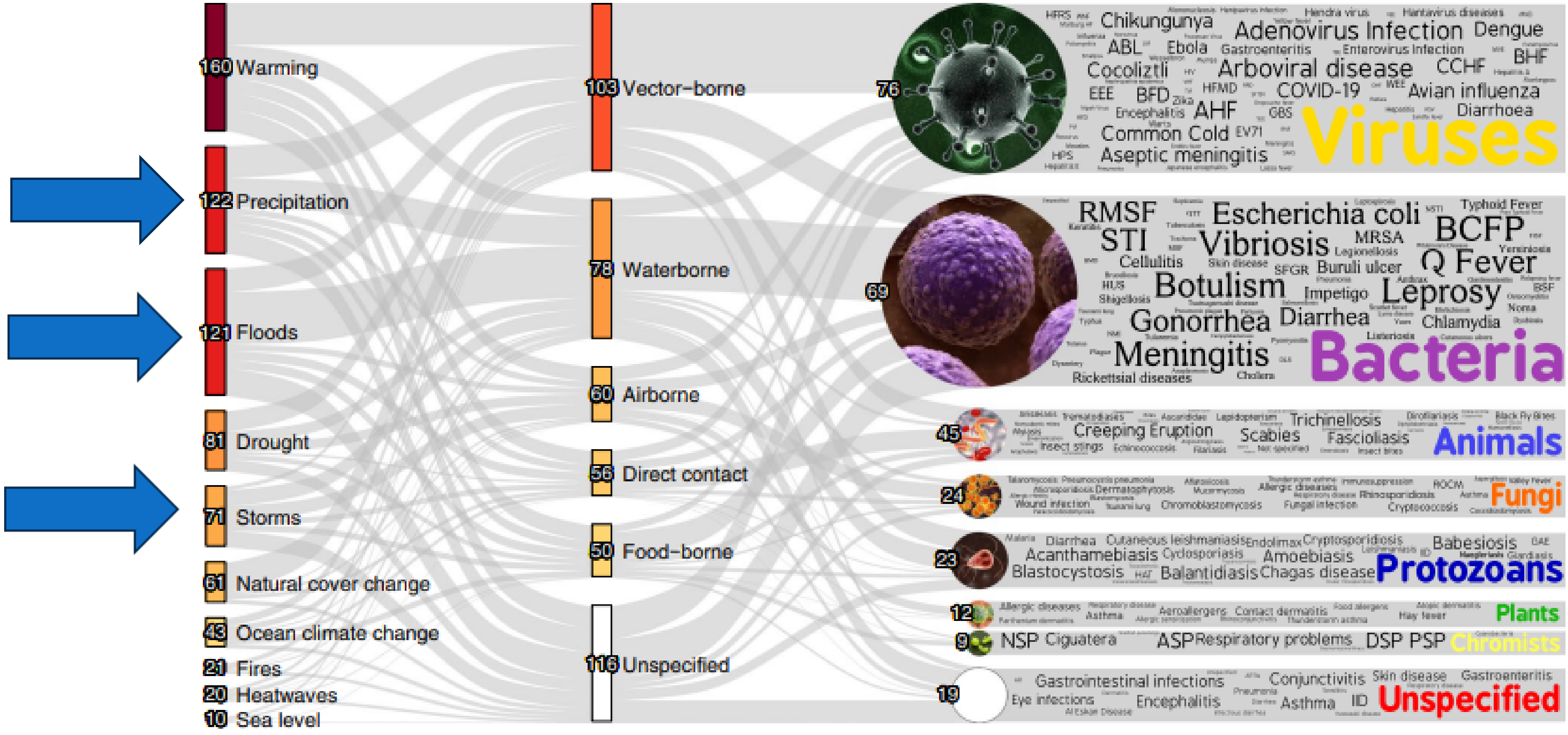

Fig. 3 | Pathogenic diseases aggravated by climatic hazards. Here we display the pathways in which climatic hazards, via specific transmission types, result in the aggravation of specific pathogenic diseases. The thickness of the lines is proportional to the number of unique pathogenic diseases. The colour gradient indicates the proportional quantity of diseases, with darker colours representing larger quantities and lighter colours representing fewer. Numbers at each node are indicative of the number of unique pathogenic diseases (caveats in Supplementary Information 1). An interactive display of the pathways and the underlying data are available at https://camilo-mora.github.io/Diseases/. Several disease names were abbreviated to optimize the use of space in the figure; their extended names are provided in Supplementary Table 1. Credits: word clouds, WordArt.com; bacteria, Wikimedia Commons (www.scientificanimations.com); other images, istockphoto.

Mora C, et al. Nature Climate Change 2022;12:869-875

IMPACT OF TROPICAL CYCLONES

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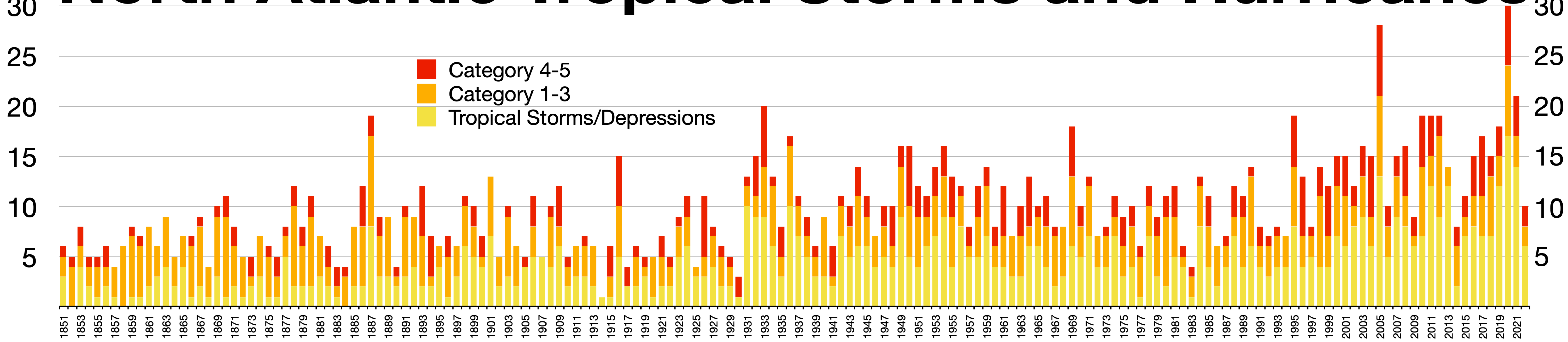
DEFINITIONS

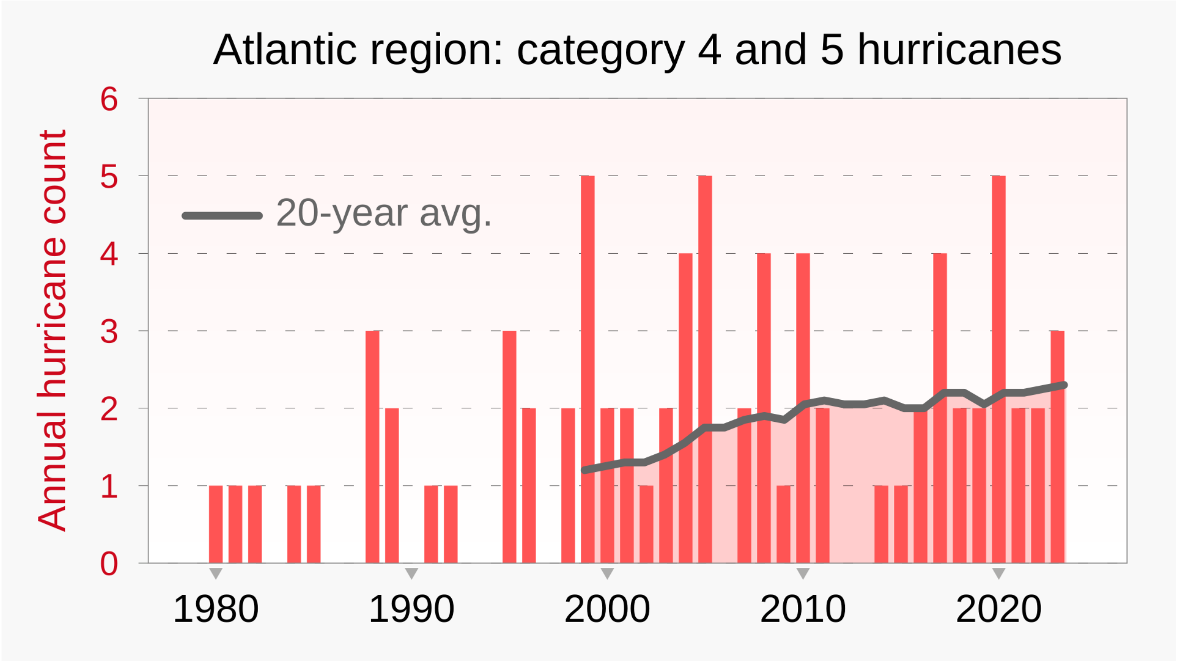
- Hurricane categories:

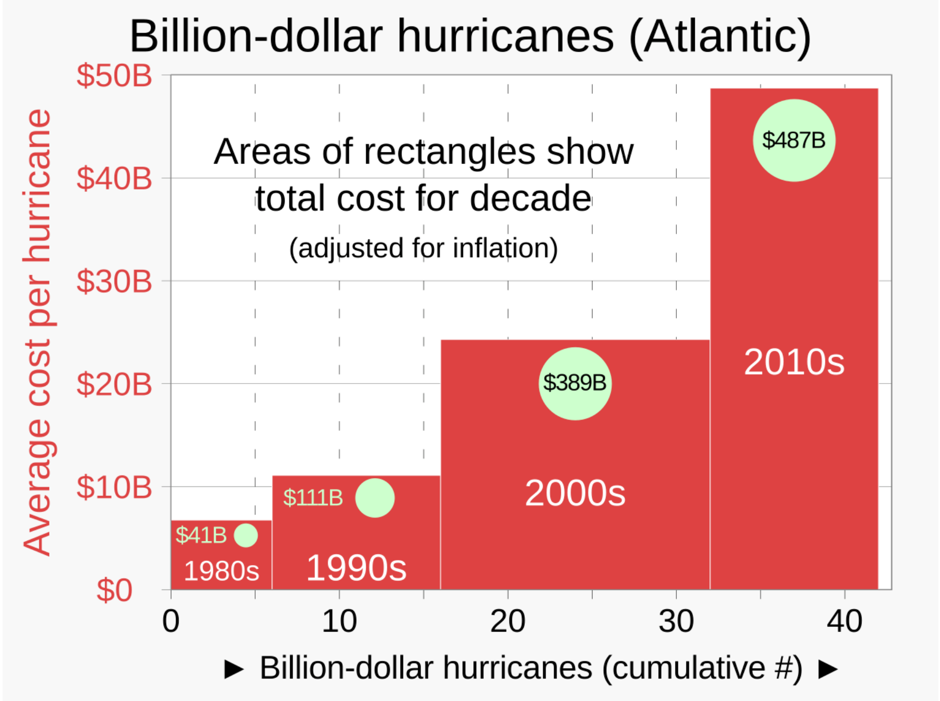
1.	74-95 mph	Some damage; tree branches and power lines down
2.	96-110 mph	Extensive damage; roof and siding damage
3.	111-129 mph	Damage to homes and buildings, trees uprooted
4.	130-156 mph	Entire loss of roof and walls to buildings
5.	157 mph and up	Entire buildings destroyed, area is uninhabitable

- Major hurricanes: Categories 3-5
- Tropical cyclones
    - Hurricanes: Tropical cyclones in Atlantic Ocean
    - Typhons: Tropical cyclones in Pacific Ocean
- Natural disasters leading to flooding: Tropical cyclones, tsunamis, storm surges, excessive rainfall, dam failures

North Atlantic Tropical Storms and Hurricanes



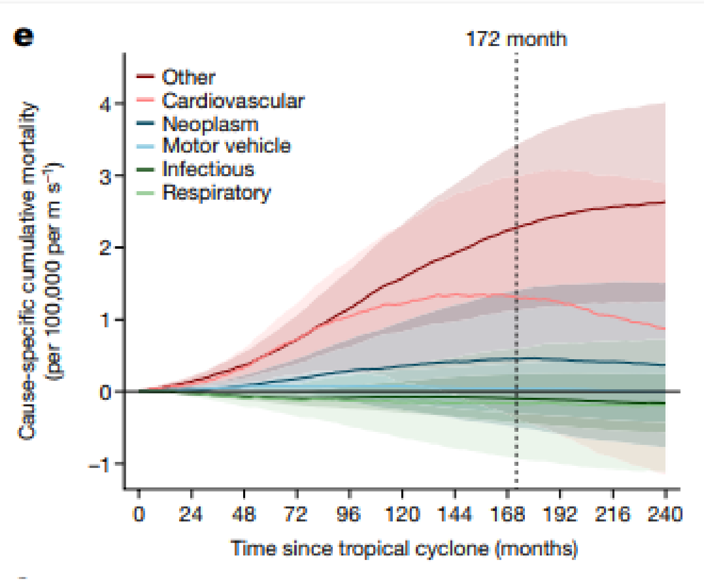


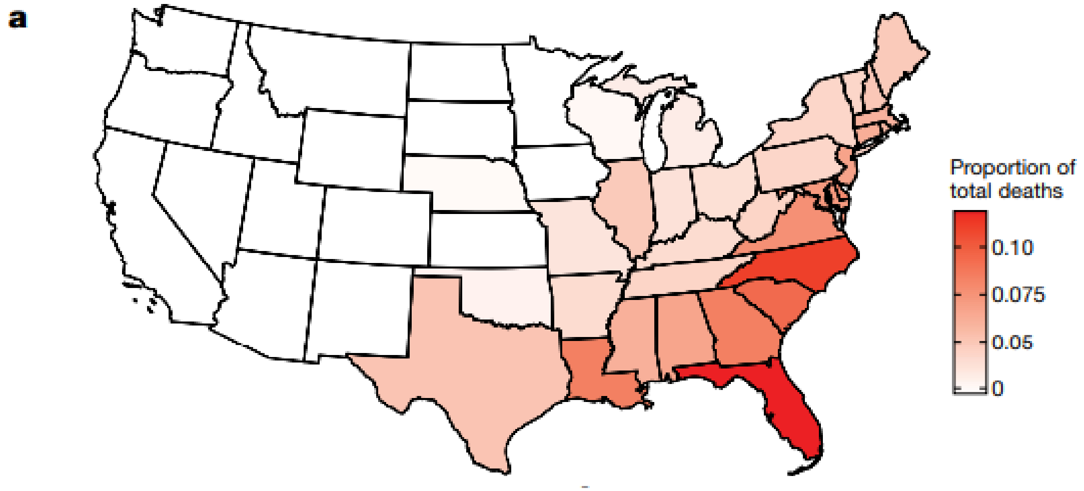


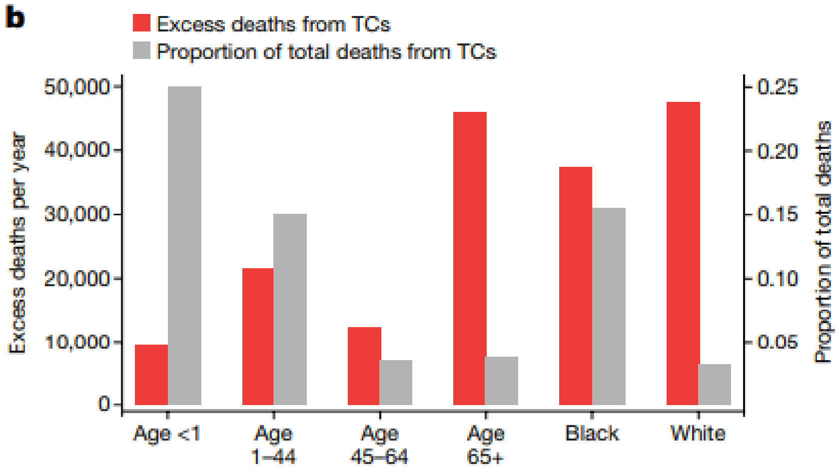
https://en.wikipedia.org/wiki/List_of_United_States_hurricanes

Mortality Caused by Tropical Cyclones in the US, 1930-2015

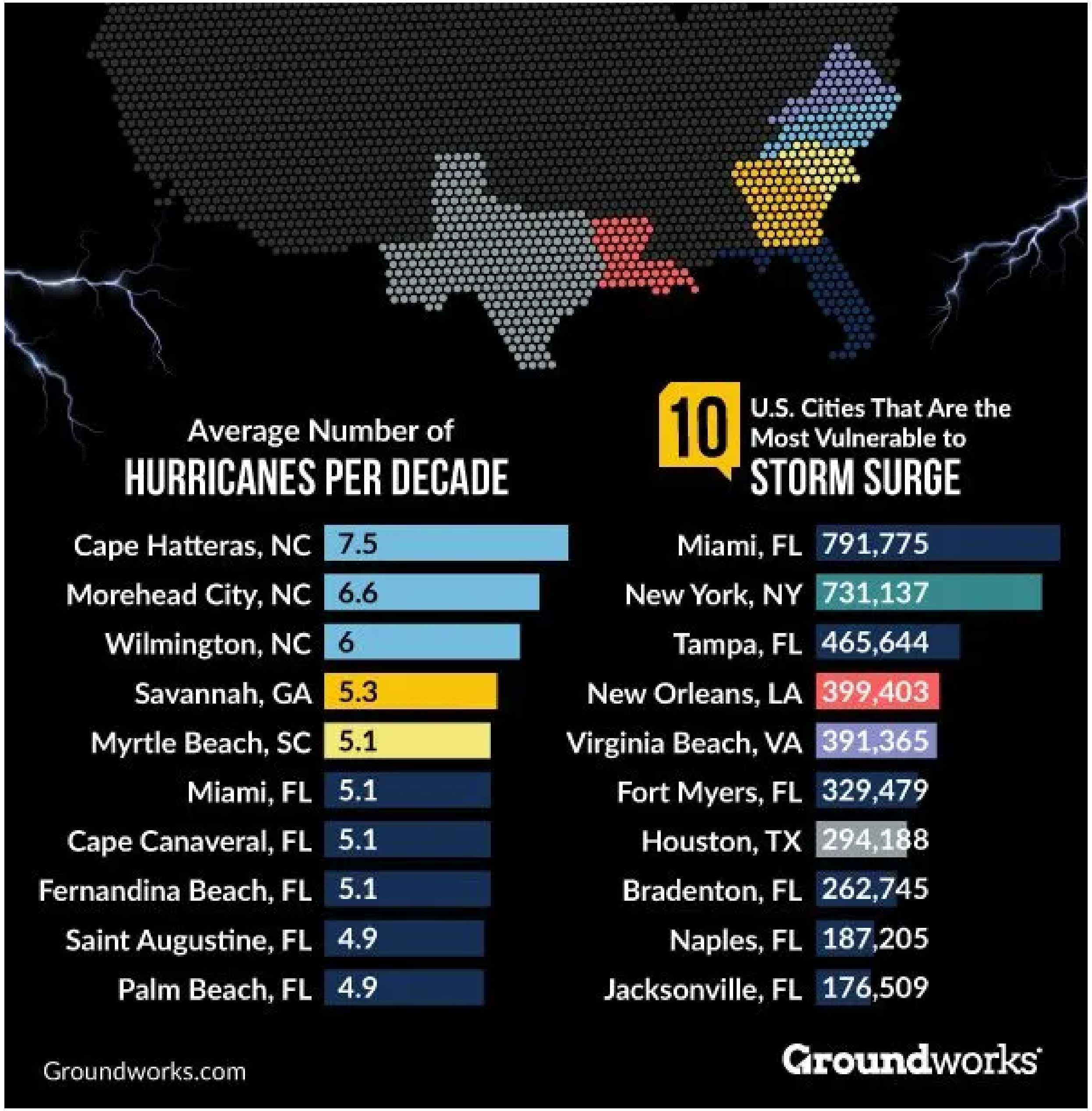
Natural disasters trigger complex chains of events within human societies. Immediate deaths and damage are directly observed after a disaster and are widely studied, but delayed downstream outcomes, indirectly caused by the disaster, are diffcult to trace back to the initial event. Tropical cyclones (TCs), that is, hurricanes and tropical Storms, are widespread globally and have lasting economic impacts, but their full health impact remains unknown. Here we conduct a large-scale evaluation of long-term efects of TCs on human mortality in the contiguous US (CONUS) for all TCs between 1930 and 2015. We observe a robust increase in excess mortality that persists for 15 years after each geophysical event. We estimate that the average TC generates 7,000–11,000 excess deaths, exceeding the average of 24 immediate deaths reported in government statistics. Higher mortality rates occurred along the Atlantic coast and is equal to roughly 3.2–5.1% of all deaths. During the period of study, we estimate that TCs contributed to more deaths in CONUS (3.6–5.2 million) than all motor vehicle accidents (2.0 million), infectious diseases (1.9 million) or US battle deaths in wars (1.3 million). Infectious disease deaths NOT linked to TCs.

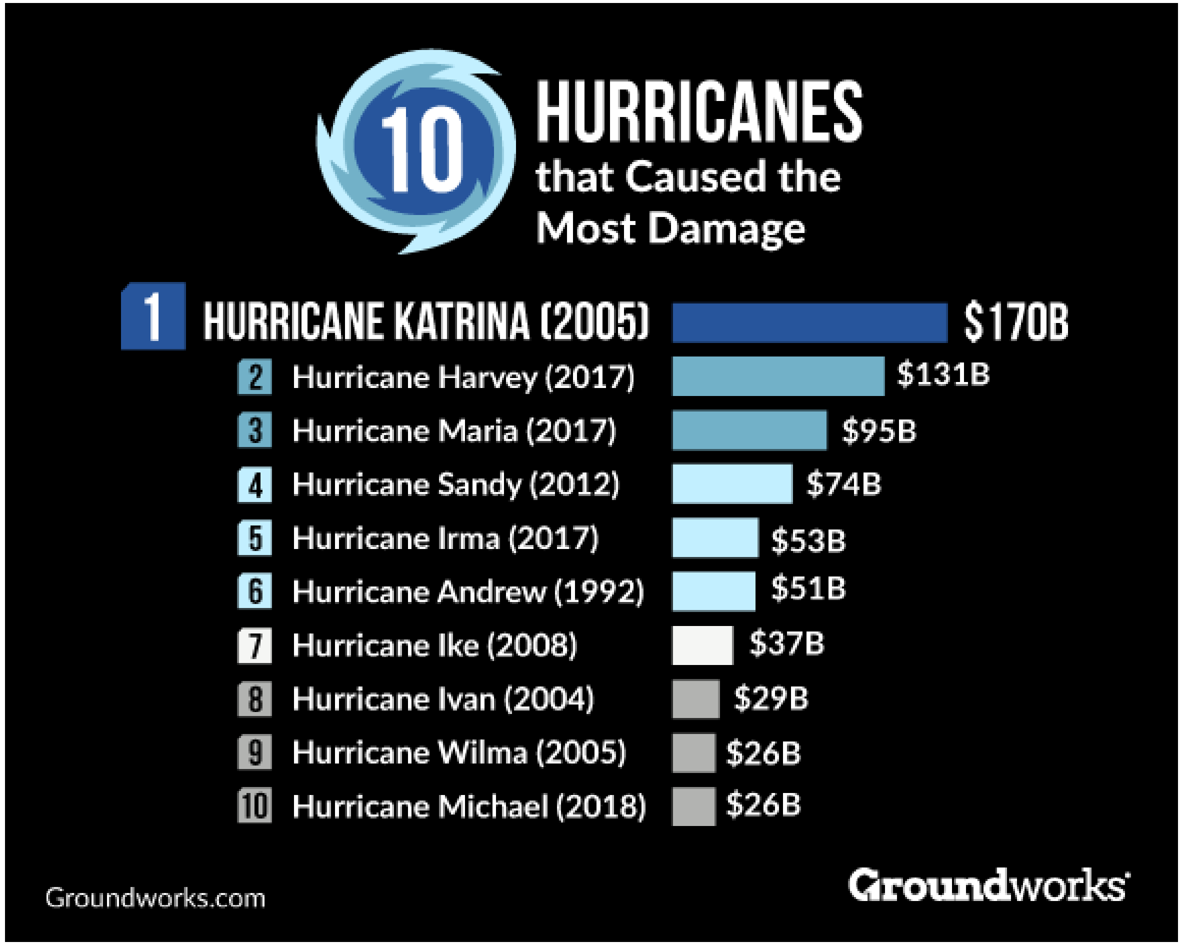






Young R, Hsiang S. Nature 2024;Oct 2





- **Cape Hatteras; since 1871 had been impact by 108 hurricanes/tropical storms**
- Most vulnerable by properties as risk
- Storm surge by Sandy in lower Manhattan was ~14 feet
- Katrina: 85% of New Orleans underwater; recovery took >14 years

https://www.groundworks.com/resources/worst-us-cities-for-hurricane-damage/

IMPACT OF CLIMATE CHANGE ON EXTREME WEATHER EVENS

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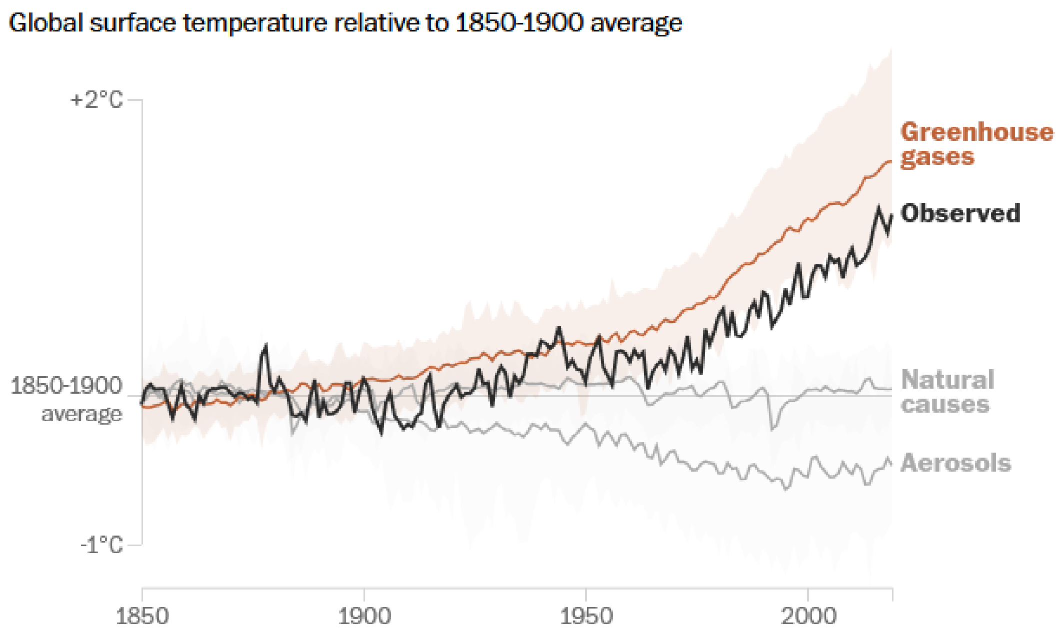
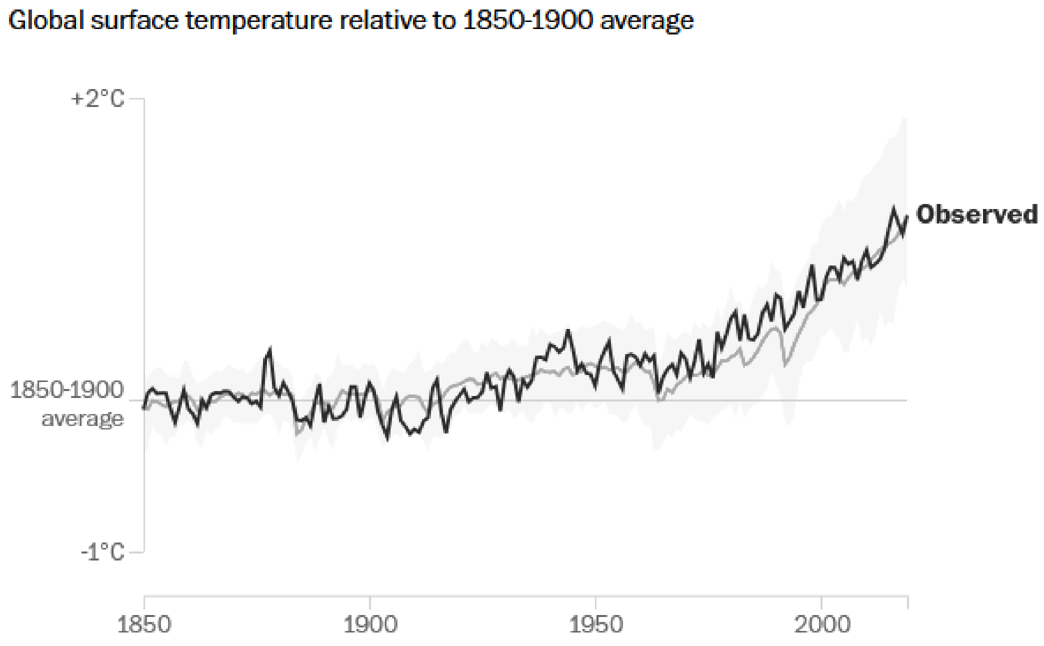
IMPACT OF CLIMATE AND POPULATIOAN CHANGES ON TROPICAL CYCLONES DAMAGES

- Population
  - Increasing US population
  - Increased number of persons living in Coastal areas
- Climate change
  - Driving factors for increased impact: Warmer ocean temperatures, rising sea water levels, and land subsidence plus increased number of persons living in "high risk" areas
  - Earlier onset of tropical cyclone activity in North Atlantic basin
  - More major hurricanes (categories 3-5)
  - More severe cyclones (measured by wind velocity)
  - More rapid development (i.e., from tropical depression to major hurricane)
  - Slower moving
  - Increased rainfall

MAIN DRIVING FACTOR FOR INCREASED SEVERITY OF TROPICAL STORMS:RISING SURFACE TEMPERATURES



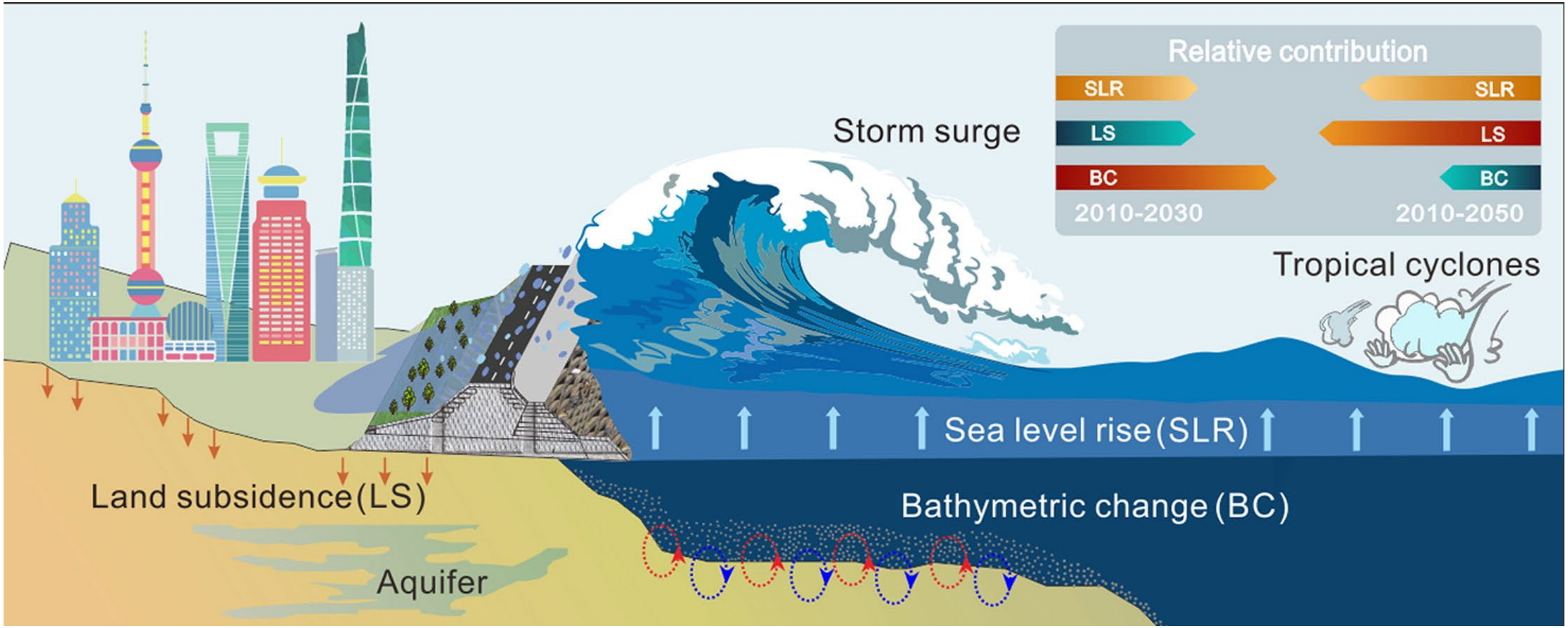


Source: UN Intergovernmental Panel on Climate Change

The biggest influence on the temperature increase has been greenhouse gas emissions, which reduce the amount of infrared light that radiates back to space, causing the planet's average temperature to increase.

Combining all these factors yields a close reproduction of the observed temperature change. The planet has warmed by about 1.2 degrees Celsius (2.2 degrees Fahrenheit), and greenhouse gas emissions are the main cause.

Effects of sea level rise, land subsidence, bathymetric change and typhoon tracks on storm flooding in the coastal areas of Shanghai



Wang J, et al. Sci of the Total Environ 2018;15:228-234

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IMPACT OF TROPIC CYCLONES AND FLOODING: FOCUS ON INFECTIOUS DISEASES

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DISASTER MANAGEMENT

Figure. 2.2 **Developmental considerations contributing to all elements of the disaster-management cycle**

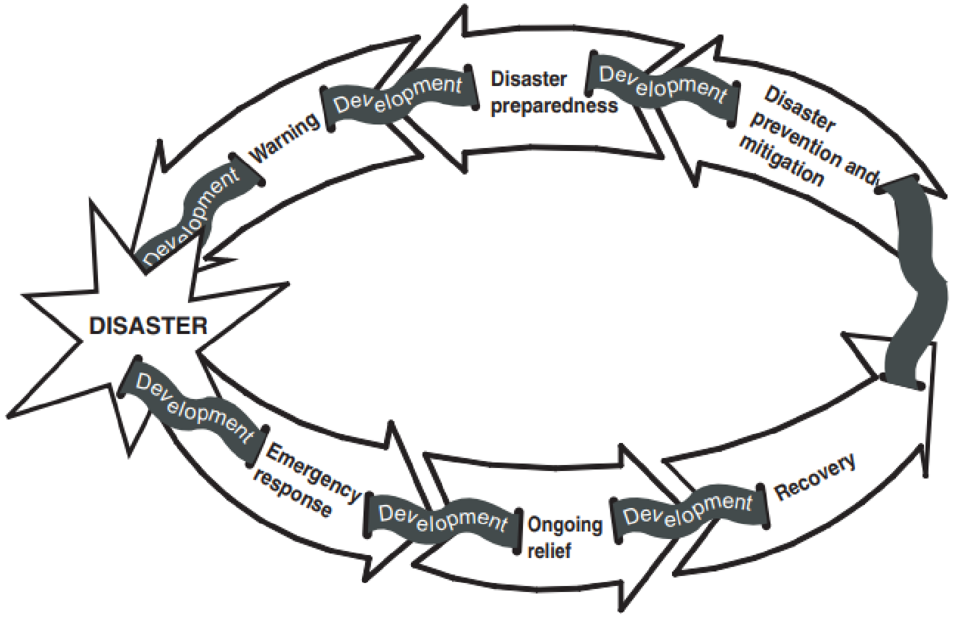
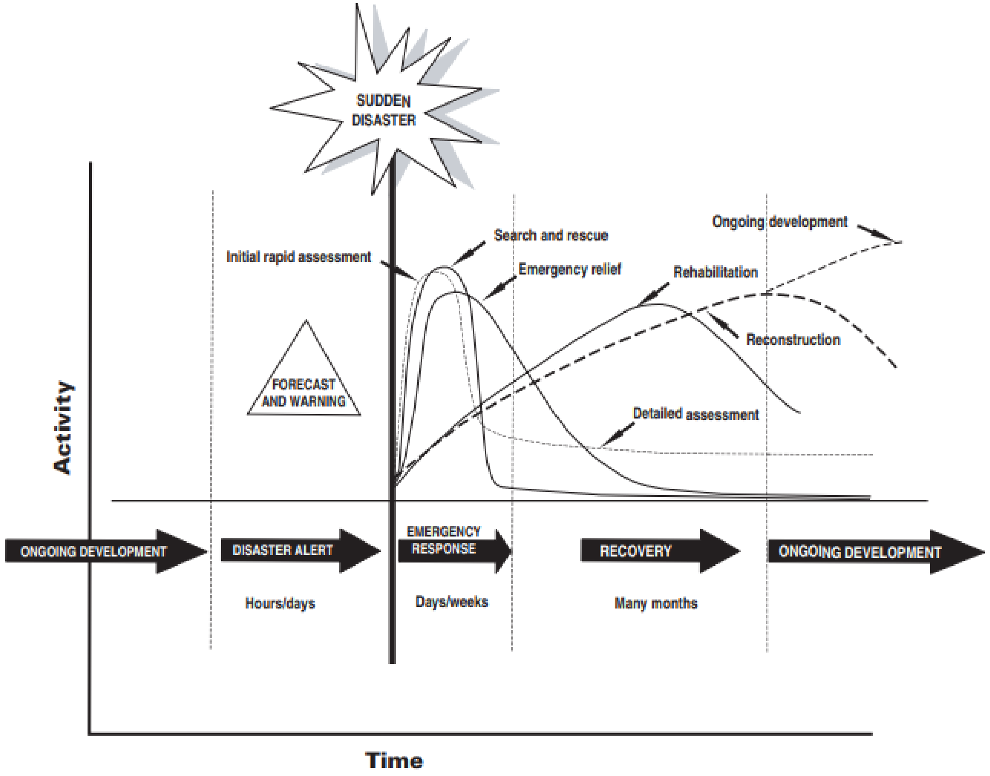


Figure. 2.3 **Development temporarily interrupted by sudden disaster**



WHO, Environmental Health In Emergencies and Disasters, A Practical Guide, 2002
https://iris.who.int/bitstream/handle/10665/42561/9241545410_eng.pdf?sequence=1

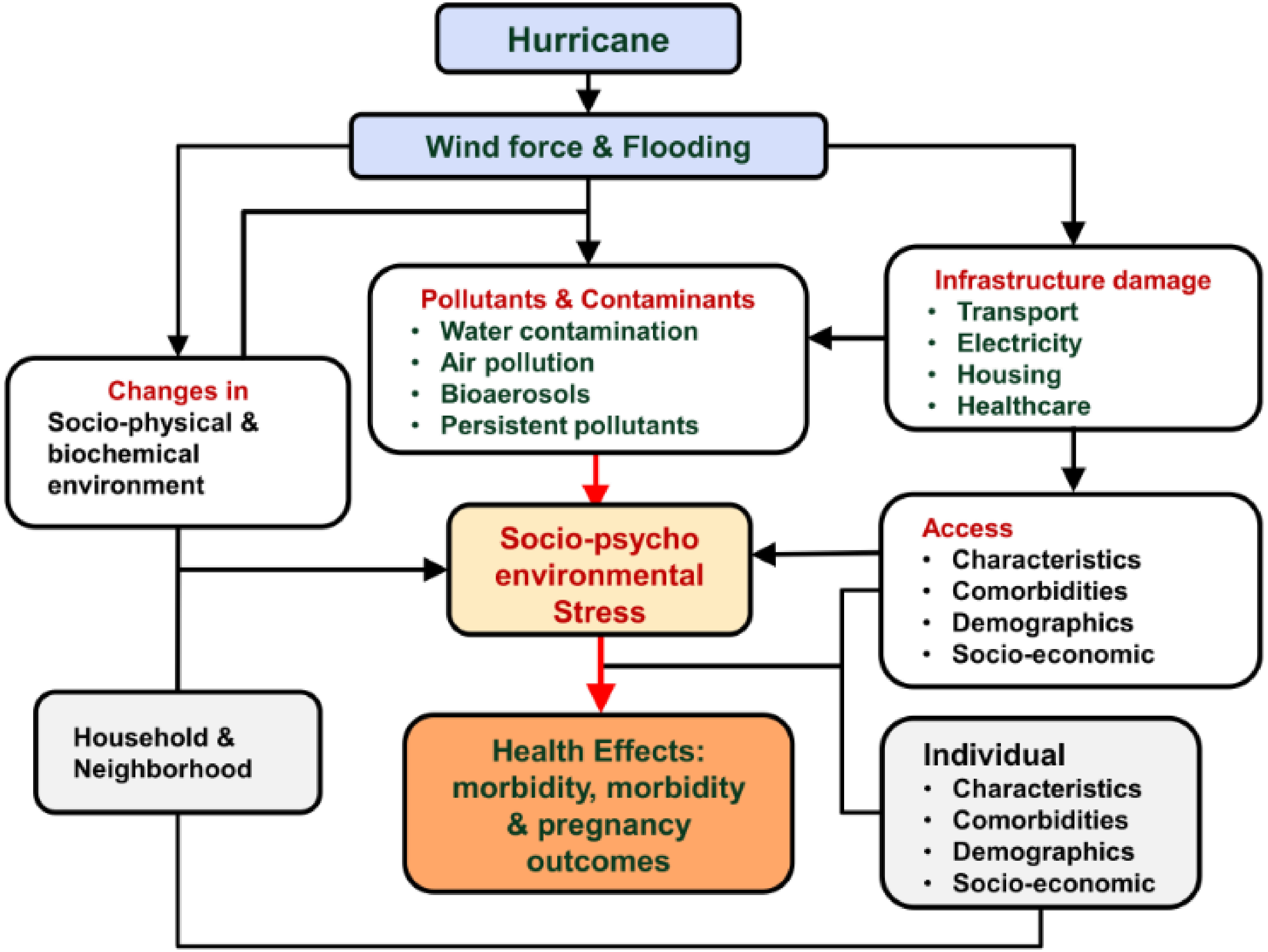


Figure 1. A conceptual model of the direct and indirect health effects of hurricanes.

Waddell SL, et al.
International J Environ Res and Public Health
2021;18:2756

NON-INFECTIOUS RISKS OF HURRICANES: IMPACT IN PERSONS IN COMMUNITIES

- Drowning
  - Riptides
  - Car immersion
  - Water intrusion into homes
  - Storm surge
  - Dam rupture
- Burn injuries (including inhalation)
  - Rupture of gas lines
  - Downed electrical lines
  - Use of gas grills for cooking or heating
  - Use of candles for light
- Bites
  - Snakes (water moccasins, coral snakes, copperheads)
  - Alligators and crocodiles
- Blunt force trauma
  - Trees or other falling objects
  - Flying objects due to wind
- Medical
  - Heart attacks and strokes (stress, excessive work)*
  - Cancer*
- Psychiatric
  - Anxiety and/or depression, affective disorders
  - PTSD*
  - Psychotic disorders, Suicide*
  - Substance abuse
- Miscellaneous
  - Electrocution (downed wires)
  - Carbon monoxide poisoning (gas grills used for heat)
  - Heat or cold exposure
  - Asthma/respiratory disease (from mold in homes)*
  - Inoperative power-dependent medical devices

*Late impact

Tracking Hurricane-Related Deaths in the Contiguous US States Using Media Reports From 2012 to 2020

Cause of death	Direct	Indirect	Unknown	Total
Illness				
Cardiac disease[a]	0	15	2	17
Respiratory	0	3	3	6
Injury				
Drowning	90	22	27	139
Blunt force trauma	31	48	10	89
CO poisoning	0	44	14	58
Falling tree	2	0	19	21
Electrocuted	0	10	4	14
Car accident	1	2	10	13
Fall	0	2	3	5
Fire	0	2	3	5
Hyperthermia	0	5	0	5
Hypothermia	0	0	4	4
Unspecified injury	0	0	3	3
Gunshot	0	2	0	2
Stroke	0	1	1	2
Sepsis	0	1	0	1
Suffocation	0	0	1	1
Total	124	204	194	522
Unknown	0	47	90	137

[a] Cardiac disease consists of the following: heart attack, myocardial infarction, cardiac disease, and cardiac arrest.

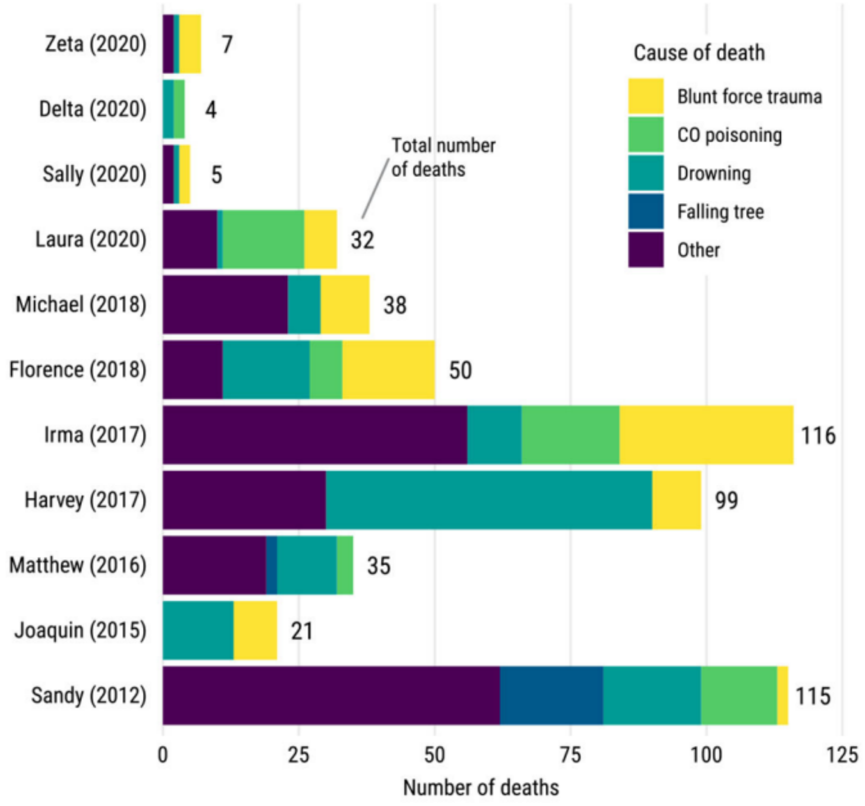


Figure 3.
Number of disaster-related deaths and cause of deaths reported by media - United States, 2012-2020.

Williams S, et al. Disaster Med Public Health Prep 2022;17:e234

As of 29 Oct. 2024, 99 verified storm-related fatalities in NC

NC DHHS Hurricane Helene Storm Related Fatalities

The Way Hurricanes Kill Is Changing. Helene Shows How

Freshwater flooding has overtaken storm surge as the greatest threat

In recent years, researchers have observed a shift in fatality trends during tropical cyclones, with freshwater flooding driven by rainfall becoming the deadliest hazard.

CAUSE OF DEATH	1963-2012	2013-2022
Storm surge	49%	11%
Freshwater flooding	27%	57%
Wind	8%	12%
Surf/rip currents	6%	15%
Offshore marine incidents	6%	3%
Tornadoes	3%	2%
Other	1%	1%

Source: National Hurricane Center · By Nick Underwood

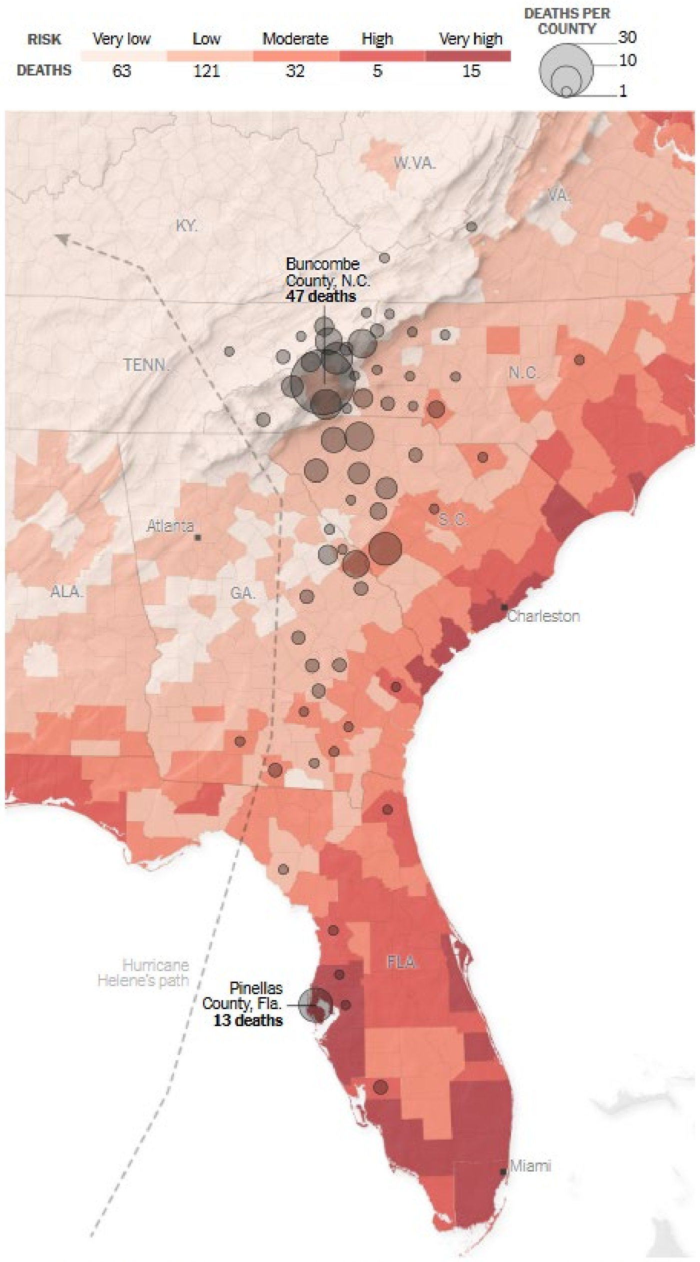
Helene also showed that indirect deaths — caused by things like power outages and traffic accidents, often after the storm is over — were distressingly common. At least two dozen people died from Helene-related causes in October, days after the hurricane had passed.

Helene killed more than 200 people, making it the deadliest tropical cyclone to strike the mainland United States since 2005.

Rain, which led to flooding and landslides, was the most deadly part of the storm, followed by wind, which toppled trees.

Helene also showed that indirect deaths — caused by things like power outages and traffic accidents, often after the storm is over — were distressingly common. At least two dozen people died from Helene-related causes in October, days after the hurricane had passed

Seventy-eight percent of the deaths caused by Helene occurred in counties designated by the Federal Emergency Management Agency as low risk for deadly hurricanes.



Sources: Federal Emergency Management Agency (hurricane risk level); State and local government agencies, law enforcement officials, media reports (deaths) · By Nick Underwood

https://www.nytimes.com/2025/02/04/us/hurricane-helene-deaths.html

Morbidity and Mortality Associated With Hurricane Floyd, NC, Sept.-Oct. 1999

On September 16, 1999, Hurricane Floyd, a storm extending 300 miles with sustained winds of 96-110 miles per hour, made landfall in NC, dropping up to 20 inches of rain in eastern NC. Rain from Hurricane Floyd, combined with rains from Hurricane Dennis beginning on August 30 and Hurricane Irene on October 17, caused extensive flooding along the Neuse, Tar, Roanoke, Lumbar, and Cape Fear rivers, affecting an estimated 2.1 million persons. 52 deaths were associated directly with the storm. Comparing the first week following Hurricane Floyd with the first week of Sept. 1998, significant increases were reported in suicide attempts (RR=5.0; 95% CI=1.4-17.1), dog bites (RR=4.1; 95% CI=2.0-8.1), febrile illnesses (RR=1.5; 95% CI=1.3-1.9), basic medical needs (e.g., oxygen, medication refills, dialysis, and vaccines) (RR=1.4; 95% CI=1.2-1.8), and dermatitis (RR=1.4; 95% CI=1.2-1.6). Comparing a week 1 month after Hurricane Floyd with the same period in 1998, significant increases were reported in 1999 for arthropod bites (RR=2.2; 95% CI=1.4-3.4), diarrhea (RR=2.0; 95% CI=1.4-2.8), violence (i.e., assault, gunshot wounds, and rape) (RR=1.5; 95% CI=1.1-2.2), and asthma (RR=1.4; 95% CI=1.2-1.7). Routine surveillance by local public health workers following Hurricane Floyd identified outbreaks in shelters of self-limiting gastrointestinal disease and respiratory disease.

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.

MMWR 2000;49:369-372

Morbidity and Mortality Associated With Hurricane Helene (Sept. 24-29), NC (as of 4 November 2024)

- **102 storm-related deaths identified (227 overall)**. The main causes have been drowning, landslides, and blunt force injuries.
- Illnesses monitored through NC DETECT*
  - After initial post-hurricane spikes, lower numbers of ED visits for electrocutions, drownings, medication refills, dehydration, burns, and hypothermia continue to be observed.
  - Overall, ED visits for motor vehicle collision injuries have remained stable since the hurricane with a spike noted on 10/11.
  - Six CO poisoning ED visits were identified from 9/26-11/3.
  - ED visits for suicide attempts and self-inflicted injuries have not increased since the hurricane.
  - Trends for acute respiratory illness have been below baseline since the hurricane, while GI illness is showing a slight increase during the past week.
- NC DHHS also monitoring several reportable diseases we might expect to see increase post-disaster and communicating regularly with the LHD and our Mission PHEs to maintain broader situational awareness

Limitations of NC DHHS surveillance – e.g., DETECT only picks up cases that present to the ED and EDSS only those who seek care and have testing done. In this circumstance, there are also issues with limited access to emergency departments in the affected areas, particularly in the immediate post-storm period.
Data from Dr. Zack Moore, NC State Epidemiologist

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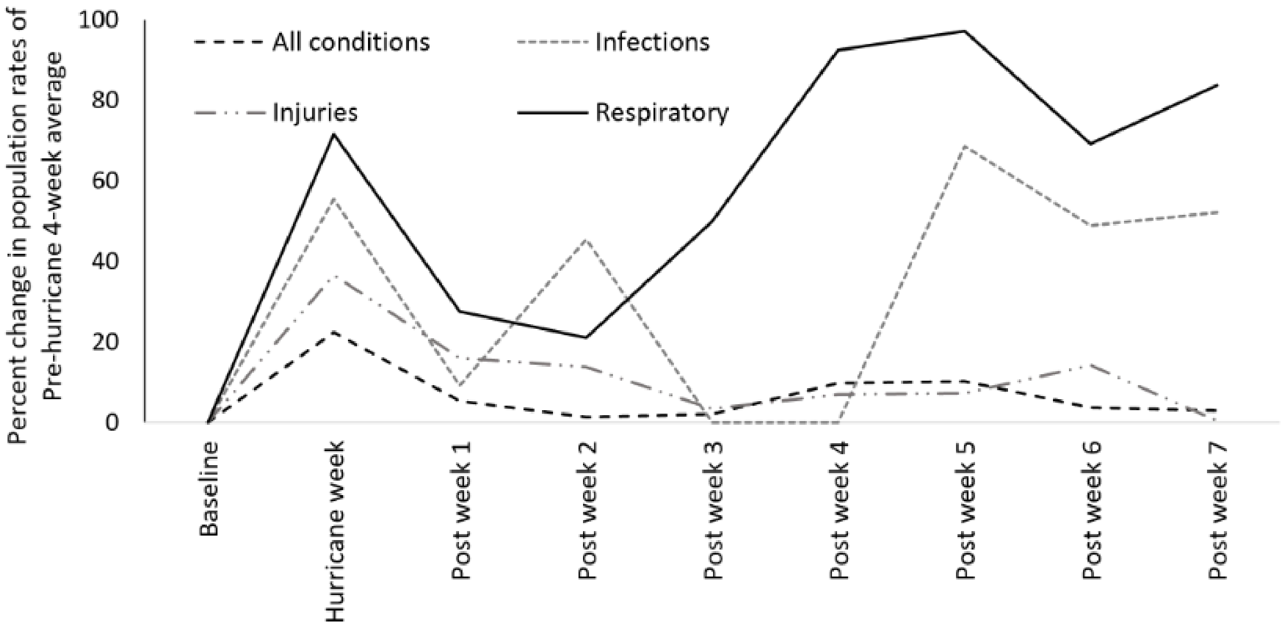
Health Impacts from Hurricane Harvey (2017)



H·CUP HEALTHCARE COST AND UTILIZATION PROJECT

Source: Agency for Healthcare Research and Quality (AHRQ), Healthcare Cost and Utilization Project (HCUP), State Emergency Department Databases (SEDD) and U.S. Census Bureau population data.

This graph shows the observed changes in the population rates of treat-and-release emergency department (ED) visits following Hurricane Harvey in August 2017. Information on ED utilization is based on data from the AHRQ HCUP State Emergency Department Databases (SEDD). Using information from NOAA and the Federal Emergency Management Agency (FEMA), counties that were in the direct path of the hurricane were identified. For these counties, the percent change in the population rate of treat-and-release ED visits during and post-hurricane were compared to the pre-hurricane average utilization rates. Over a 7-week period after the hurricane, the largest increase in population rates of treat-and-release ED visits were observed for respiratory conditions, with relatively smaller increase for infections, injuries and all conditions.

https://www.hhs.gov/climate-change-health-equity-environmental-justice/climate-change-health-equity/climate-health-outlook/hurricane/index.html

IMPACT OF HURRICANES: WATER-RELATED INFECTIONS

- Hepatitis A (ingestion; hepatitis)
- Hepatitis E (ingestion; hepatitis)
- Norovirus (ingestion; gastroenteritis)
- Cholera (ingestion; gastroenteritis)
- Leptospirosis (ingestion; systemic)
- Enterotoxigenic *E. coli* (ingestion; gastroenteritis)
- *Cryptosporidium* (ingestion; gastroenteritis)
- Giardia (ingestion)
- Group A strep (injury, immersion; skin)
- *Staphylococcus aureus* (injury, immersion; skin)
- *Aeromonas* (injury, immersion; skin and systemic)
- *Aeromonas* (inhalation; pneumonia)
- *Vibrio* spp. (injury, immersion; skin and systemic)
- Polymicrobial; *Pseudomonas, Klebsiella, E. coli* (injury, immersion; skin)
- Non-tuberculous bacteria (injury, immersion; skin)
- Melioidosis (injury; skin)
- Tetanus (injury in water or by wood; systemic)
- Fungi (inhalation or injury/immersion; skin or pneumonia)*
- Legionellosis (inhalation; pneumonia)*
- Mosquito-Borne*
  - West Nile, Zika, Dengue, Chikungunya, Japanese encephalitis
  - Malaria

Table 1. Breakdown of natural disasters recorded from 2000 to 2011 and potential secondarily-associated infectious diseases†.

Country	Disaster event	Year(s)	Infectious disease outbreak following natural disaster	Ref.
USA	Tornado	2011	Cutaneous mucormycosis	[25]
Japan	Earthquake	2011	Diarrhea (norovirus), influenza	[109]
Haiti	Earthquake	2010	Cholera	[108]
Cote d'Ivoire	Flood	2010	Dengue	[113]
Brazil	Flood	2008	Dengue	[112]
USA	Hurricane (Katrina)	2005	Diarrhea, TB	[18,24]
Pakistan	Earthquake	2005	Diarrhea, hepatitis E, ARI, measles, meningitis, tetanus	[11,21]
Dominican Republic	Flood	2004	Malaria	[110]
Bangladesh	Flood	2004	Diarrhea	[8]
Indonesia	Tsunami	2004	Diarrhea, hepatitis A and E, ARI, measles, meningitis, tetanus	[13,22]
Thailand	Tsunami	2004	Diarrhea	[14]
Iran	Earthquake (Bam)	2003	Diarrhea, ARI	[12]
Indonesia	Flood	2001–2003	Diarrhea	[9]
USA	Hurricane (Allison)	2001	Diarrhea	[17]
Taiwan	Typhoon (Nali)	2001	Leptospirosis	[20]
China	Typhoon (Nali)	2001	Leptospirosis	[20]
El Salvador	Earthquake	2001	Diarrhea, ARI	[15]
Thailand	Flood	2000	Leptospirosis	[110]
Mozambique	Flood	2000	Diarrhea	[10]
India (Mumbai)	Flood	2000	Leptospirosis	[19]

†Summarizes natural disasters that had resulted first in substantial population displacement and then exacerbated risk factors for disease transmission and outbreaks.
ARI: Acute respiratory infection.

Table 2. Risk factors and onset of communicable diseases following natural disasters†.

Major risk factors following natural disasters	Water-borne diseases			Air-borne/droplet diseases				Vector-borne diseases		Contamination from wounded injuries		Clinical phase of natural disasters		
	Diarrhea (cholera; dysentery)	*Leptospirosis*	*Hepatitis*	*ARI (pneumonia/ influenza)*	*Measles*	*Meningococcal meningitis*	*TB*	*Malaria*	*Dengue fever*	*Tetanus*	*Cutaneous mucormycosis*	*Impact phase (0–4 days)*	*Postimpact phase (4 days- 4 weeks)*	*Recovery phase (>4 weeks)*
Population displacement from nonendemic to endemic areas								✓	✓					✓
Overcrowding (close and multiple contacts)	✓			✓	✓	✓	✓						✓	
Stagnant water after flood and heavy rains	✓	✓						✓	✓					✓
Insufficient/contaminated water and poor sanitation conditions	✓		✓										✓	
High exposure and proliferation to disease vectors		✓						✓	✓					
Insufficient nutrient intake/ malnutrition	✓			✓	✓		✓							✓
Low vaccination coverage					✓									
Injuries										✓	✓		✓	✓

†Disasters do not carry diseases/epidemics. Disease risk factors need to be in place and exacerbated as a result of the after effects of the disaster.
ARI: Acute respiratory infection.

Kouadio I, et al. Expert Rev Anti Infect Ther 2012;10:95-104

Waterborne Infectious Diseases Associated with Exposure to Tropical Cyclonic Storms, US, 1996–2018

In the US, tropical cyclones cause destructive flooding that can lead to adverse health outcomes. Storm-driven flooding contaminates environmental, recreational, and drinking water sources, but few studies have examined effects on specific infections over time. We used 23 years of exposure and case data to assess the effects of tropical cyclones on 6 waterborne diseases in a conditional quasi-Poisson model. We separately defined storm exposure for windspeed, rainfall, and proximity to the storm track. Exposure to storm-related rainfall was associated with a 48% (95% CI 27%–69%) increase in Shiga toxin–producing *E. coli* infections 1 week after storms and a 42% (95% CI 22%–62%) in increase Legionnaires' disease 2 weeks after storms. Cryptosporidiosis cases increased 52% (95% CI 42%–62%) during storm weeks but declined over ensuing weeks. Cyclones are a risk to public health that will likely become more serious with climate change and aging water infrastructure systems.

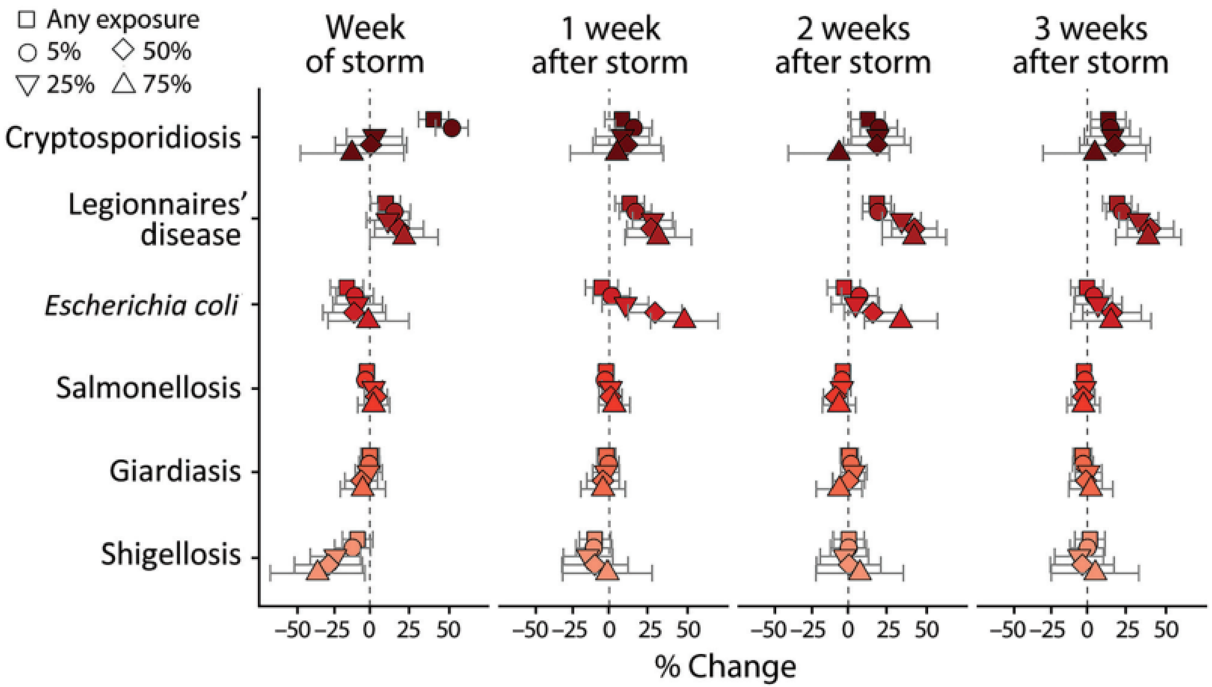
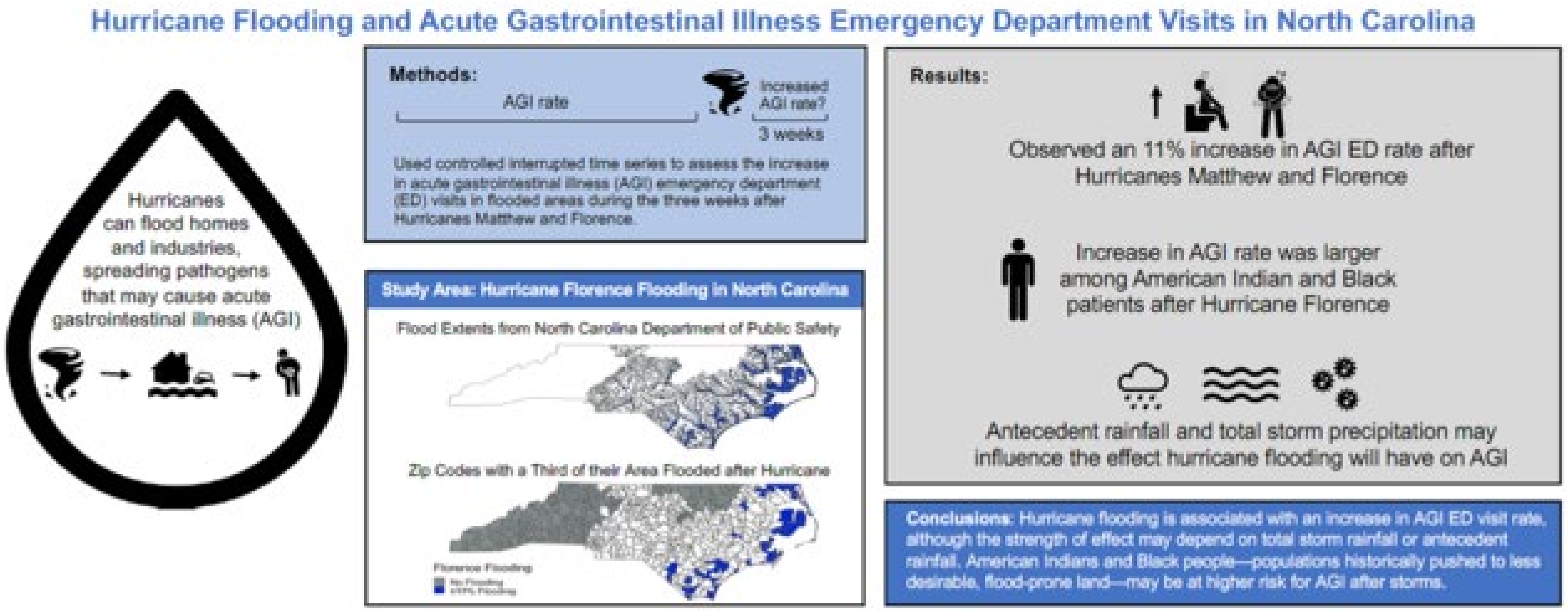


Figure 3. Average percent change in weekly case rates in a study of waterborne infectious diseases associated with exposure to tropical cyclonic storms, United States, 1966–2018. Estimated percentage change (shapes) and Bonferroni-corrected 95% CI (bars) are reported for each infectious disease and population-exposure threshold. Estimates are reported for week of the storm (week 0) and 1–3 weeks after the storm and are associated with exposure to ≥75 mm of storm-related rainfall.

Lynch VD, Shaman J. EID 2023;29:1548

Hurricane Flooding and Acute Gastrointestinal Illness, NC

Hurricanes often flood homes and industries, spreading pathogens. Contact with pathogen contaminated water can result in diarrhea, vomiting, and/or nausea, known collectively as acute gastrointestinal illness (AGI). Hurricanes Matthew and Florence caused record-breaking flooding in NC) in 10/2016 and 9/2018, respectively. We observed an 11% increase (rate ratio (RR): 1.11, 95% CI: 1.00, 1.23) in AGI ED visit rates after Hurricanes Matthew and Florence. This effect was particularly strong among American Indian patients and patients aged 65 years and older after Florence and elevated among Black patients for both hurricanes. When restricted to bacterial AGI, we found an 85% (RR: 1.85, 95% CI: 1.37, 2.34) increase in AGI ED visit rate after Florence, but no increase after Matthew. Hurricane flooding is associated with an increase in AGI ED visit rate, although the strength of effect may depend on total storm rainfall or antecedent rainfall.



Quist AJL, et al.
Sci Total Environ 2022;8089:151108

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VIBRIO VULNIFICUS AFTER HURRICANES, US

Clusters of *Vibrio vulnificus* infections have been reported after Hurricane Katrina, Hurricane Irma (2017) and more recently after Hurricane Ian (2022). After Hurricane Ian, there were a total of 38 reported vibriosis cases with the most common isolated pathogen being *V vulnificus*. *V vulnificus* can cause life threatening, necrotizing skin infections that warrant urgent surgical debridement. Presentation typically occurs after an open wound is directly exposed to flood waters. Patients often present with systemic signs of illness, including fever, hypotension, sepsis, and bullous skin lesions.[7-9]

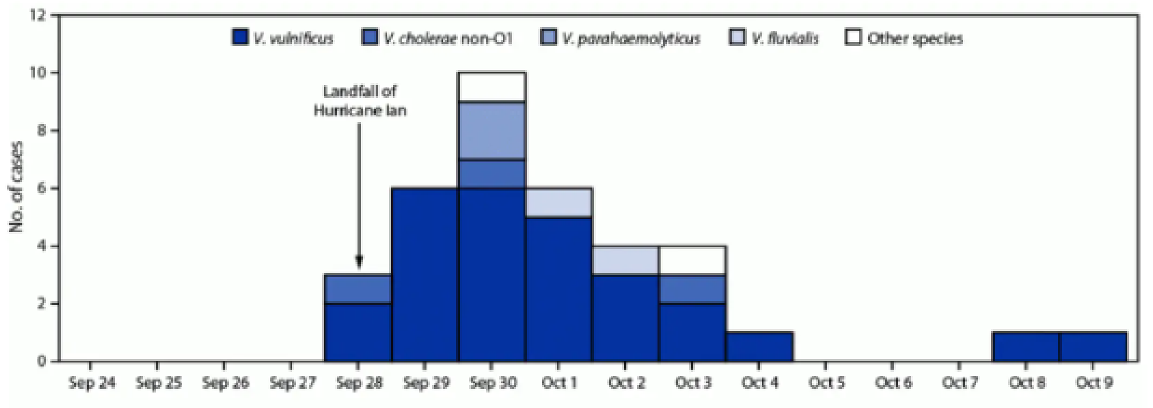

Figure 2. Hurricane Ian-associated vibriosis cases, (N = 38), and deaths (N = 11), by illness onset and Vibrio species—Florida, September 28-October 9 2022.[9]

Florida (10/21/24): Cases/deaths: 2022, 74/17; 2023, 46/11; 2024, 77/15

In 2024 Citrus, Hernando, Hillsborough, Lee, Pasco, Pinellas, and Sarasota Counties experiences unusual increase due to the impacts of Hurricane Helene.*

https://www.contagionlive.com/view/in-the-aftermath-post-hurricane-infections

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IMPACT OF TROPICAL STORMS AND FLOODS ON VECTORBORNE DISEASES

Table. Natural disasters in the continental United States since 1975[a]

Year	State/region	Event	Surveillance done?	Activity detected?	Human cases	Veterinary cases
1975	N.D., Minn.	Red River flood	Yes	WEE[b] in mosquitoes	55 WEE, 12 SLE[c]	281 WEE (estimated)
1989	S.E. United States	Hurricane Hugo	Yes	EEE[d] in mosquitoes	None	(No data)
1992	Fla., La.	Hurricane Andrew	Yes	None	None	None
1993	Ariz.	Gila River flood	Yes	SLE, WEE in mosquitoes	None	None
1993	Midwestern United States	Mississippi, Missouri river flooding	Yes (7 states)	WEE - S.D., SLE - Il.	None	None
1994	Ala., Fla., Ga.	Tropical storm Alberto	Yes	EEE-Al, Fl	None	EEE in horses, emus - Al, Fl
1995	Calif.	Winter & spring floods	Yes	WEE, SLE in sentinel flocks	None	WEE
1996	Calif.	Winter flood	Yes	WEE, SLE in chickens, WEE in mosquitoes	None	None
1996	Oregon, Wash.	Winter flood	No	No	None	None
1996	N.C.	Hurricane Fran	Yes	EEE in mosquitoes	1 EEE	EEE in horses
1997	Colo.	Summer floods	Yes	WEE in chickens	None	None
1997	N.D., Minn.	Red River flood	Sporadic	None reported	None	None

[a] Surveillance data collected by the Division of Vector-Borne Infectious Diseases, Centers for Disease Control and Prevention (CDC). State and local health departments assisted during emergency response. Federal Emergency Management Agency and Emergency Response Coordination Group, National Centers for Environmental Health, CDC, provided field support.
[b] Western equine encephalitis
[c] St. Louis encephalitis
[d] Eastern equine encephalitis

US vectorborne diseases: EEE, WEE, SLE, LAC - Several major floods and hurricanes have been evaluated since 1975 (Table)
Nasci RS, Moore CG. EID 1998;4:333

The types of mosquitoes that can spread viruses may increase 2 weeks after a hurricane.

- These mosquitoes can increase in areas that did not flood but received more rainfall than usual.
- It can take several more weeks before mosquitoes could start spreading viruses to people.

https://www.cdc.gov/mosquitoes/response/index.html#:~:text=Once%20flooding%20recedes%2C%20residents%20can,Use%20air%20conditioning%20when%20possible.

IMPACT OF HURRICANES: SHELTER-RELATED AND EMERGENCY SETTLEMENTS

- Respiratory infections (inhalation)
  - Viral respiratory infections: COVID-19, influenza, RSV, etc.
  - Systemic infections: Measles, mumps, rubella, varicella
  - Tuberculosis
  - Invasive meningococcal disease
- Skin (direct and indirect contact)
  - Ectoparasites: Scabies, lice, bed bugs
  - MRSA
- Gastrointestinal (ingestion)
  - Norovirus
  - Rotavirus
  - *Shigella*
  - *Cryptosporidium*
- Systemic (ingestion)
  - Hepatitis A

Box 10.1 Vectors and diseases likely to be present in emergency settlements

Vector	*Main diseases*
Mosquitoes	Malaria, yellow fever, dengue, viral encephalitis, filariasis.
Houseflies	Diarrhoea, dysentery, conjunctivitis, typhoid fever, trachoma.
Cockroaches	Diarrhoea, dysentery, salmonellosis, cholera.
Lice	Endemic typhus, pediculosis, relapsing fever, trench fever, skin irritation.
Bedbugs	Severe skin inflammation.
Triatomid bugs	Chagas' disease.
Ticks	Rickettsial fever, tularaemia, relapsing fever, viral encephalitis, borreliosis.
Rodent (mites)	Rickettsial pox, scrub typhus.
Rodent (fleas)	Bubonic plague, endemic typhus.
Rodents	Rat bite fever, leptospirosis, salmonellosis, melioidosis.

WHO, Environmental Health In Emergencies and Disasters, A Practical Guide, 2002
https://iris.who.int/bitstream/handle/10665/42561/9241545410_eng.pdf?sequence=1

Infectious Disease and Dermatologic Conditions in Evacuees and Rescue Workers After Hurricane Katrina, Multiple States, August–September, 2005

TABLE. Number of cases of selected diseases and conditions reported in evacuees and rescue workers during the 3 weeks immediately after Hurricane Katrina made landfall — multiple states, August–September 2005

Disease/Condition*	No. of cases	States reporting	Population
Dermatologic conditions			
Infectious			
Methicillin-resistant *Staphylococcus aureus* infections	30 (3 confirmed)	Texas	Evacuees
Vibrio vulnificus and *V. parahaemolyticus* wound infections	24 (6 deaths)	Arkansas, Arizona, Georgia, Louisiana, Mississippi, Oklahoma, Texas	Evacuees
Tinea corporis	17	Mississippi	Rescue workers
Noninfectious			
Arthropod bites (likely mite)	97	Louisiana	Rescue workers
Diarrheal disease			
Acute gastroenteritis, some attributed to norovirus	Approximately 1,000	Louisiana, Mississippi, Tennessee, Texas	Evacuees
Nontoxigenic *V. cholerae* O1	6	Arizona, Georgia, Mississippi, Oklahoma, Tennessee	Evacuees
Nontyphoidal *Salmonella*	1	Mississippi	Evacuee
Respiratory disease			
Pertussis	1	Tennessee	Evacuee
Respiratory syncytial virus	1	Texas	Evacuee
Streptococcal pharyngitis	1	Texas	Evacuee
Tuberculosis	1	Pennsylvania	Evacuee
Other condition			
Presumed viral conjunctivitis	Approximately 200	Louisiana	Evacuees

* Other diseases and conditions, for which the number of cases was unknown, included scabies; circumferential lesions at waist; contact dermatitis; erythematous, papular, pustular rash consistent with folliculitis; immersion foot; prickly heat; influenza-like illness and upper respiratory infections; and head lice.

CDC MMWR 2005;54:961-964

Widespread Outbreak of Norovirus Gastroenteritis among Evacuees of Hurricane Katrina Residing in a Large "Megashelter" in Houston, Texas: Lessons Learned for Prevention

Background. After Hurricane Katrina, an estimated 200,000 persons were evacuated to the Houston metropolitan area, 127,000 of whom were housed in 1 large "megashelter," the Reliant Park Complex

Results. During a period of 11 days, 11000 patients were treated at the clinic for gastroenteritis, which accounted for 17% of all clinic visits. Norovirus was the sole enteric pathogen identified, but multiple different strains were involved. Among the evacuees residing in the Reliant Park Complex, the incidence of gastroenteritis was estimated to be 4.6 visits per 1000 persons per day, and among the evacuees who resided there for 9 days, 1 (4%) of 24 persons would have been ill. Intensive public health measures were promptly instituted but did not definitively slow the progression of the outbreak of norovirus gastroenteritis.

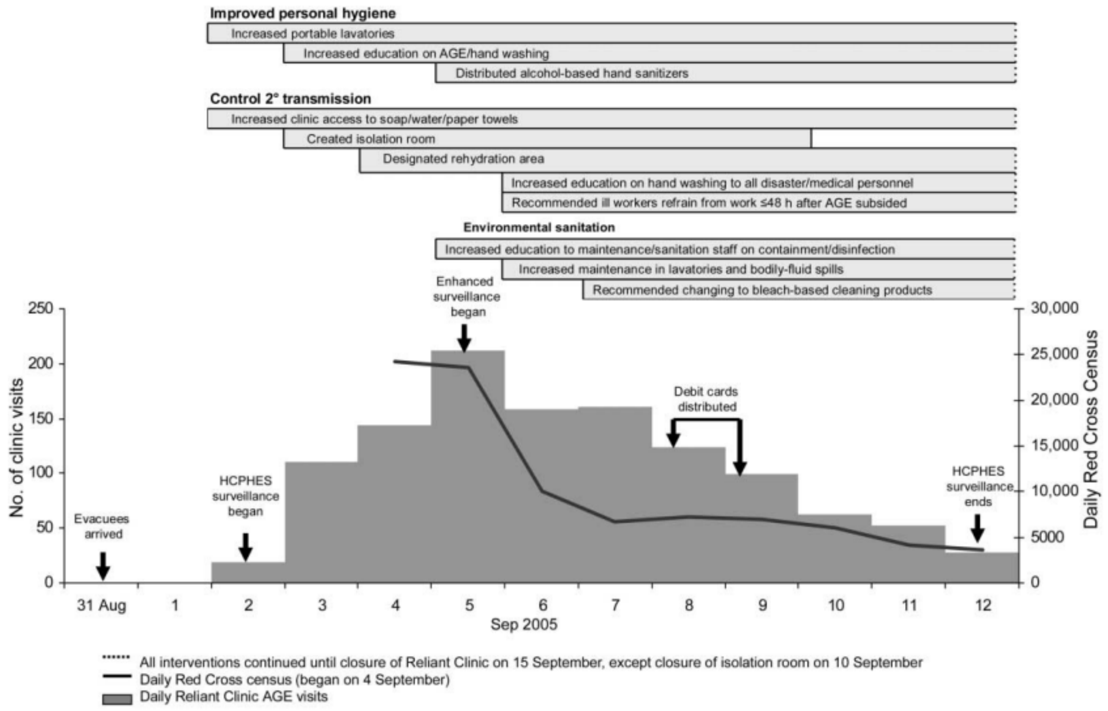

Figure 1. Timeline of interventions used, events, and epidemic curve for the outbreak of norovirus gastroenteritis at the Reliant Park Complex, with the daily Red Cross census, during 2–12 September 2005. AGE, acute gastroenteritis; HCPHES, Harris County Public Health and Environmental Services.

Yee EL, et al. Clin Infect Dis 2007:44:1032-9

MITIGATING RISK OF INFECTIOUS DISEASES POST-TROPICAL CYCLONES OR FLOODING

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Natural disasters and infectious disease in Europe: a literature review to identify cascading risk pathways

Table 3 Lessons learned from natural disasters

Document title	Type of natural disaster	Prevention—before and during disasters					Prevention—after disasters						Long-term prevention	
		Raise healthcare professionals' awareness of post-disaster risks	Advise the public to avoid flood water or bodies of water after flooding/heavy rain	Advise professionals and the public to use PPE around floodwater	Encourage hygiene measures, e.g. hand washing	Vaccination	Prophylactic antibiotics	Surveillance—water sampling	Closure of affected areas	Surveillance—vectors	Vector control	Rodent control	Preparedness plans need flexibility to respond	Improved refuse management
Christova and Tasseva[27]	Flooding		•	•								•		
De Man et al.[28]	Flooding		•	•	•									
Desai et al.[20]	Flooding			•			•							
Gertler et al.[29]	Flooding				•			•	•					
Hubálek et al.[21]	Flooding									•	•			
Kaya et al.[23]	Earthquake					•								
Nigro et al.[24]	Earthquake							•						
Pérez-Martín et al.[25]	Earthquake	•											•	
Radl et al.[22]	Flooding		•											
Socolovschi et al.[32]	Flooding	•												•
Wójcik et al.[34]	Flooding			•	•									

Suk JE, et al. Eur J Public Health 2020;30:928-935

RISK FACTORS FOR POST-FLOOD INFECTIOUS DISEASE MORTALITY, WORLDWIDE

Risk factors for emergence and incidence increase of the most fatal post-flood infectious diseases described worldwide comprise:

1. Poor economic status and living in flood prone areas;
2. Destruction of infrastructures, disruption of public utilities, and interruption of basic public health services;
3. Direct physical exposure to sewage-polluted flood water;
4. Lack of adequate potable water and water-supply from contaminated ponds and tube wells along with lack of distribution of water purification tablets;
5. Aggravation of environmental conditions comprising rapid cooling of the environment and heightened humidity;
6. Population displacement resulting in densely populated and overcrowded regions;
7. Unfavorable living conditions in emergency shelters;
8. Improper and inadequate sanitation or no access to clean water and sanitation;
9. Proliferation and abrupt increase of vector and rodent populations after flooding; and
10. Contamination of water, damp soil, mud or vegetation caused by rodent urine, dead animals, and overflow of latrines.

Mavrouli M, et al. Int J Environ Res and Public Health 2022;19:10206

MITIGATING RISK OF INFECTIOUS DISEASES

- Ensure early diagnosis and treatment of diarrheal diseases and ARI, particularly in those aged <5 years.
- Ensure early diagnosis and treatment for malaria in endemic areas (within 24 hours of onset of fever, using artemisinin-based combination therapy ACT for falciparum malaria).
- Ensure the availability and application of treatment protocols for the main communicable disease threats.
- Ensure proper wound cleaning and care. Tetanus toxoid with or without tetanus immunoglobulin, as appropriate, should accompany wound treatment post disaster.
- Ensure availability of drugs included in the interagency emergency health kit, e.g. oral rehydration salts for management of diarrheal diseases, antibiotics for ARI.
- Distribute health education messages, including: encouraging good hygienic practices;
    - promoting safe food preparation techniques;
    - ensuring boiling or chlorination of water;
    - encouraging early treatment seeking behavior in case of fever;
    - encouraging use of insecticide-treated mosquito nets as a personal
    - protection measure in malaria-endemic areas.

WHO, Communicable diseases following natural disasters, 2006
https://cdn.who.int/media/docs/default-source/documents/emergencies/communicable-diseases-following-natural-disasters.pdf?sfvrsn=4a185b2c_2&download=true

Table 3. Prevention and control checklist of recorded infectious diseases following natural disasters.

Prevention and control of infectious diseases following natural disasters	Water-borne diseases			Air-borne/droplet diseases				Vector-borne diseases		Contamination from injury/wound	
	Diarrhea (cholera; dysentery; others)	*Leptospirosis*	*Hepatitis*	*ARI/pneumonia/ influenza*	*Measles*	*Meningococcal meningitis*	*TB*	*Malaria*	*Dengue fever*	*Tetanus*	*Cutaneous mucormycosis*
Site planning	✓			✓	✓	✓					
Clean water	✓										
Good sanitation (e.g., excreta disposal)	✓		✓								
Solid waste management								✓	✓		
Water and food hygiene	✓		✓								
Nutrition and supplements				✓	✓		✓				
Vaccination					✓						
Vector control								✓	✓		
Personal hygiene (e.g., hand washing)	✓		✓	✓			✓				
Personal protection		✓		✓				✓	✓		
Insecticide-treated nets								✓			
Isolation of the sick				✓			✓				
Prophylactic treatment								✓			
Wound/injury care										✓	✓
Health education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Disease management/treatment and or supportive care (follow national guidelines)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Specific communicable diseases applicable to the preventive and control measure given.
ARI: Acute respiratory infection.

Kouadio I, et al. Expert Rev Anti Infect Ther 2012;10:95-104

IMPACT OF HURRICANES: HEALTHCARE FACILITIES WITHIN DESTRUCTION ZONE

Water intrusion from rain or flooding

- Possible microbial contamination of environment/equipment with pathogens, human/animal waste and hazardous chemicals
- Wet areas unless properly remediated may lead to fungal growth with risks for infection (especially among immunocompromise patients) and/or respiratory aliments (e.g., asthma)
- May lead to electrical hazards
- May damage key equipment
- May impair all healthcare services

Impact of high winds

- Direct infrastructure damage
- Flying objects
- Tornados
- Impaired transportation
- Staffing shortages

IMPACT OF HURRICANES: HEALTHCARE FACILITIES WITHIN AND NEABY DESTRUCTION ZONE

Loss of power

- Inability to perform sterilization/disinfection
- Inability to use EMR (e.g., isolation alerts)
- Possible impact on laboratory (microbiology)
- Spoilage of food
- Inability to provide heat and cooling (may result in high humidity; may impact sterile packs)
- Impaired transportation; to and within hospital (elevators)

Loss of potable water

- Inability to use sinks for HH
- Inability to flush toilets
- Impact on sterilization/disinfection
- Impact on dialysis
- Boiled water advisories (will not eliminate chemical contaminants)

Infections

- Increase in patients admitted with MDRO pathogens (e.g., MRSA)
- Outbreaks and pseudo-outbreaks due to fungi

Other

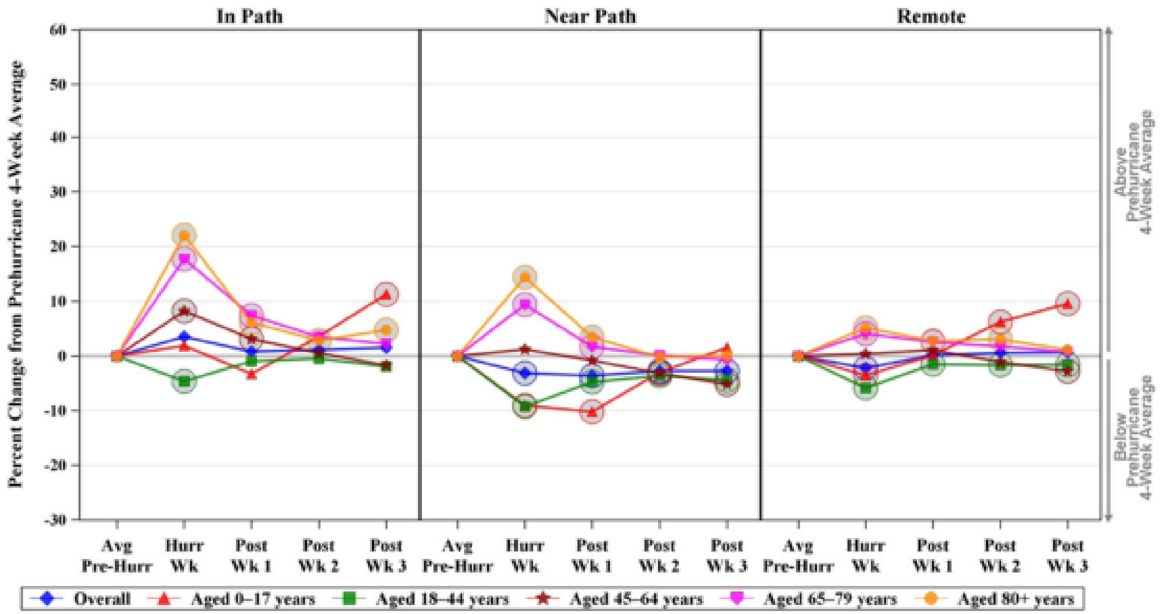
- Staffing difficulties due to transportation issues and/or staff housing
- Increased patient demand
    - Storm related medical events
    - Closing of local medical offices
- Supply shortages
    - Limited transportation
    - Damage to production facilities
- Increased staff stress
- Lack of access to healthcare exacerbating pre-existing conditions
- Increase in violence

Effects of Hurricanes on Emergency Department Utilization: An Analysis Across Seven U.S. Storms

Objective: EDs are critical sources of care after natural disasters such as hurricanes. This study examines changes in ED utilization for residents in 344 counties after seven U.S. hurricanes between 2005 and 2016.

Methods: This retrospective observational study used ED data from the Healthcare Cost and Utilization Project State Inpatient Databases and State Emergency Department Databases.

Results: The overall population rate of weekly ED visits changed little post-hurricane, but rates by disease categories and age demonstrated varying results. Utilization rates for respiratory disorders exhibited the largest post-hurricane increase, particularly 2–3 weeks following the hurricane. The change in population rates by disease categories and age tended to be larger for people residing in counties closer to the hurricane path.



Source Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, State Emergency Department Databases and State Inpatient Databases, 11 states, 2005–2016

Notes Statistically significant change in population-weighted rate from the prehurricane 4-week average to the week of and the 3 weeks after the hurricanes denoted by a circle, $P<0.05$. Avg is average, Hurr is hurricane, Wk is week.

Figure 1.

Percent Change in Weekly ED Visits per 10,000 from Prehurricane to the Hurricane Week and 3 Weeks Posthurricane, by Hurricane Proximity and Patient Age

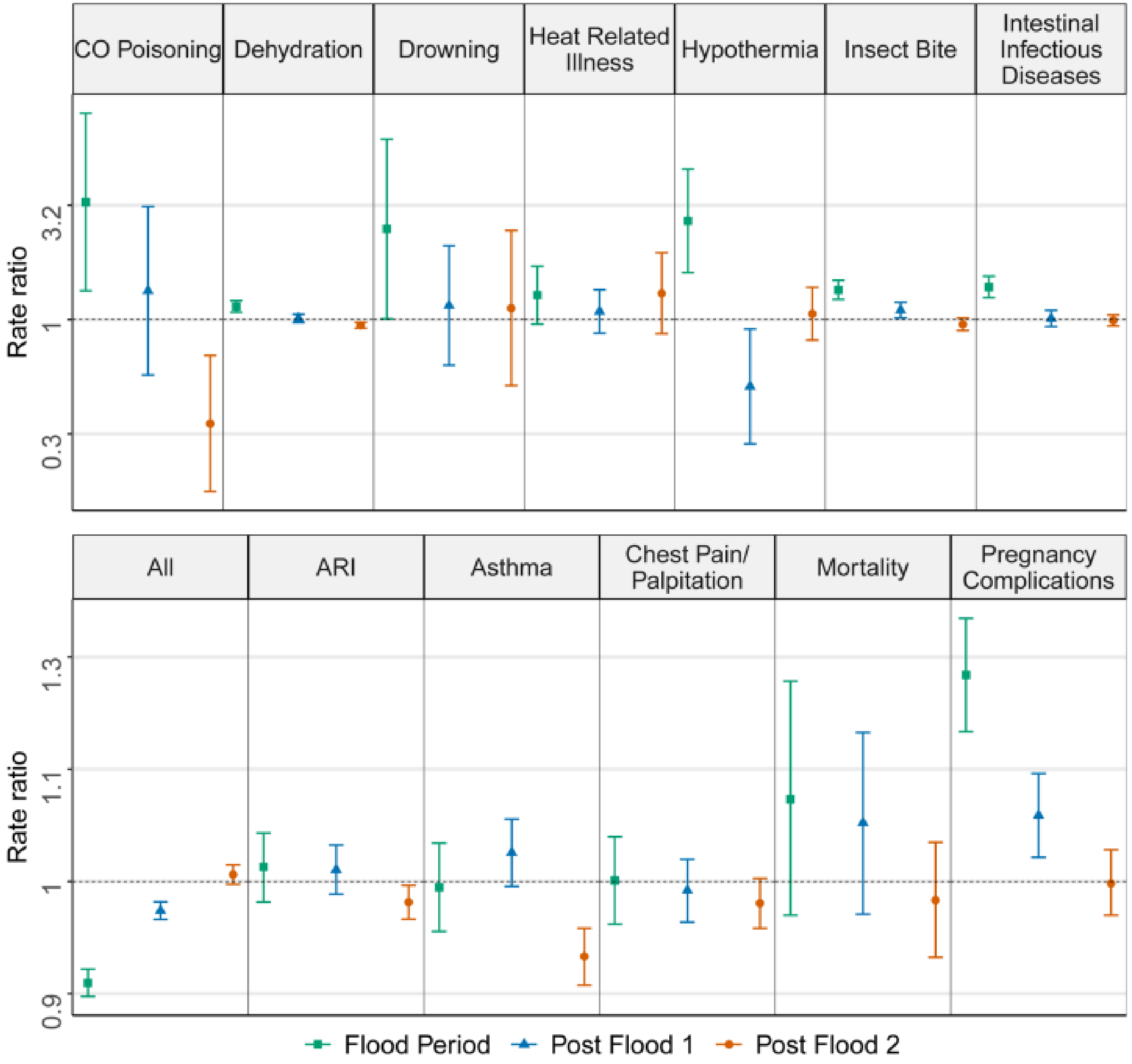
Heslin KC, et al. Disaster Med Public Health Prep. 2021 December ; 15(6): 762–769

Emergency Department visits associated with satellite observed flooding during and following Hurricane Harvey

Background: Flooding following heavy rains precipitated by hurricanes has been shown to impact the health of people.

Objective: To evaluate emergency department (ED) visits before, during, and following flooding caused by Hurricane Harvey in 2017 in Texas.

Results: Flooding was associated with increased ED visits for carbon monoxide poisoning, insect bite, dehydration, hypothermia, intestinal infectious diseases, and pregnancy complications. During the month following the flood period, the risk for pregnancy complications and insect bite was still elevated in the flooded tracts.



Remesh B, et al. J Expo Sci Environ Epidemiol 2021;31:832-841

Colonization With Multidrug-Resistant Organisms in Evacuees After Hurricane Katrina

After Hurricane Katrina, 50 patients were evacuated to Grady Memorial Hospital in Atlanta, Georgia, with limited medical records. The infection control department ordered contact precautions for16 patients. Surveillance cultures performed on admission identified colonization with multidrug-resistant (MDR) bacteria in 9 patients (18%). Presence of a wound was the strongest predictor for MDR colonization. More data are needed to reliably predict MDR bacterial colonization.

Seybold U, et al. ICHE 2007;28:726-729

TABLE 1. Characteristics and Univariate Analysis of Risk Factors for Colonization With Multidrug-Resistant (MDR) Bacteria Among 50 Hurricane Katrina Evacuee Patients

Risk factor	All (N = 50)	Not colonized with MDR bacteria (N = 41)	Colonized with MDR bacteria (N = 9)	Crude prevalence odds ratio (95% CI)	P[a]
Contact precautions initiated[b,c]	16 (32)	**9 (22)**	**7 (78)**	**12.4 (2.2-70.7)**	**.003**
Age, median (range), years	53.5 (0-101)	52 (0-96)	65 (19-101)	NA: continuous	.31[d]
Age >71 years (upper quartile)	12 (24)	8 (20)	4 (44)	3.3 (0.72-15.2)	.19
Female sex	26 (52)	20 (49)	6 (67)	2.1 (0.46-9.6)	.47
African American race	39 (78)	34 (83)	5 (56)	0.26 (0.05-1.2)	.09
Location prior to evacuation					
Private residence	27 (54)	24 (59)	3 (33)	0.36 (0.08-1.6)	.27
Long-term care facility	5 (10)	**2 (5)**	**3 (33)**	**9.7 (1.3-80.0)**	**.03**
Hospital	17 (34)	14 (34)	3 (33)	0.96 (0.21-4.4)	1.00
Evacuated via shelter	11 (22)	10 (24)	1 (11)	0.39 (0.04-3.5)	.66
Wheelchair- or bed-bound[b]	24 (48)	18 (44)	6 (67)	2.6 (0.56-11.6)	.28
Admission to ICU[b]	7 (14)	4 (10)	3 (33)	4.6 (0.82-26.0)	.10
Wound[b]	13 (26)	**7 (17)**	**6 (67)**	**9.7 (1.9-48.4)**	**.006**
Invasive device[b,e]	11 (22)	**6 (15)**	**5 (56)**	**7.3 (1.5-35.2)**	**.02**
Systemic antibacterial therapy[b]	20 (40)	14 (34)	6 (67)	3.9 (0.84-17.8)	.13
Length of hospital stay, median (range), days	7 (1-44)	7 (1-44)	6 (2-15)	NA: continuous	.13[d]
Crude in-hospital mortality	2 (4)	2 (5)	0	0	1.00

TABLE 2. Characteristics of the 9 Patients Evacuated After Hurricane Katrina Who Were Colonized by Multidrug-Resistant Bacteria

Patient	Age in years; sex	Race or ethnicity	Location prior to evacuation	Wound present	Invasive device present	Systemic antibacterial therapy given on admission	Culture sample, organism recovered
1[a]	51; F	African American	Hospital	Yes	Yes	Yes	Rectal, VR *Enterococcus faecalis*
2[a]	19; F	White	LTCF	No	Yes	No	Nares and rectal, ESBL *Klebsiella oxytoca*; oral, MDR *Pseudomonas aeruginosa*
3[a]	33; M	Hispanic	Hospital	Yes	Yes	Yes	Rectal, MDR *Enterobacter aerogenes*
4[a]	65; M	African American	LTCF	Yes	Yes	Yes	Oral, MDR *Morganella morganii*
5[a]	101; F	African American	Hospital	Yes	No	Yes	Rectal, VR *Enterococcus faecium*
6	50; F	African American	Home	No	No	No	Nares, MRSA USA100 (PVL−)
7[a]	80; F	White	Home	Yes	No	Yes	Nares, MRSA USA1000 (PVL−); rectal, MDR *Escherichia coli*
8[a]	74; M	Asian	LTCF	Yes	Yes	Yes	Nares, MRSA USA300 (PVL+); rectal, MRSA USA100 (PVL−)
9	73; F	African American	Home	No	No	No	Nares, MRSA USA300 (PVL+)

NOTE. USA100, USA1000, and USA300 are MRSA clones defined by McDougal et al.[7] VR, vancomycin resistant; LTCF, long-term care facility; ESBL, extended-spectrum β-lactamase–producing; MRSA, methicillin-resistant *Staphylococcus aureus*; PVL−, genes for Panton-Valentine leukocidin not detected by polymerase chain reaction (PCR) assay; PVL+, genes for Panton-Valentine leukocidin detected by PCR assay.

[a] Enhanced precautions implemented on admission by the Infection Control/Hospital Epidemiology Department.

Healthcare-associated infections and their prevention after extensive flooding

KEY POINTS

- There is evidence to suggest an increase in HAIs due to some bacteria (e.g., *Legionella* spp.), nontuberculous *Mycobacterium* spp., and environmental molds following extensive flooding.
- Surveillance and early case detection together with prompt investigation may help avert unnecessary workups and exposure to unnecessary antibiotic and/or antifungal therapy.
- Hospital infection prevention policies, particularly with air quality monitoring, mold remediation and area decontamination with repeated and thorough environmental cleaning play a key role in reducing HAIs following extensive flooding.

Apisarnthanarak A, et al
Curr Opin Infect Dis 2013;26:359-365

Table 1. Organisms resulting in healthcare-associated infections after extensive flooding, risk factors and preventive measures

Type of organism/references	Specific pathogens	Risk factors	Preventive measures
Bacteria [12–14,23,24••]	Water-borne enteric GNB (e.g., *Aeromonas* spp., *Vibrio* spp.)	Contamination of water source	Periodic potable water quality assessment and investigation for point source, if indicated
		Contamination of internal plumbing	Environmental cleaning
		Contaminated wound	
	Legionella spp.	Contamination of water source	Periodic potable water quality assessment and investigation for point source
		Contamination of internal plumbing	Remediate with chlorine dioxide and then copper–silver ionization of water sources
	MDROs[a]	Hospital with lack of environmental cleaning policy	Repeated and thorough environmental cleaning
		Lapses in basic infection control practices	Consider using special approaches (e.g., hydrogen peroxide vaporizer) in high-risk units
Mycobacterium spp. [25–29]	Nontuberculous *Mycobacterium* spp.	Contamination from laboratory	Periodic water quality assessment
		Contamination of water source	Remove contaminant from water source, if detected
		Contamination of ice machine and drinking water	Prompt investigation after case detection
		Contamination in patient sputum	
Molds [35–37]	Environmental molds (e.g., *Aspergillus* spp., *Penicillium* spp., *Fusarium* spp.)	High fungal air bio-burden	Repeated and thorough environmental cleaning
		No HEPA filtration	Serial monitoring of fungal air bio-burden
		Contaminated HVAC system	Consider using special approaches (e.g., hydrogen peroxide vaporizer) in high-risk units
		Poor maintenance of air filtration	Contain construction sites
		Construction/demolition in/near hospital	Scheduled maintenance for HVAC/HEPA system

GNB, Gram-negative bacilli; HEPA, high efficiency particulate air; HVAC, heating, ventilation and air conditioning system; MDROs, multidrug-resistant organisms.
[a]including methicillin-resistant *Staphylococcus aureus*, extended-spectrum beta-lactamases producing Enterobacteriaceae, multidrug resistant *Acinetobacter baumannii*, multidrug-resistant *Pseudomonas aeruginosa*.

A Polymicrobial Fungal Outbreak in a Regional Burn Center after Hurricane Sandy

Objective: To describe a polymicrobial fungal outbreak after Hurricane Sandy

Design: An observational concurrent outbreak investigation and retrospective descriptive review.

Setting: A regional burn intensive care unit in the greater Baltimore area

Results: A polymicrobial fungal outbreak in burn patients was temporally associated with Hurricane Sandy and associated with air and water permeations in the hospital facility. The outbreak abated after changes to facility design.

Pathogens: *Aspergillus* spp. (predominate pathogen), *Fusarium, Mucor, Rhizopus, Curvularia, Trichosporon, Aurreobasidum*, and *Penicillium*.

Sood G, et al. Am J Infect Control 2018;46:107-50

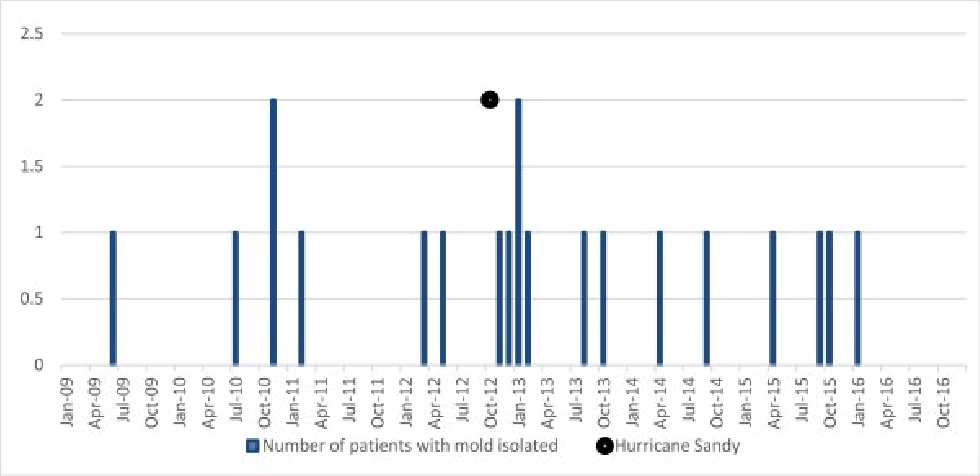


Fig 1. Epidemiologic curve, 2009-2016 – unique patients

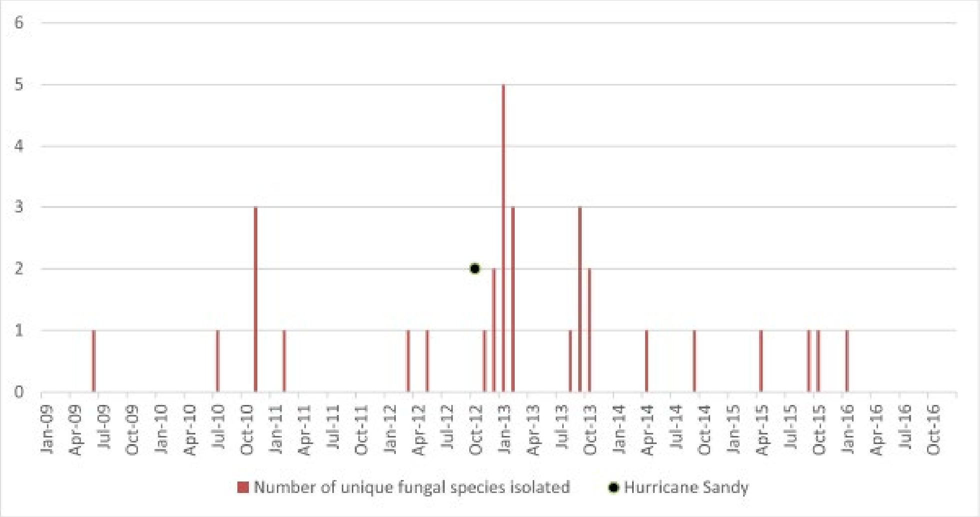


Fig 2. Epidemiologic curve, 2009-2016 – unique fungal species

Hospital Flood Preparedness and Flood-Related Psychological Consequences in 15 Provinces in Central Thailand after Implementation of a National Guideline

Severe flooding occurred in central Thailand during the period Sept-Nov 2011, which resulted in the closure of more than 30 regional hospitals. A national guideline for hospital preparedness after flooding was made available in Thailand on May 14, 2012. From May 15, 2012, through June 30, 2012, there were several meetings to promote this national guideline for hospital flood preparedness. To evaluate hospital preparedness as well as to assess the psychological impact of floods among infection preventionists (IPs) in the initial 6-month interval after flooding, we conducted a survey.
In this follow-up survey, several gaps identified during the flooding (eg, surge capacity plans for patients and staff, plan for environmental cleaning, and fungal decontamination protocols) were significantly improved by 50%-100% after implementation of the national guideline for hospital flood preparedness. We also identified that this major flood had significant psychological consequences for lead IPs.

TABLE 1. Reported Obstacles Related to Hospital Flood Preparedness (HFP) Plan and HFP Improvement after Flooding among Infection Preventionists at 32 Flooded Hospitals

	No. (%) of hospitals	
Hospital flood preparedness plan	Lack of adequate plans during flood (n = 32)	Plan improved 6 months after flood (n = 8)
Flood protocol	8 (25)	8/8 (100)
Exercise or drill of flood protocol	16 (50)	16/16 (100)
Protocol to help hospital personnel and families during and after flood	15 (47)	6/15 (40)
Stockpile of PPE for use	6 (19)	5/6 (83)
Protocol for appropriate PPE use	5 (16)	3/5 (60)
Surge capacity plans	21 (66)	11/21 (52)
Plans for opening flood-unaffected units for use	3 (9)	2/3 (67)
Environmental cleaning and fungal decontamination protocols	26 (81)	17/26 (65)
Plans for operating isolation units	10 (31)	5/10 (50)
Plans for operating clinical laboratories	3 (9)	2/3 (67)
Protocol for equipment disinfection and sterilization	8 (25)	7/8 (88)
Protocol to mitigate odor	18 (56)	7/18 (39)
Protocol for waste management	5 (16)	4/5 (80)
Administration support	3 (9)	2/3 (67)

NOTE. PPE, personal protection equipment.

Apisarnthanarak A, et al. ICHE 2013,34:655-6

Latent TB Infection in Nurses Exposed to TB Patients Cared for in Rooms without Negative Pressure after the 2011 Great East Japan Earthquake

- In the aftermath of the Great East Japan Earthquake on March11, 2011, Miyagi Cardiovascular and Respiratory Center, a designated tuberculosis (TB) center, was unable to provide negative pressure rooms as a result of lack of electricity and damage to our generator.
- **Baseline** TB infection prevention: Use of N95 respirators by HCP; patient placement in rooms maintained at negative pressure with respect to the corridor and direct out exhausted air.
- At the time during which there was inadequate ventilation, there were 23 smear-negative TB patients and 2 smear-positive TB patients (1+ and 3+). Compliance poor with N95 use; N95s not worn at nurses station. Smear positive patients cared for on team Y.
- Overall, 3 (20%) of 15 nurses were IGRA positive

Kanamori H…Weber DJ, et al. ICHE 2012;33:204-206

TABLE 1. Exposure Time to Patients with Smear-Positive Tuberculosis (TB) among Nurses and Result of Interferon-γ Release Assay (IGRA)

		Total time, hours			
Nurse	Age, years	Working under no negative pressure room	Exposure time to smear-positive TB	Aerosol-generating procedures for smear-positive TB	IGRA result
Team X					
A	30–39	16	5	1	Negative
B	40–49	32	2	0	Negative
C	40–49	32	1.3	0	Negative
D	40–49	24	1.5	0	Negative
E	50–59	24	0.5	0	Negative
F	50–59	24	1.5	1	Negative
Team Y					
G	20–29	16	2	0	Negative
H	40–49	32	9	1	Negative
I	40–49	24	10	2	Negative
J	40–49	16	1	0	Negative
K	40–49	24	9	1	Positive
L	50–59	8	5	0	Negative
M	50–59	24	9	1	Positive
No team					
N	40–49	24	0.5	0	Negative
O	60–69	24	1.5	0	Positive

Two IGRA-positive nurses were derived from team Y, whereas all nurses in team X were IGRA negative. Two (50%) of the 4 nurses who were exposed to smear-positive TB for more than 9 hours were IGRA positive, whereas 1 (9.1%) of the 11 nurses who were exposed to smear-positive TB for less than 5 hours was IGRA positive.

IMPACT OF HELENE ON NC BAXTER PLANT

- NC Baxter facility damaged by hurricane Helene
- No timetable for reopening
- Products ~60% of IV fluids used in US
- IV fluids on allocation
- Hospitals to receive only 40% of usual allotment
- FDA working with alternative suppliers to increase production
- Key conservation methods for ID and Stewardship
  - Change TKO IV to heplocks
  - If appropriate change IV bags to IV push (e.g., cefepime)
  - Early IV to PO switch (or only PO)
  - Appropriate duration of IV antibiotics
  - Eliminate IV fluid lavage during surgeries

Baxter's North Cove manufacturing facility after Hurricane Helene in Marion, N.C., on Oct. 2, 2024. *Retrieved from Aerial Lens on October 04, 2024*

Key issues

- A natural disaster is a catastrophic event defined as a disruption of human ecology that exceeds the community's capacity to adjust, so that the outside assistance is needed.
- The overwhelming number of deaths immediately after a natural disaster are directly associated with blunt trauma, crush-related injuries and burn injuries.
- No certain risk of an infectious disease epidemic occurring in the short-term period after a disaster has been well documented.
- There is no proven evidence that corpses resulting from natural disasters increase the risk of infectious disease transmission.
- Infectious diseases transmission or outbreaks may be seen days, weeks or even months after the onset of the disaster and is due to massive population displacement and exacerbation of risk factors for disease transmission, such as the increasing size and characteristics of the displaced population within the local disease ecology, unplanned and overcrowded shelters or camps, lack of food, safe water and functioning latrines, poor personal hygiene and nutritional status, and low level of immunity to vaccine-preventable diseases.
- The potential infectious diseases resulting from natural disasters in our study included diarrheal diseases, leptospirosis, hepatitis fever, typhoid fever, acute respiratory infection, measles, meningitis, TB, malaria, dengue fever, tetanus and cutaneous mucormycosis.
- Epidemiological assessment for public health planning and resource allocation (e.g., drugs and water purification tablets) is essential in emergency assistance situations.
- Flooding is the most common natural disaster described with an increase in cases or outbreaks of infectious diseases including diarrhea, malaria and leptospirosis.
- Ideal prevention and control measures should include a strong disaster preparedness plan; surveillance systems for early case detection and treatment; adequate site planning following international guidelines; appropriate management of water and sanitation systems; adequate food supplies and storage; and a strong vector control and vaccination programs.
- Several management protocols are available, but those in accordance with the national guidelines must be used.
- The recommended control approach remains re-establishng and improving the delivery of primary healthcare through the restoration of affected health services.

Kouadio I, et al. Expert Rev Anti Infect Ther 2012;10:95-104

CONCLUSIONS

- Climate change is leading to increased temperatures, precipitation (in certain locals), heat waves and extreme weather (e.g., tropical cyclones).
- Health effects of climate change include temperature related illnesses and death, water- and foodborne diseases, vector- and rodentborne diseases, and extreme weather events-related health effects (including infectious diseases).
- Natural disasters kill ~40,000 to 50,000 persons per year. Deaths from disasters have decreased over the last century but climate change may lead to a reversal of this pattern.
- The frequency of the very most damaging hurricanes in the US has increased at a rate of 330% per century.
- Driving factors for the increased impact of tropical cyclones include warmer ocean temperatures, rising sea water levels, and land subsidence plus increased number of persons living in "high risk" areas.
- Three NC cities lead the list of the most number of hurricanes per decade making landfall in the US.
- Major risks of hurricanes:
    - Non-infectious: Drowning, blunt force trauma, CO poisoning, electrocution, psychiatric, and medical (heart attacks, stokes, respiratory ailments)
    - Infectious: Skin and wound infections, gastroenteritis, respiratory tract infections, and vectorborne-infections
- Planning can decrease the impact of tropical cyclones including at the hospital level
- **Major Concern**: NOAA Planning to Shrink Staff by 20% (Of 13,000 workers, 1,300 already resigned/laid off, 1,000 additional likely)*

*https://www.nytimes.com/2025/03/08/climate/noaa-layoffs-trump.html

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