When Disasters and Pandemics Interact: State-Level Predictors of Compound vs. Cascading Effects

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Background

- Given the extended timelines of epidemics and pandemics, multiple disasters are likely to arise concurrently.
- Frequency and severity of natural disasters and infectious disease outbreaks have increased with the intensifying impacts of climate change.
- **US National Oceanic & Atmospheric Administration** (NOAA) maintains a **database of Billion-Dollar Disasters** (BDDs) – disasters in the US causing over a billion dollars in damages.[1]
- The COVID-19 pandemic demonstrated firsthand the challenges and consequences that **compound** (or concurrent) and **cascading** (with one event triggering another) public health emergencies and natural disasters can have across all levels.
- **Aim: To identify state-level characteristics that might increase the likelihood or severity of health and disaster impacts when these events occur concurrently.**

COPEWELL Model

The COPEWELL Framework and system dynamics-based resiliency model were developed to conceptualize and model a community's ability to deliver essential goods and services (community functioning) following a disaster. In our study, measures from each domain within Figure 1 were considered as predictors of whether a billion-dollar disaster is a compound or cascading event.

Figure 1. The Composite of Post-Event Well-Being (COPEWELL) Framework [2,3]

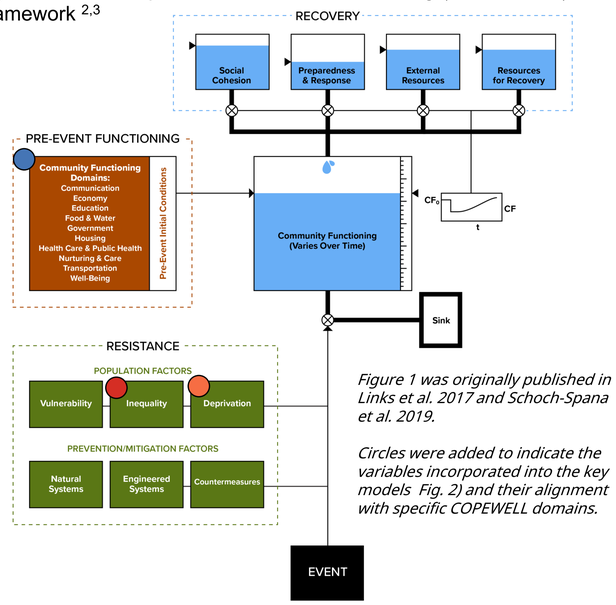
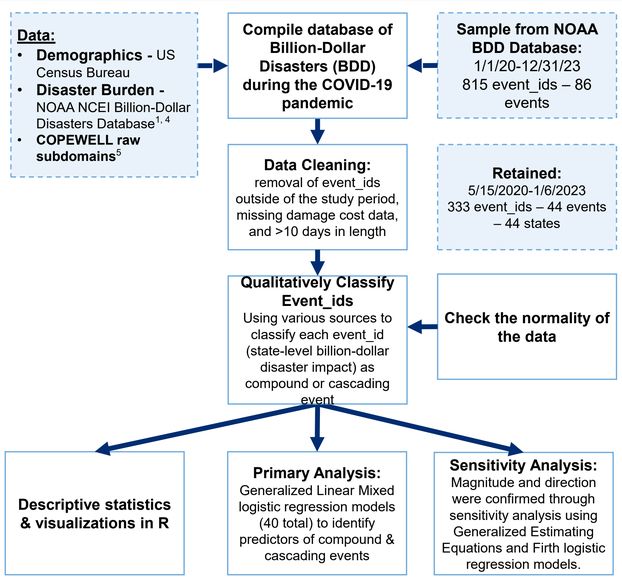


Figure 1 was originally published in Links et al. 2017 and Schoch-Spana et al. 2019.

Circles were added to indicate the variables incorporated into the key models Fig. 2) and their alignment with specific COPEWELL domains.

Methods



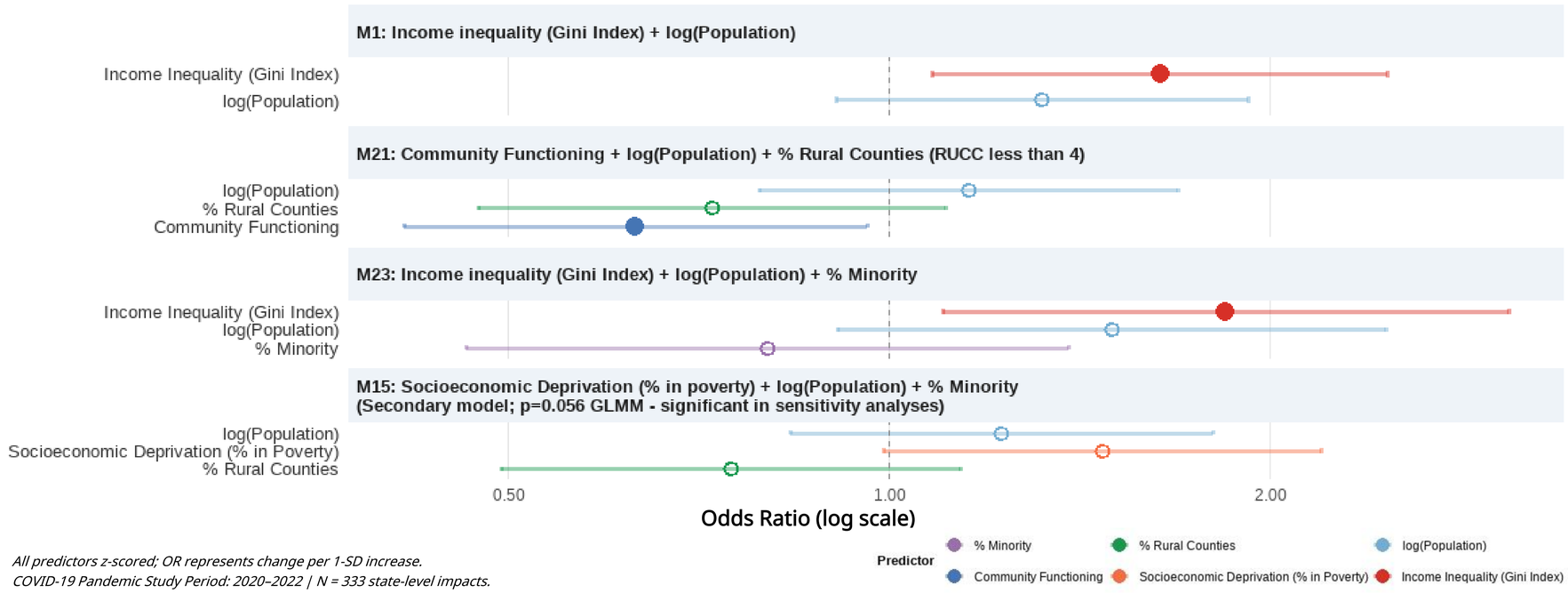
Results

- **Within our study period (2020-2022) and meeting inclusion criteria, 44 BDDs** impacted 44 **US States** (avg. length of **3.2 days**) from 2020-2022, resulting in **333 state-level** billion-dollar disaster impacts.
- Each billion-dollar disaster from 2020-2022 impacted an average of **7.1 states,** with most disasters occurring in 2021.
- **Among the included 333 state-impacts of billion-dollar disasters:**
  - **42 state-impacts** were qualitatively classified **as cascading events (n=12.6%)**
  - **291 state-impacts** were classified as **compound events (n=87.4%)**

Figure 2. State-Level Predictors of Cascading vs. Compound Billion-Dollar Disasters During the COVID-19 Pandemic

Below are significant models from the primary analysis: Generalized linear mixed models (GLMM) with random intercept for the parent billion-dollar disaster event with 95% CIs.

Circles represent Odds Ratios (ORs): Filled circle = $p < 0.05$ | Open circle = $p \geq 0.05$ | Odds Ratios (OR) > 1 = higher odds of a cascading event



All predictors z-scored; OR represents change per 1-SD increase.
COVID-19 Pandemic Study Period: 2020–2022 | N = 333 state-level impacts.

Interpretation

- A 1-standard deviation (SD) increase in **state-level income inequality** was associated with an estimated **64% increase** in the odds of a state-level impact of a billion-dollar disaster being a cascading event (M1; OR = 1.64; $p < 0.05$).
- A 1-standard deviation increase in **state-level community functioning** was associated with an estimated **37% decrease** in the odds of a state-level impact of a billion-dollar disaster being a cascading event, suggesting a protective effect(M21; OR = 0.63; $p < 0.05$).
- Although not statistically significant in the primary model, sensitivity analysis supported that a 1-standard deviation increase in state-level socioeconomic deprivation (% in poverty) was associated with an estimated **a 40-47% increase** in the odds of a state-level impact of a billion-dollar disaster being a cascading event compared to a compound event (M15; Primary analysis - OR = 1.47; $p = 0.056$).

Key Findings

- State-level impacts of Billion-dollar disasters with **cascading potential** during the pandemic were **rather rare** (<15%) compared to compound events.
- **Statistically significant associations** ($p < 0.05$**)** were observed **between the odds** of a state-level impact of a Billion-Dollar Disaster being a cascading event and (1) **income inequality** and (2) **community functioning**.
- **Income inequality** consistently functioned as a **risk factor**, associated with increased odds of cascading events, while **community functioning** served as a **protective factor**.
- Interestingly, model M21, which includes community functioning and adjusts for rurality, demonstrated improved model fit (AIC) compared to a simpler model with only community functioning and log(population).
- **Sensitivity analyses** conducted using Firth, GEE, and crossed GLMM models demonstrated **consistent direction and similar effect size**.

Discussion

Strengths

- Uniquely, utilizes qualitative methods to classify and assess compound and cascading events that occurred during a pandemic
- Assesses the COPEWELL domains as predictors of compound and cascading events
- Identifies risk factors and protective factors of the odds of a billion-dollar disaster being a cascading vs. compound event
- Uses multiple modeling approaches to assess

Limitations

- Qualitative classification comes with the risk of misclassification, but this was mitigated by checking for errors and consulting a second reviewer.
- Given cascading event were relatively rare, it may affect the statistical power and limits the number of variables included in the model.
- Potential for residual confounding not captured within the state-level factors included in the models.

Research Applications

- This study identifies modifiable community-level factors that could increase or decrease the likelihood of an event being a compound or cascading event
- Emphasizes the importance of considering the impact of equity and legacy factors on resilience
- Future research will involve working towards adapting the COPEWELL model to be applied to scenarios involving compound and cascading disasters, especially in a pandemic context

References

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Let's Connect!

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