Spatial and temporal analysis of the transmissibility and mortality burden of a 1853 cholera epidemic in Copenhagen

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1. Context

- **Cholera is still a serious disease** responsible for several million cases annually (Sack, Sack et al.).
- **Uncertainty persists** on the relative roles that **human-to-human vs. environment-to-human** routes of transmissions play in outbreak situations (King, Ionides et al. , Chao, Longini et al.).
- **Little quantitative historical research** has been done on cholera outbreaks, most have been qualitative in nature.

2. Motivation

- To characterize the spatial and temporal spread of cholera in a fully susceptible population.
- To provide historic data needed to validate models of contemporary cholera epidemics used to guide vaccine and other interventions (Andrews and Basu).

3. Data & methods

- Outbreak morbidity & mortality data digitized from 1854 Health Commission report.
- All-cause mortality data for 1852 – 1854 digitized from the “Statistisk Tabelværk” surveillance system. Population data was interpolated from 1850 and 1855 censuses.

4. Results

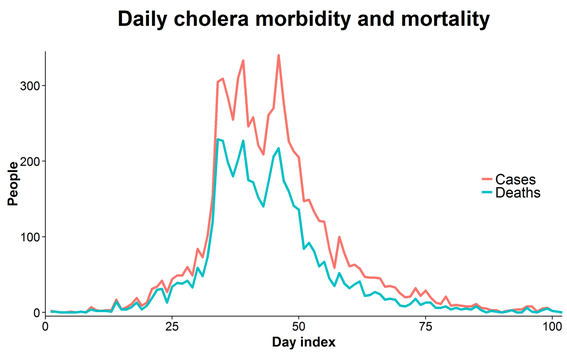

Figure 1. Case surveillance listed 7,219 patients (5.6% of population) as cholera cases. Of these, 4,737 died for a Case Fatality Ratio (CFR) of 66%.

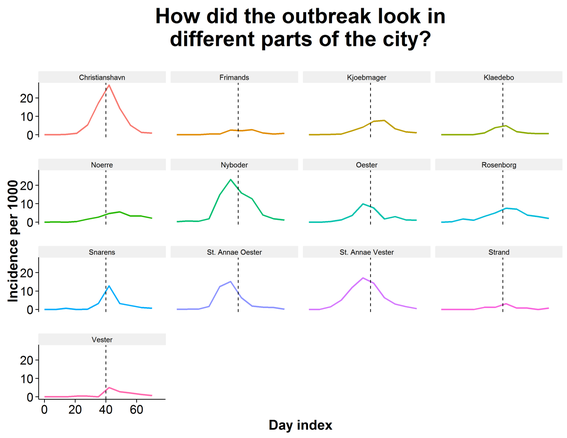

Figure 2. Normalized weekly incidence rates show each city quarter experiencing only a single epidemic peak with much variability in severity across quarters.

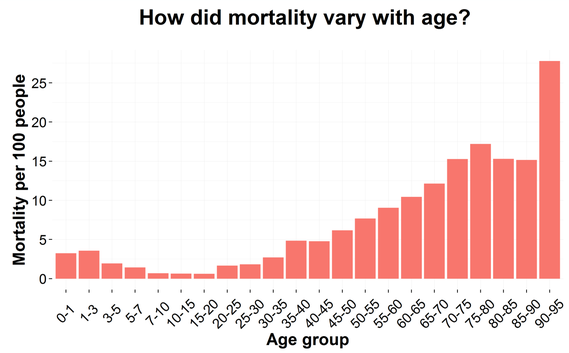

Figure 3. Stratifying and adjusting for age shows that the elderly were disproportionately affected; 15% of persons over age 70 died as compared to <1% of children.

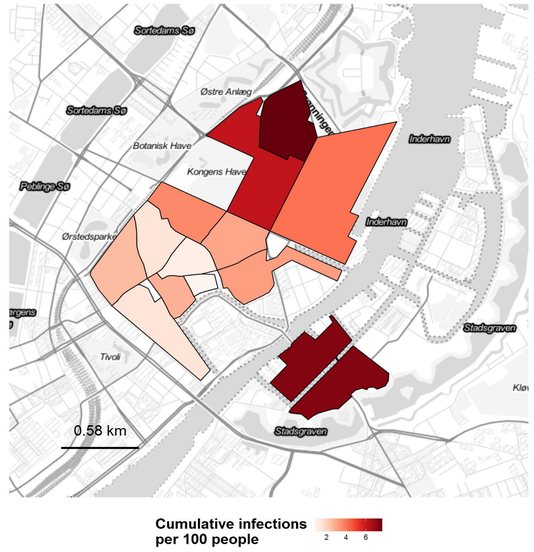

Figure 4. The dense, older quarters, such as Strand, had the lowest cumulative infection rate, while less dense areas had higher rates.

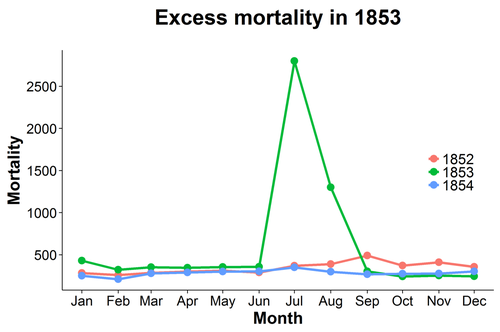

Figure 5. The outbreak caused an estimated 3500 excess deaths (2.1% of the population) during the peak months July & August 1853 as compared to the baseline years of 1852 & and 1854.

5. Conclusions

- A high CFR of 66% is comparable to other cholera outbreaks in Scandinavia at the time but may be **biased upwards** as a result of the cholera case definition used at the time.
- The **double peak** apparent in the city-level analysis is likely an **artifact of aggregation** and disappears at higher spatial resolutions. We are investigating if this same phenomenon can explain the double peak seen in cholera outbreaks in other Danish cities (data not shown) of the time period (1853 – 1857).
- The outbreak was spatially heterogeneous, even across the small area represented in this dataset**. City-level or larger analyses** of cholera outbreaks **may not be appropriate.**
- Future work will combine a **meta-population model** (Azman, Luquero et al.) with data on **water-flow** in 19th century Copenhagen to address uncertainty on the strength of the different transmission pathways of cholera.

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