Modelling the COVID-19 outbreak in Denmark

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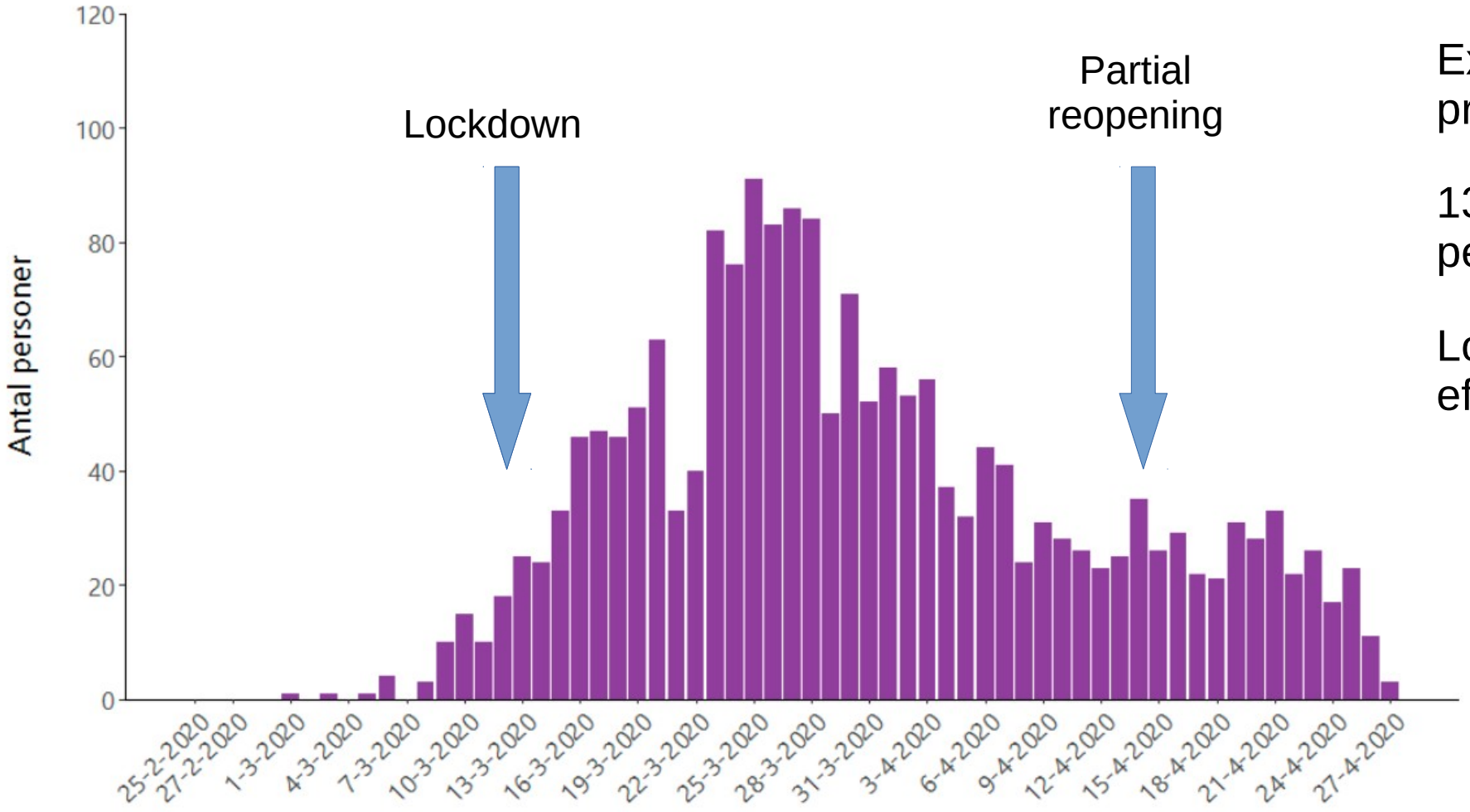
About me

- Assoc.prof. In Applied Mathematics; Mathematical Biology
- Member of the Expert Group formed by the Danish authorities to model the epidemic
- Do *not* speak on the behalf of this group

The course in Denmark: Daily hospitalizations



Initial surge: Winter vacation

Exponential growth phase less pronounced

13 days from lockdown to peak

Lockdown was (surprisingly) effective

Source: sst.dk

Lockdown

- Schools closed (daycare → universities)
- Restaurants, malls, liberal professions closed
- Large gatherings prohibited
- Non-essential government workers sent home
- Borders closed

Reopening:

- Opening daycare, schools → 5th grade
- Liberal professions

Models employed

An **ODE model** of SIR type for epidemic dynamics

An stochastic **individual-based model** for do.

A **time series analysis** model for estimation & prediction

A “**survival analysis**” model for flows through hospitals

Various statistical models

Idealised model components for process studies

The ODE model

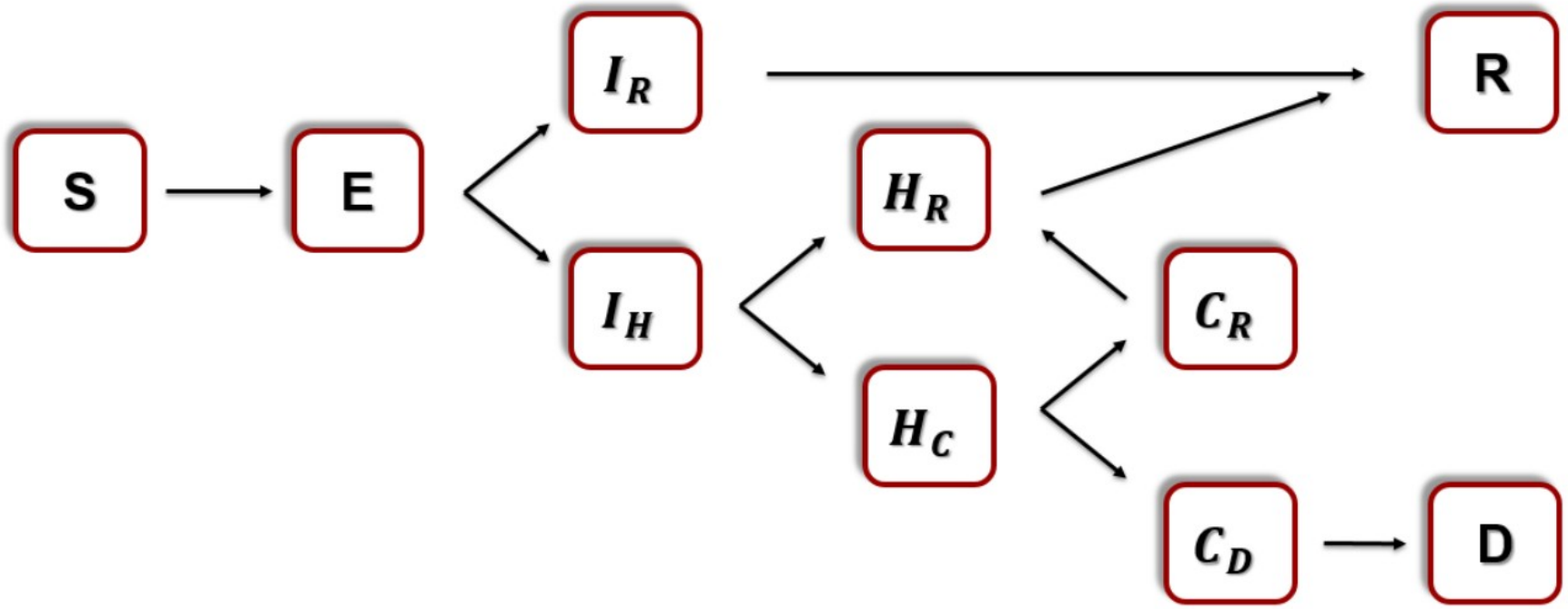
SIR type but with more states

Originally with two age groups (0-59, 60+)

$$\frac{dS}{dt} = -\beta IS,$$

$$\frac{dI}{dt} = \beta IS - \gamma I,$$

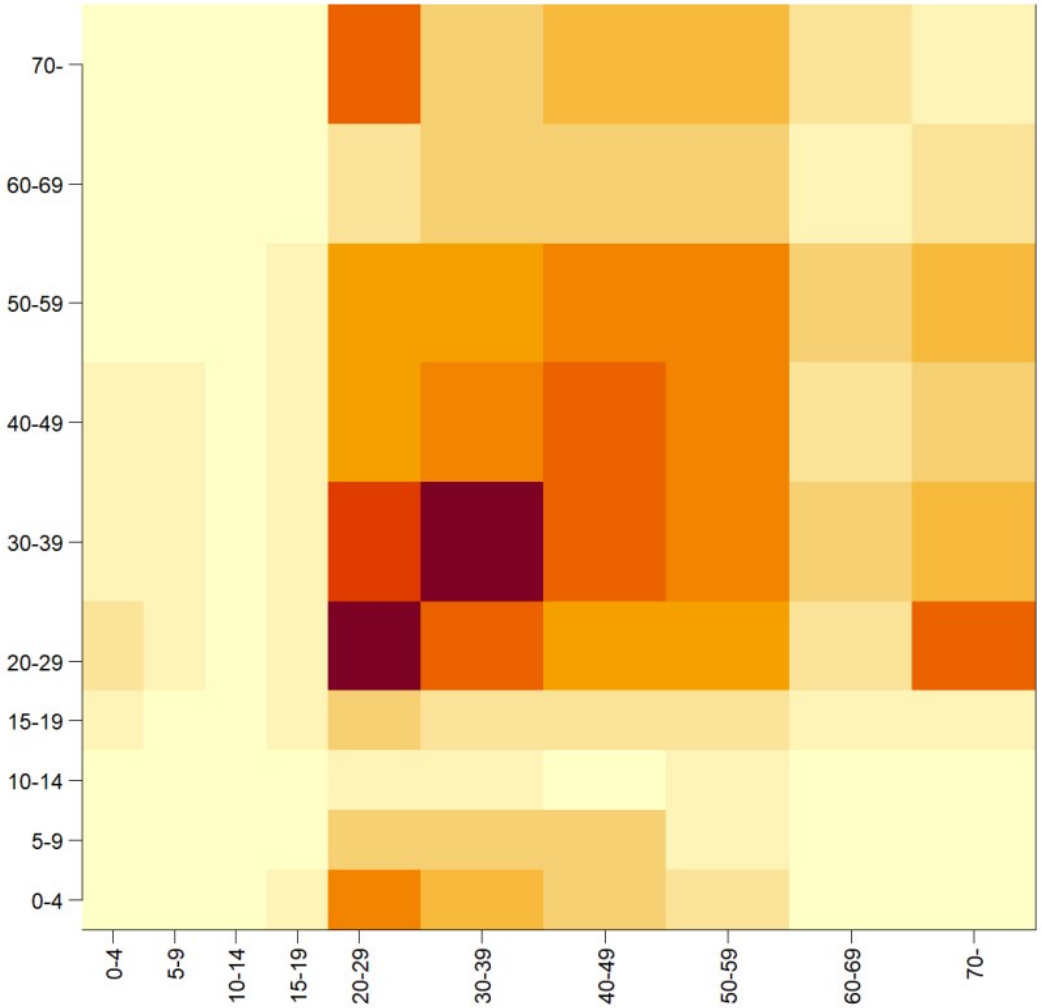
$$\frac{dR}{dt} = \gamma I.$$



Contact structures

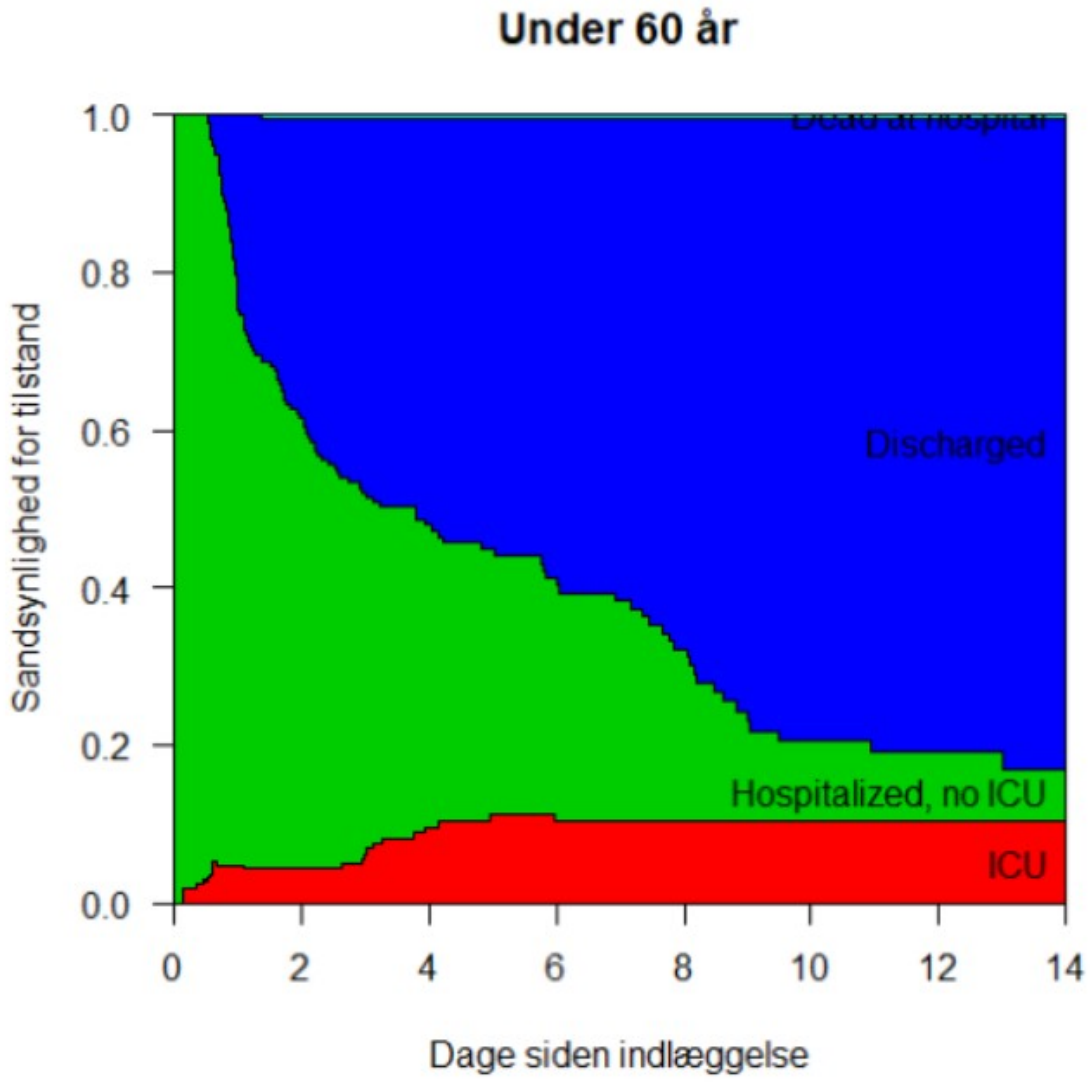
Based on observed contacts between age groups in different contexts (family, work, etc)

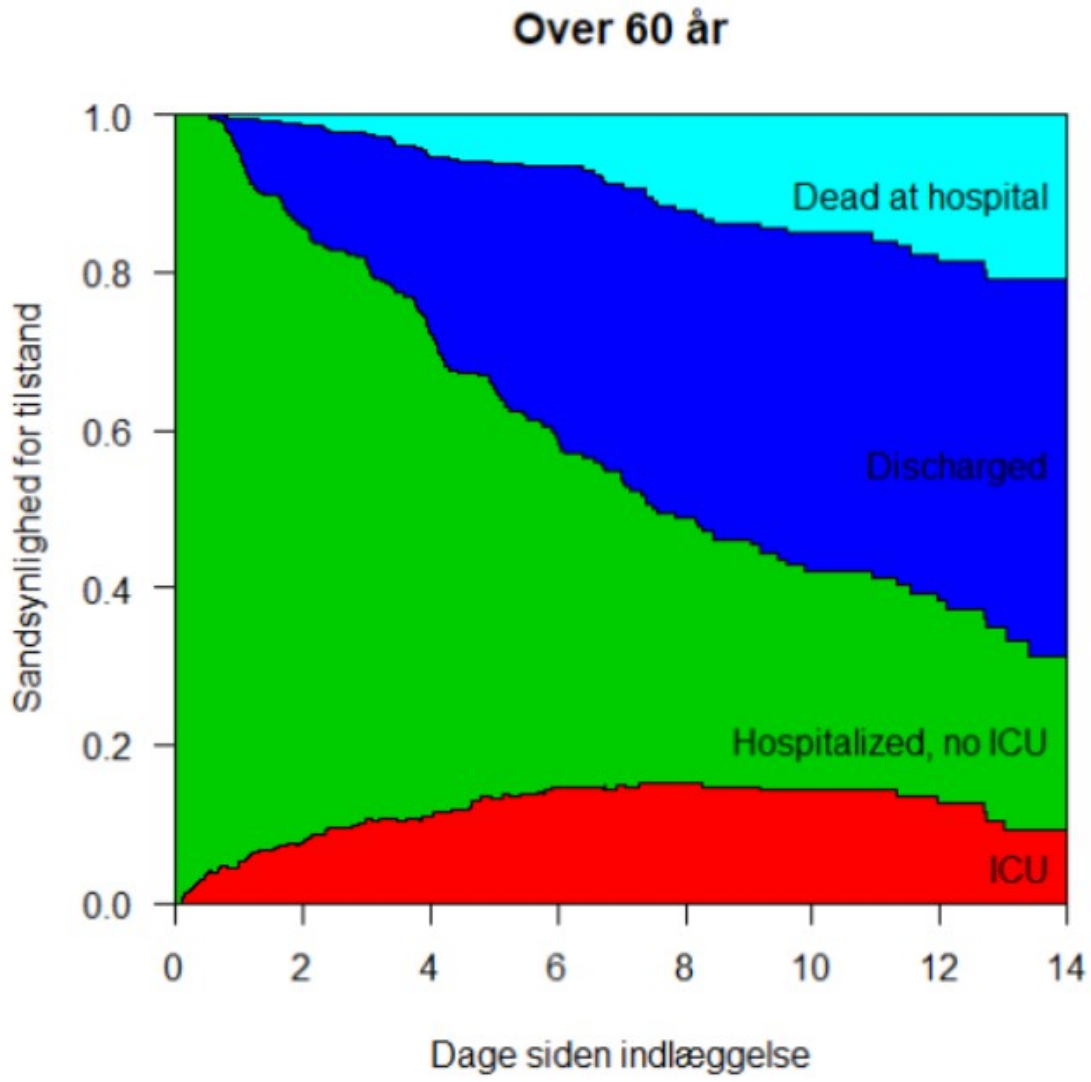
Scaled with estimated risks of transmission



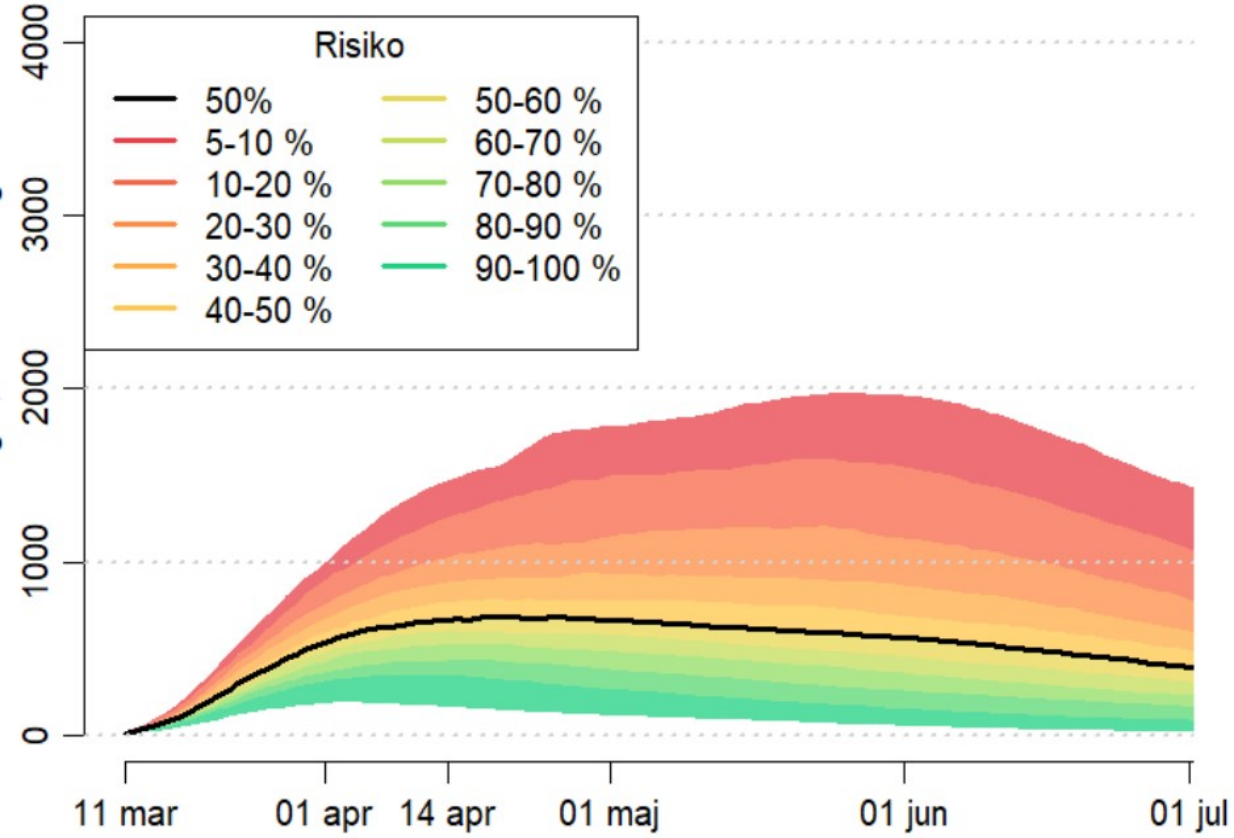
Mossong et al (2018), Klepac et al (2020)

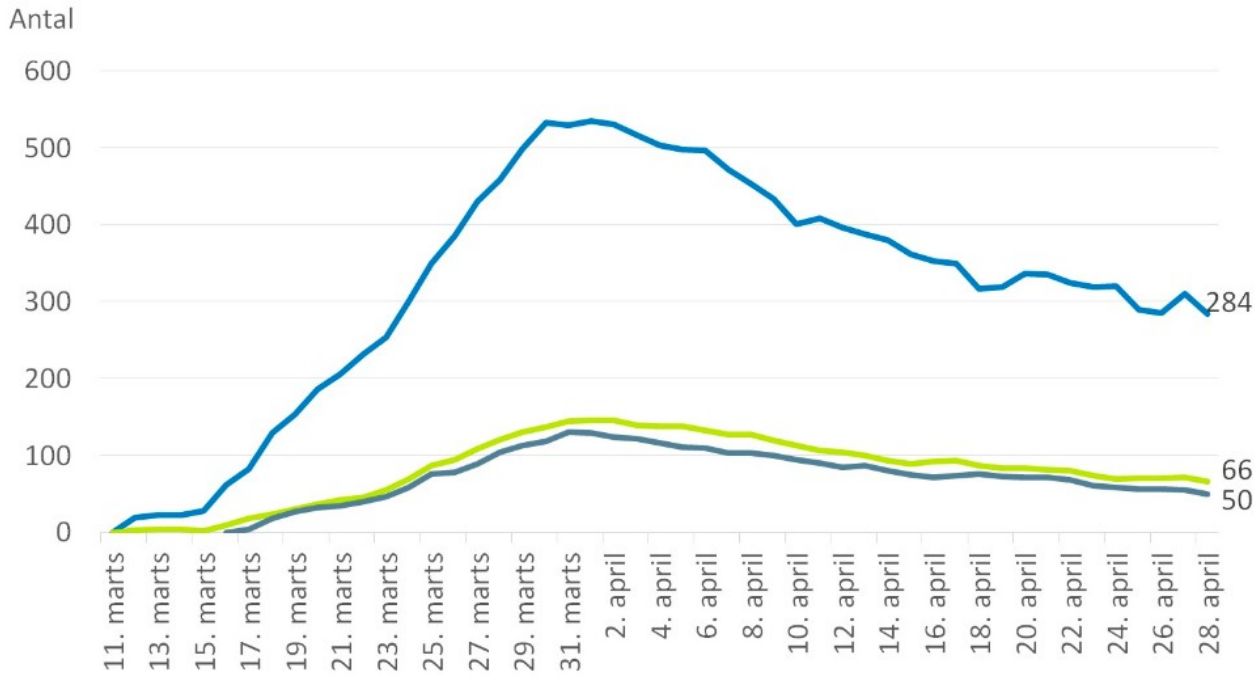
Course of patients through the hospitals





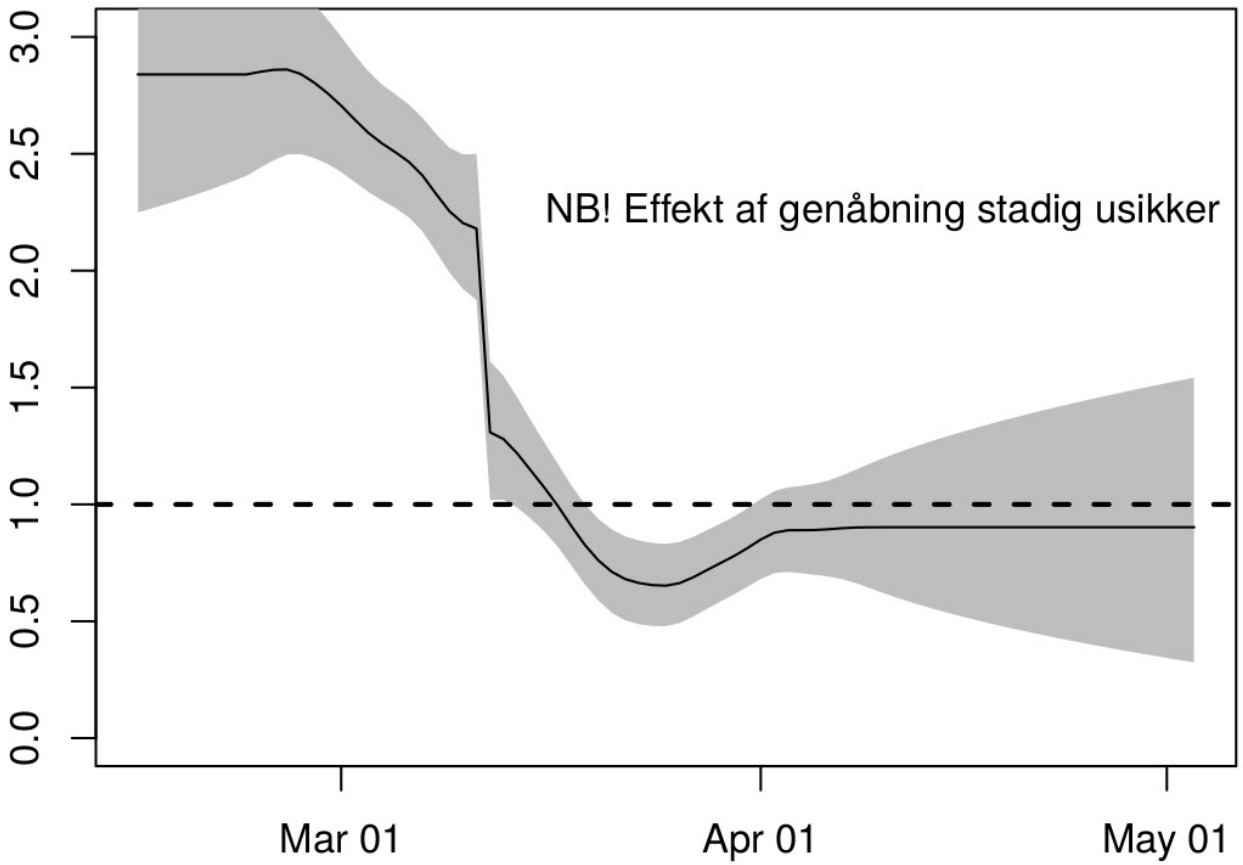
Loads on hospitals: Predictions per April 2 vs observed

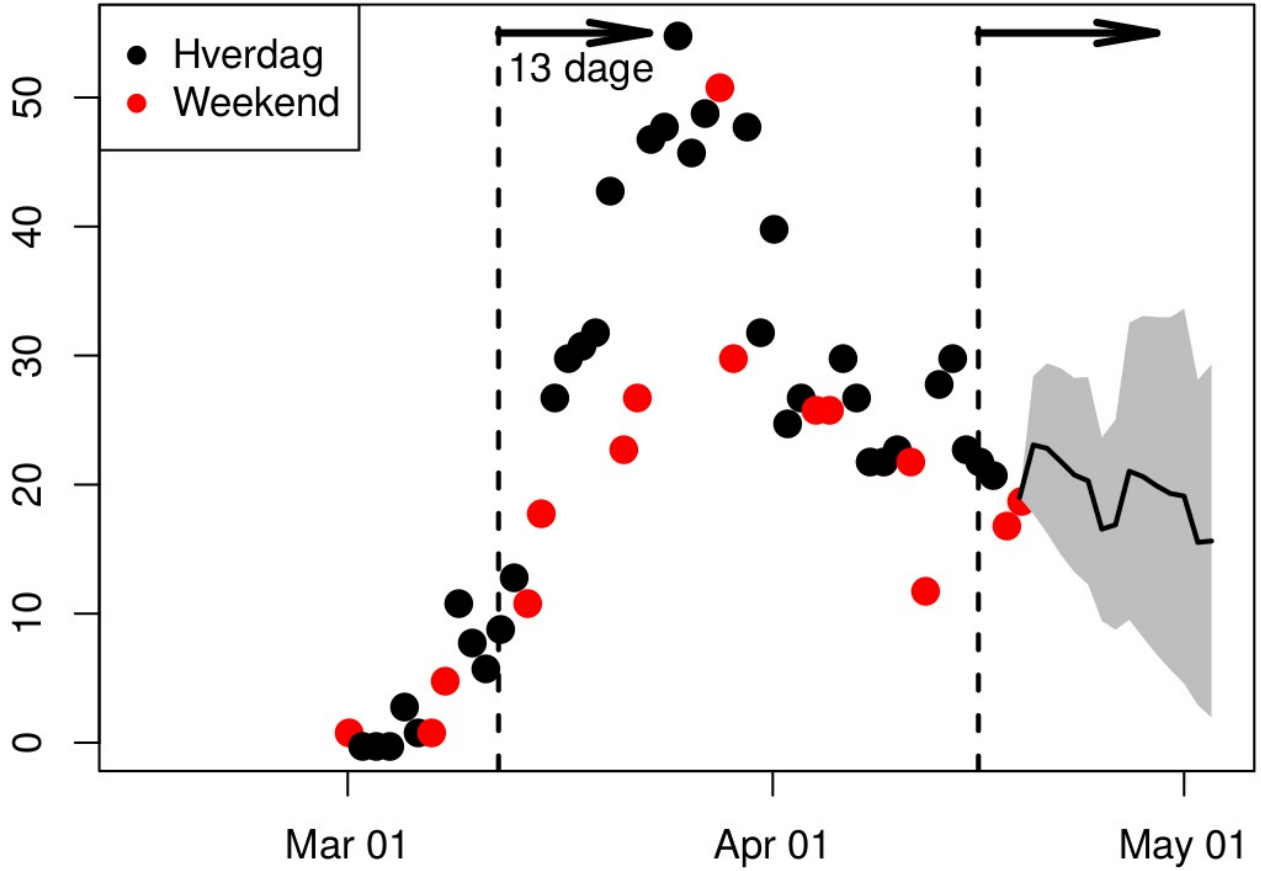




Social distancing was more effective than predicted!

Reproduction number and short-term prediction





Usual caveats re. R apply

The effect of the reopening remains to be seen

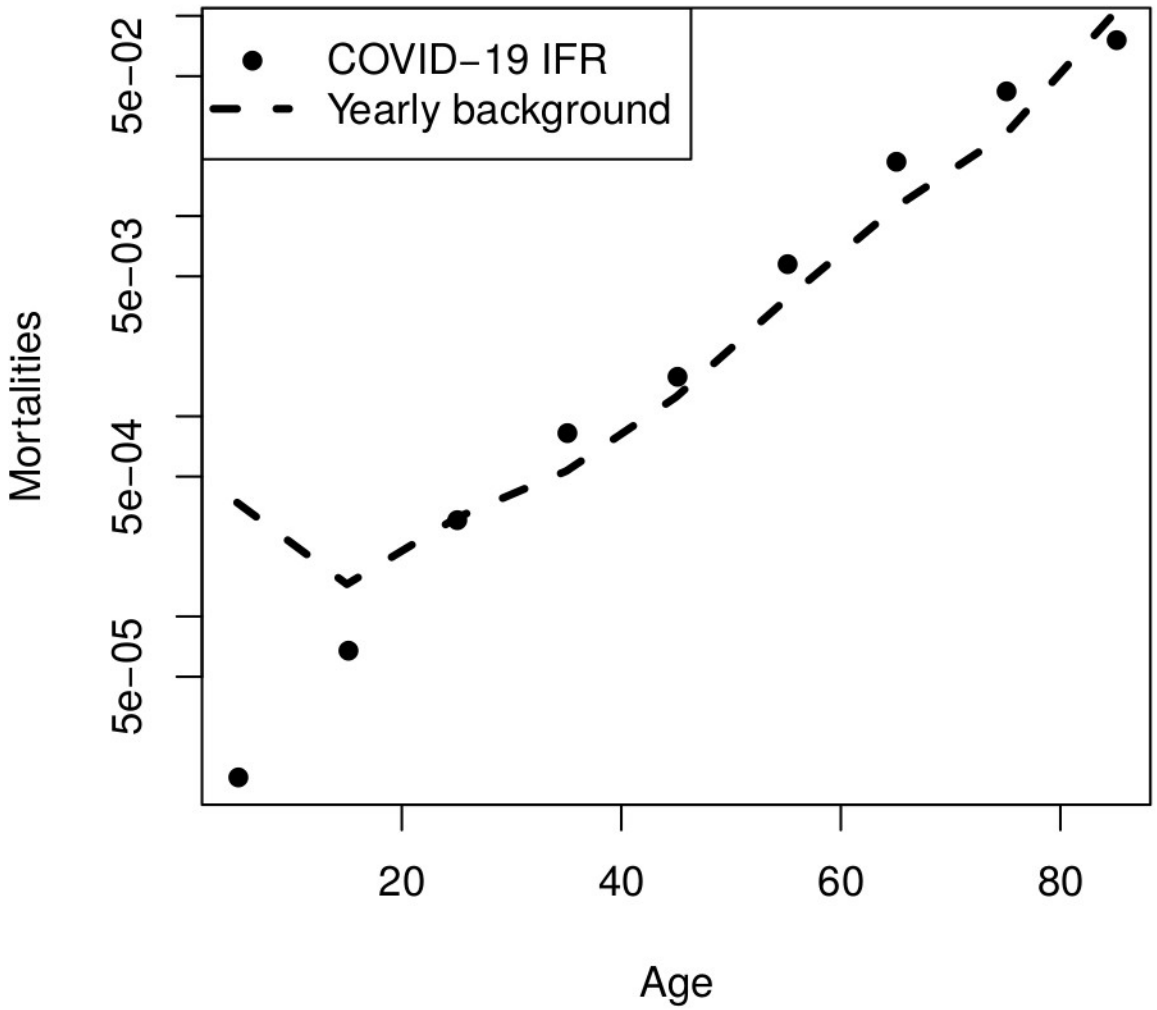
Current challenge

Predict the effect of various reopening decisions

Key uncertainties

- Number and role of asymptomatic cases (dark figure, children)
- In which situations is the disease transmitted?
- Importance of heterogeneity
- Who are most at risk?
- Acquisition and loss of immunity, mutations, etc.

COVID-19 mortalities follow the background



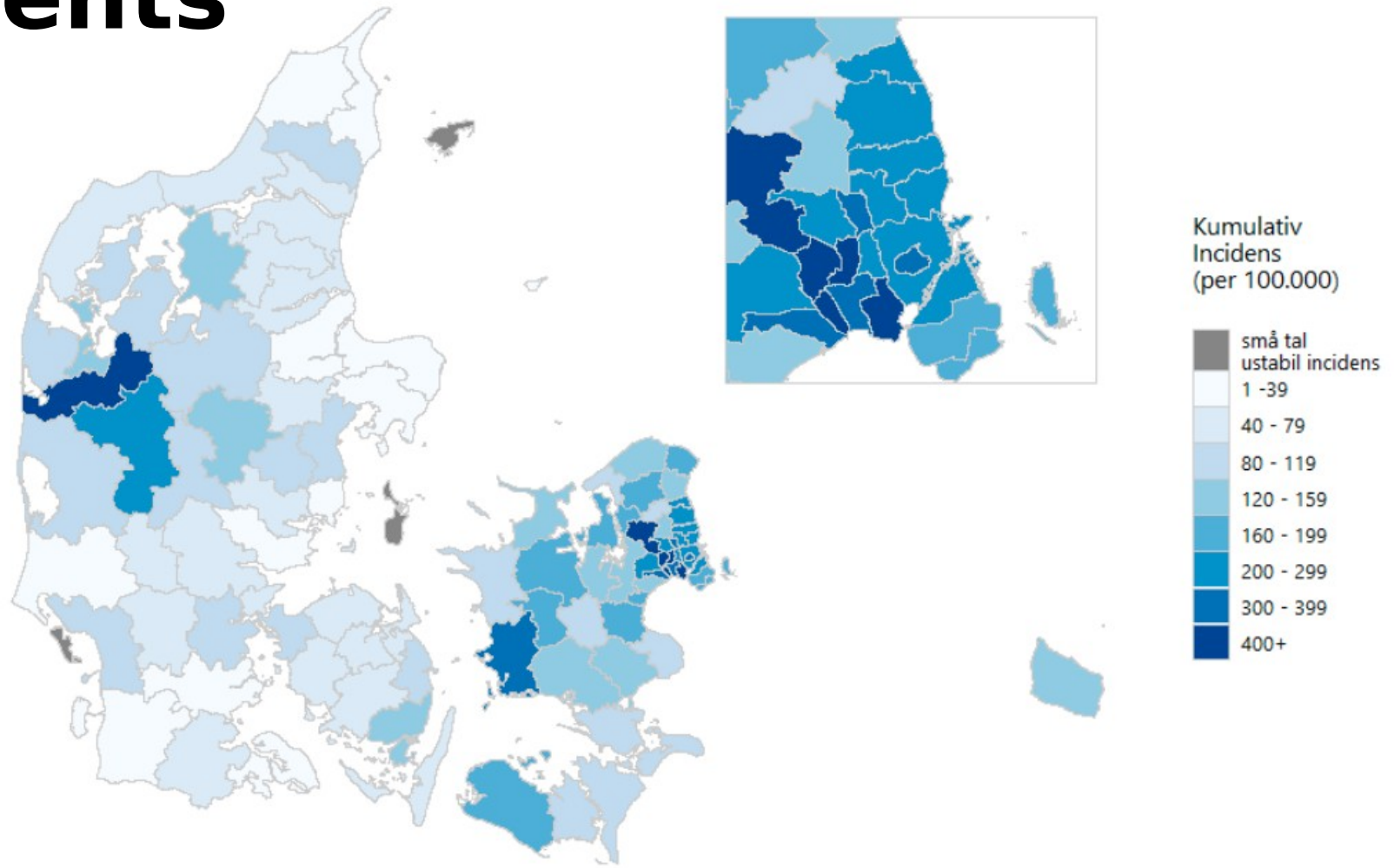
COVID-19 IFR corresponds to 1.5 years background mortality

The role of prior health conditions is still incompletely understood:

Cardiovascular disease
Diabetes
Chronic respiratory disease
Hypertension
Cancer
Obesity

Data: Verity et al (2020), Statistics Denmark (dst.dk)

Spatial structure: Socioeconomics, subcultures, singular events



Conclusions

The situation requires very fast modeling cycles

We rely on a suite of models rather than a single model

Actual knowledge about the disease is a bottleneck

Science-based advice will be crucial to overcoming the crisis