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Epidemiological Description of Unmitigated Cholera Epidemics in 19th Century Denmark

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1. Context

- **Mathematical models** are used to evaluate potential interventions in endemic and epidemics settings and need **empirical parameterizations**[1].

- **Historical outbreak data** are underutilized as a source of empirical data for **model parameterization**.

- **In 1853 & 1857** singular cholera outbreaks occurred across Denmark in populations with **no previous exposure** and **no effective interventions** were implemented.

2. Objectives

- Describe **unmitigated** cholera outbreaks in **immunological naïve populations.**

- To infer key parameters such as the **serial interval** and the **reproductive number (R_0)** from the data.

- To compare key metrics of the Danish outbreaks with **Haitian 2010** outbreak.
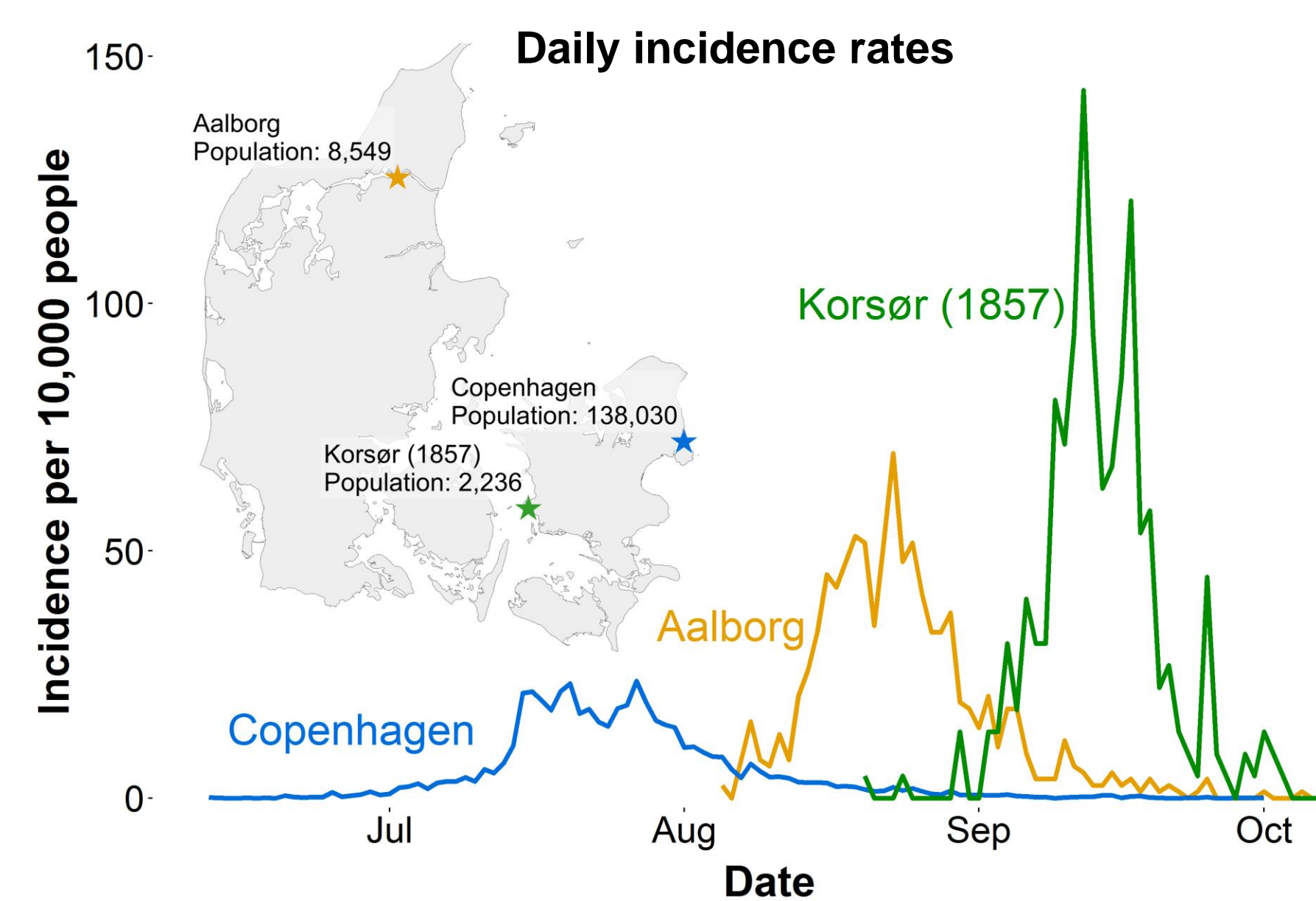
3. Data & methods

- Daily cholera morbidity & mortality data from three cities digitized from municipal cholera commission reports.

- All-cause monthly mortality data for Copenhagen, 1852 – 1854 digitized from the "Statistisk Tabelværk".

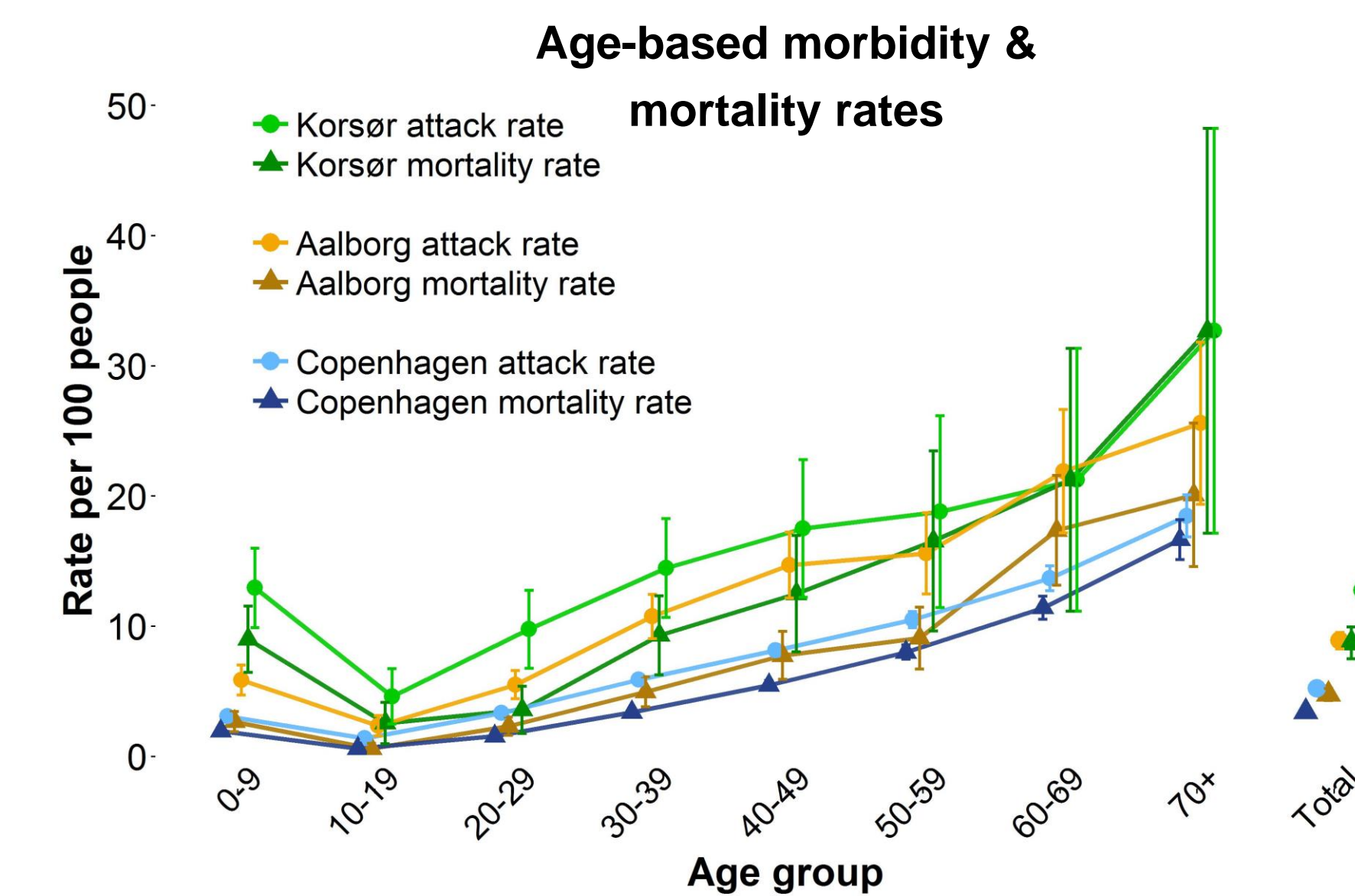- Transmission chains reconstructed from physician narratives of index cases.

4. Results

- The outbreak was severe for all age groups.
- A 14-fold increase in monthly all-cause mortality was seen among those aged 50+ in Copenhagen.

Monthly all-cause mortality counts

Age group
<10
10-25
26-50
50+
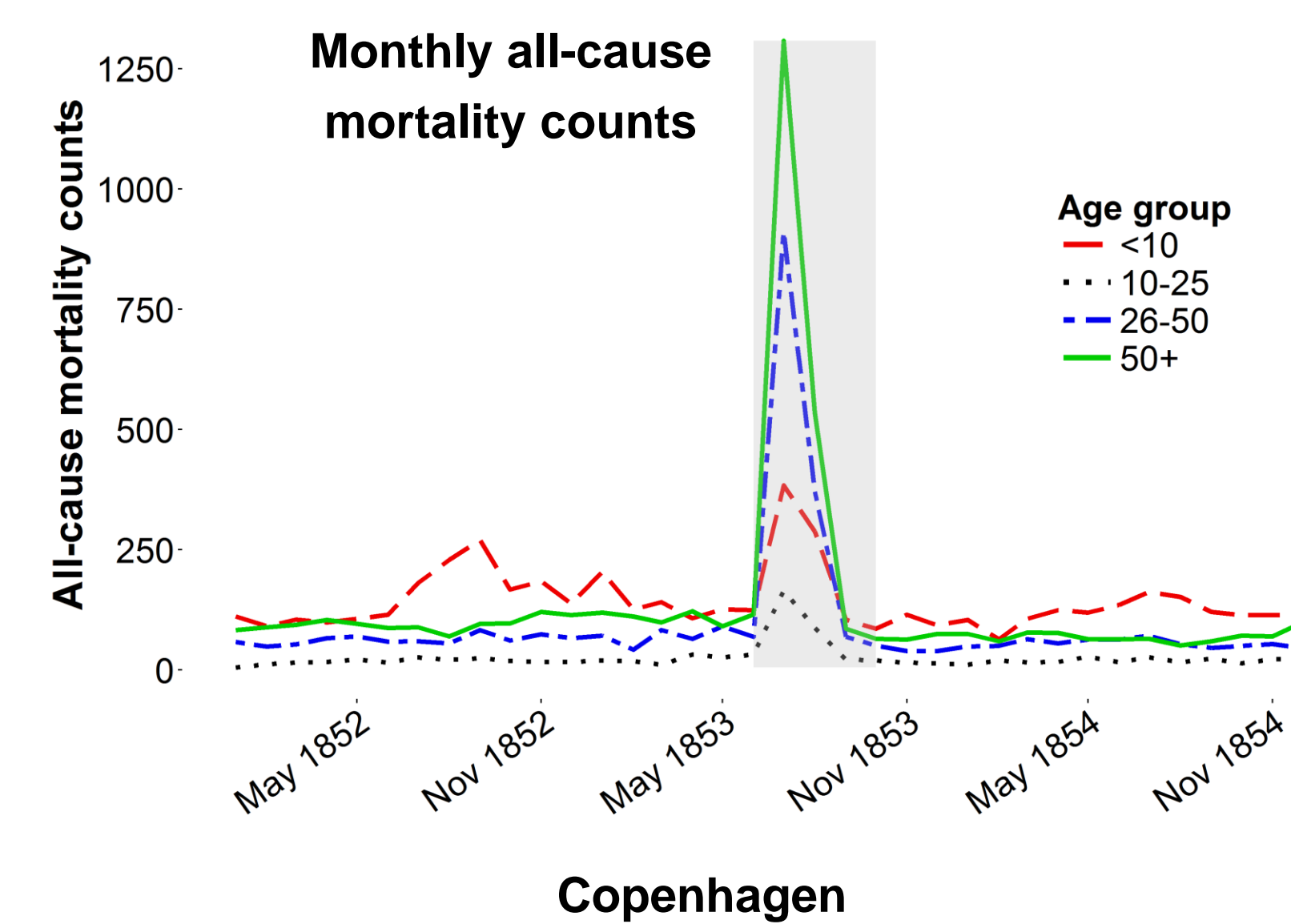
Copenhagen

- Outbreaks all occurred in late summer / autumn.
- Copenhagen's outbreak was likely an amalgamation of multiple outbreaks in sub-populations resulting in a flatter epidemic curve.

Daily incidence rates

Aalborg Population: 8,549
Copenhagen Population: 138,030
Korsør (1857) Population: 2,236

Korsør (1857)
Aalborg
Copenhagen

- Adults were at highest risk of infections and death in all three locations.

Age-based morbidity & mortality rates

Korsør attack rate
Korsør mortality rate
Aalborg attack rate
Aalborg mortality rate
Copenhagen attack rate
Copenhagen mortality rate

- Copenhagen and Haiti outbreaks have comparable reported attack rates & reproductive numbers (R_0).
- Improvement in case-management and interventions likely lowered the CFR and excess mortality in Haiti.

Location	Copenhagen 1853	Haiti 2010-11
R_0	(1.5 – 1.8)	1.9 (2.1 – 1.6)* [2]
Reported attack rate (95% CI)	5.2% (5.1% – 5.4%)	6%*† [3]
Adjusted attack rate using R_0	58% - 69%	NA
Excess mortality as % of population (95% CI)	2.4%	0.4% (0.3% - 0.7%)** [4]
Reported CFR	66%	~2%† [3]
Adjusted CFR using R0	5% - 6%	>2%†
% of cases in patients <5 years	8.4%	15.5%*‡ [3]

*Port-au-Prince; **Gonaives; †first 4 months; ‡first 2 years

- The reproductive numbers were comparable across the locations despite dissimilar water supply infrastructure.

Reproductive number (R_0) estimates

Exponential Growth
Maximum Likelihood

Town: Åalborg, Copenhagen, Korsør
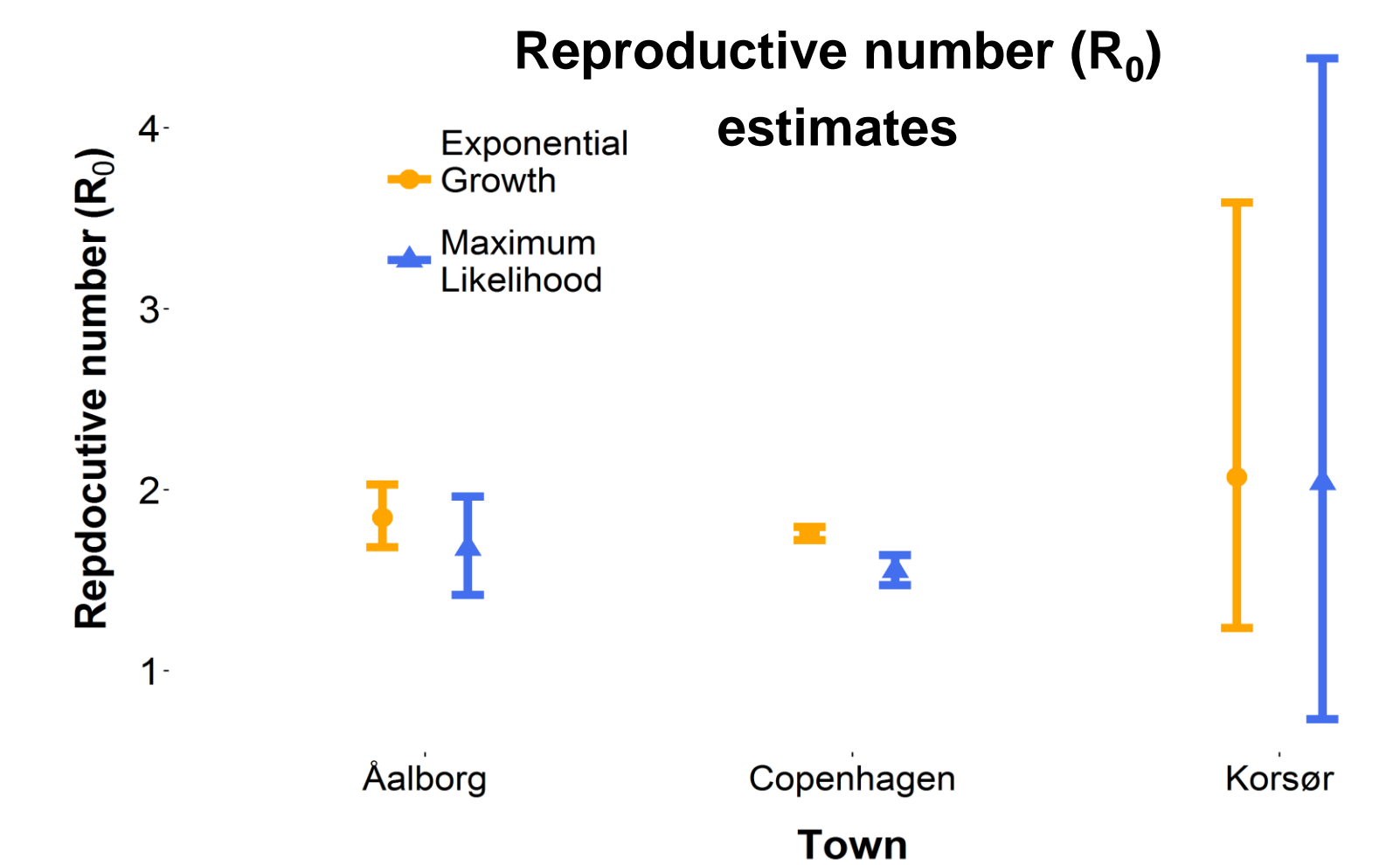
- The serial interval was estimate to be **3.1 days** (95% CI: 1.9 – 4.5) and is the first estimate from an outbreak setting to our knowledge.

5. Conclusions

- **Severe unmitigated cholera** epidemics in **entirely susceptible populations** provide a unique opportunity to describe the **natural course** of a cholera outbreak.

- Despite a focus on water supply interventions in cholera outbreak response, the role of **non-waterborne transmission** routes in **epidemic settings** merits further consideration.

- In spite of **dissimilar water infrastructure** in the three towns, the reproductive numbers (R_0) and age distribution of cases/deaths were **comparable**, suggesting **non-waterborne** transmission routes were **important**.

- The serial interval estimate of 3.1 days is the **first** to our knowledge from an **outbreak setting**

- **High** morbidity & mortality in **adults** and **low** among the **young** is the **inverse** of **endemic** settings. The is likely due to the **lack** of **acquired immunity** and **under-reporting** of moderate cases in the young due to the **strict case-definition** used at the time.

Literature cited

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