

Superimposed threats to population health from tropical cyclones in the prevaccine era of COVID-19



The COVID-19 pandemic has produced a public health emergency of international concern throughout 2020, surpassing 30 million cases and 1 million deaths worldwide during September. As we progress through the peak of the 2020 cyclone seasons, the COVID-19 threat will intersect with the growing risk from extreme storms, spurred by global environmental climate change.¹

Evidence continues to mount that climate change is making tropical systems stronger (rapid intensification, higher peak wind speeds, and more category 4 and 5 storms), wetter (towering storm surge, elevated precipitation rates and rainfall totals, and coastal and inland flooding risks), and slower forward moving when they come onshore.^{2,3} As a corollary, as climate change modifies the behaviour of tropical cyclones, human health is imperiled for storm-impacted communities, as these populations are exposed to more injurious and traumatising storm hazards, coupled with incapacitating damage to infrastructure, crippling resource losses, enduring life changes, and disproportionate effects on the most vulnerable.^{4,5}

Worldwide, proven approaches for population protection from tropical cyclones include storm detection, tracking, and warning systems coupled with evacuation and sheltering. These strategies move and gather people together into safer, durable structures. In contrast, strategies that aim to curb COVID-19 transmission rely on physical distancing, lockdowns, and restricting mass gatherings, approaches that separate and keep people apart. This fundamental incompatibility makes it impossible to eliminate both risks concurrently when a tropical cyclone threatens a population in which COVID-19 is actively circulating.^{6,7}

The incompatibility creates two offsetting concerns. First, a primary preoccupation of emergency managers is that people will fail to heed evacuation orders owing to fear of COVID-19, leading to preventable injury and death. Second, the reciprocal issue is that evacuation and sheltering procedures might lead to a spike in COVID-19 cases. This likelihood is underscored by evidence indicating that COVID-19 spreads readily via asymptomatic⁸ and airborne transmission⁹ and super-spreader events.¹⁰ Recent tropical cyclones that have

made landfall on island-based populations and coastal populations illustrate the dangers inherent in these intersecting challenges.

Prepandemic, category 5 hurricane Dorian decimated the Abaco Islands, The Bahamas, in September, 2019, bearing the stronger-wetter-slower-moving signature of a climate-driven storm.⁵ Most residents had to abandon their destroyed homes and relocate off island. Then came COVID-19. The Bahamas imposed strict travel bans and border lockdowns, successfully minimising cases through to late July 2020, but severely stalling the Dorian recovery efforts. In the late summer, when The Bahamas eased restrictions, COVID-19 immediately proliferated, with cases reaching the Abaco Islands.

In April 2020, tropical cyclone Harold strengthened to category 5 intensity over warm South Pacific waters, sequentially interacting with the Solomon Islands, Vanuatu, Fiji, and Tonga. Stalling over Vanuatu, Harold destroyed 80% of homes on the islands of Espiritu Santo and Pentecost, displacing 80 000 residents and devastating crops and livestock. Tight border controls, travel restrictions, and port closures enacted before Harold limited COVID-19 transmission to 32 cases in Fiji, even through to September, and no cases in the other three island nations. Conversely, these measures greatly diminished the timeliness, extent, and effectiveness of relief efforts. Humanitarian aid workers were forced to leave just weeks before the storm and are required to quarantine before re-entry. The economic effects of the global COVID-19 crisis decreased donations to fund relief efforts.

Moving northward over anomalously warm waters of the Bay of Bengal separating east India from Bangladesh, super-cyclone Amphan rapidly intensified from category 1 to category 5 in less than 24 h. Despite enforced COVID-19 lockdowns in both nations, the overriding imperative was to implement mass evacuation. Bangladesh moved 2.2 million citizens, and India evacuated 4.3 million into thousands of shelters before Amphan's devastating impact on the Sunderbans and Kolkata on May 21, 2020. Amphan was the costliest storm ever in the north Indian Ocean (US\$13.6 billion), but mortality was held to 118 deaths even as the relief

efforts are likely to have spurred COVID-19 spread. Although reports of spikes in COVID-19 cases related to Amphan evacuation were difficult to confirm and quantify, there was no doubt that relief workers had to contend with the double danger of conducting rescue operations in areas with high prevalence of contagion. The overarching focus on pandemic control has diluted and prolonged the recovery process.

In just over 2 months, Hanna, Laura, Marco, Sally, Beta, and Delta all moved over warm Gulf of Mexico waters before impacts in Texas, Louisiana, Mississippi, Alabama, and Florida at the time when the hurricane coast states were enduring a dramatic summer surge of COVID-19 cases.⁷ Many of the actions taken were experimental tests of pandemic safety protocols that were devised and modified depending on the nature of the storm.

Hanna was strengthening as it made landfall close to Corpus Christi, Texas and then veered southwestward over the Rio Grande Valley; locales that had the highest prevalence of COVID-19 hospitalisations in the nation as Hanna was striking. Sheltering was modified to attempt to increase personal space and separate those with known COVID-19 infection.

Laura was the Atlantic basin's first major hurricane, rapidly intensifying to just below category 5 wind speeds as it came ashore near Lake Charles, Louisiana, retaining hurricane strength as it moved northward through the state, almost to the Arkansas border. At that moment, Louisiana had the highest per capita prevalence of COVID-19 of any US state. More than 1.5 million people were notified to evacuate as Laura approached. The National Hurricane Center warned of an "unsurvivable storm surge with large and destructive waves". Various shelter arrangements were improvised including single-occupancy hotel rooms and restricting spaces in some shelters to groups of less than 50 people. The situation post-storm was grave owing to extensive structural damage, widespread power outages, shortage of water, closed COVID-19 testing sites along the coast, and population displacement.

Hurricane Sally hovered for days offshore from the northern Gulf coast, undergoing multiple cycles of re-intensification, and pummeling Alabama and the Florida panhandle with flooding rains and coastal wave action. Rainfall totals exceeded 30 inches (75 cm) and 500 000 lost power. Just days later, Beta likewise stalled,

producing flooding conditions for days in Houston and its vicinity. Delta was the second, rapidly-intensifying, major hurricane to impact the Gulf, coming ashore just 12 miles away from where Laura made landfall, re-impacting areas that had previously sustained severe damage, and bringing deluging rains through the southeastern states.

In the northwestern Pacific, super typhoon Haishen increased to category 4 strength over the Sea of Japan, clipping Japan before moving through the South China Sea and making landfall in South Korea as a category 2 storm. Haishen was the third typhoon to affect South Korea in a period of 2 weeks, preceded by typhoons Bavi and Maysak. Both Japan and South Korea have had some degree of COVID-19 resurgence during the summer months but both nations appear able to contain the spread through standard public health measures.

A remarkably active season is underway as cyclonic storms continue to develop worldwide. Case examples through mid-October illustrate the complex challenges for mitigating superimposed cyclone and COVID-19 risks. Most storms formed over unseasonably warm waters, many intensified rapidly, and several stalled over land, factors that are likely to be linked to climate change. Populations in the path modified and contrived evacuation and sheltering protocols to minimise COVID-19 spread, tailored to the specific hazards encountered. Communities grappled with finding safer accommodations for storm-displaced survivors despite the unrelenting COVID-19 transmission risks. While these dilemmas are particularly acute during the pre-vaccine era for COVID-19 in 2020, they serve as a portent for future compound-threat scenarios as climate change exacerbates harm from natural disasters and, concurrently, pandemic diseases emerge with increasing frequency.

We declare no competing interests.

Copyright © 2020 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY-NC-ND 4.0 license.

*James M Shultz, James P Kossin, Aleeza Ali, Veronica Borowy, Craig Fugate, Zelde Espinel, Sandro Galea
jshultz1@med.miami.edu

Center for Disaster and Extreme Event Preparedness, Department of Public Health Sciences, University of Miami Miller School of Medicine, Miami, FL 33136, USA (JMS); NOAA's National Centers for Environmental Information, Center for Weather and Climate, Madison, WI, USA (JPK); Herbert Wertheim College of Medicine, Miami, FL, USA (AA); Department of Public Health Sciences, University of Miami Miller School of Medicine, Miami, FL, USA (VB); Craig Fugate

Consulting, Gainesville FL, USA (CF); Sylvester Comprehensive Cancer Center, Department of Psychiatry and Behavioral Sciences, University of Miami Miller School of Medicine, Miami, FL, USA (ZE); and School of Public Health, Boston University, Boston, MA, USA (SG)

- 1 Salas RN, Shultz JM, Solomon CG. The climate crisis and COVID-19: a major threat to the pandemic response. *N Engl J Med* 2020; **383**: e70.
- 2 Kossin JP, Knapp KR, Olander TL, Velden CS. Global increase in major tropical cyclone exceedance probability over the past four decades. *Proc Natl Acad Sci USA* 2020; **117**: 11975–80.
- 3 Knutson T, Camargo SJ, Chan JCL, et al. Tropical cyclones and climate change assessment: Part I: Detection and attribution. *Bull Am Meteorol Soc* 2019; **100**: 1987–2007.
- 4 Shultz JM, Kossin JP, Shepherd JM, et al. Risks, health consequences, and response challenges for small-island-based populations: observations from the 2017 Atlantic hurricane season. *Disaster Med Public Health Prep* 2019; **13**: 5–17.
- 5 Shultz JM, Sands DE, Kossin JP, Galea S. Double environmental injustice—climate change, Hurricane Dorian, and the Bahamas. *N Engl J Med* 2020; **382**: 1–3.
- 6 Shultz JM, Kossin JP, Hertelendy A, et al. Mitigating the twin threats of climate-driven Atlantic hurricanes and COVID-19 transmission. *Disaster Med Public Health Prep* 2020; published online July 14. <https://doi.org/10.1017/dmp.2020.243>.
- 7 Shultz JM, Fugate C, Galea S. Cascading risks of COVID-19 resurgence during an active 2020 Atlantic hurricane season. *JAMA* 2020; **324**: 935–36.
- 8 Oran DP, Topol EJ. Prevalence of asymptomatic SARS-CoV-2 infection: a narrative review. *Ann Intern Med* 2020; **173**: 362–67.
- 9 Morawska L, Milton DK. It is time to address airborne transmission of COVID-19. *Clin Infect Dis* 2020; published online July 6. <https://doi.org/10.1093/cid/ciaa939>.
- 10 Kwok KO, Chan HHH, Huang Y, et al. Inferring super-spreading from transmission clusters of COVID-19 in Hong Kong, Japan, and Singapore. *J Hosp Infect* 2020; **105**: 682–85.