# How well can we predict weekly death counts?

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# The forecasting perspective on excess deaths

**The credibility of any COVID-19 pandemic excess deaths model**

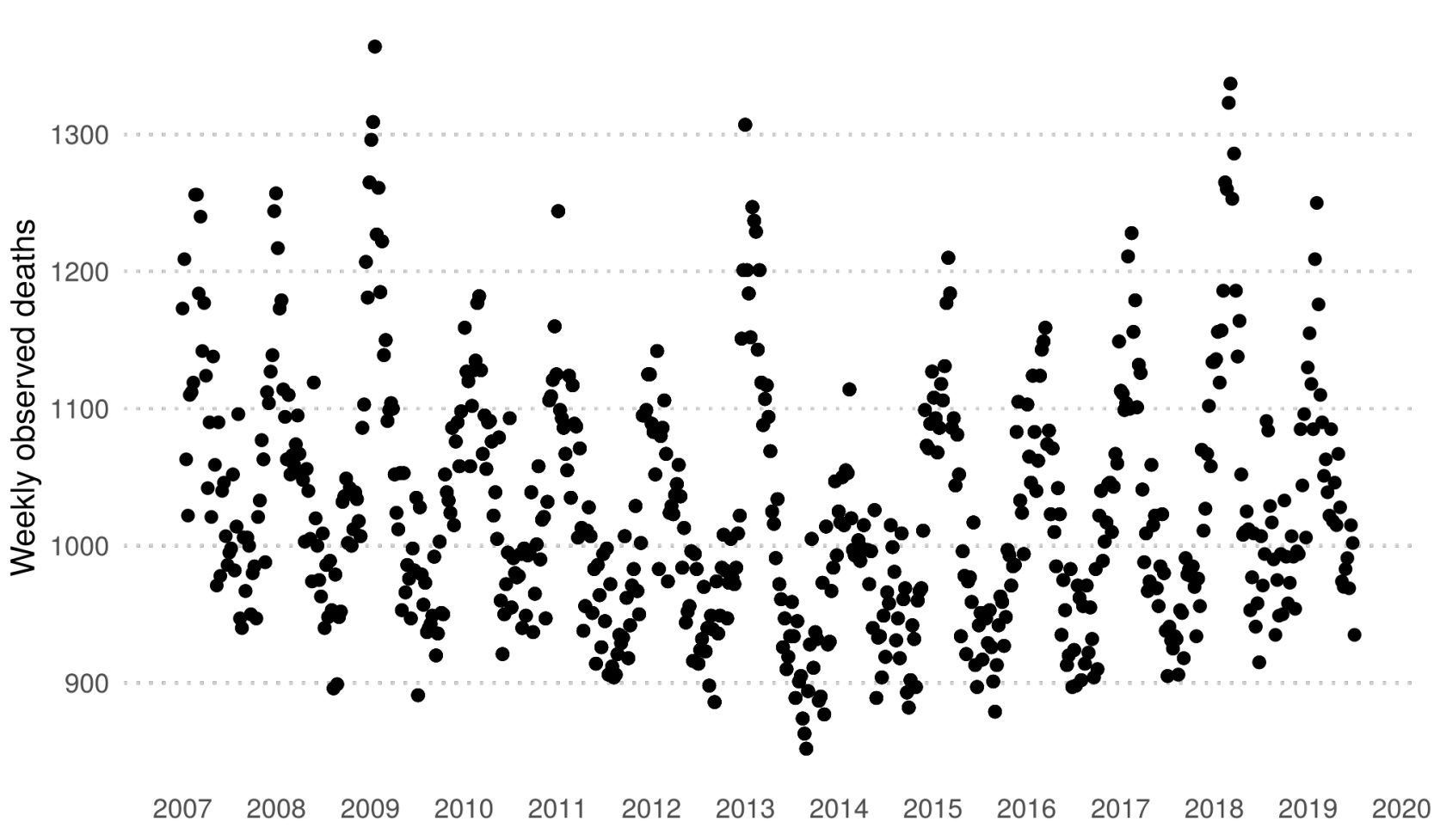
**derives from its ability to correctly forecast death counts in non-COVID situations**

# The challenge

Given 3 years of Danish weekly death counts by age and sex

How well can we predict weekly deaths over the next year?

# Training-test split of time-series




**Weekly death counts**
Denmark.

Complete population.

Data: HMD.

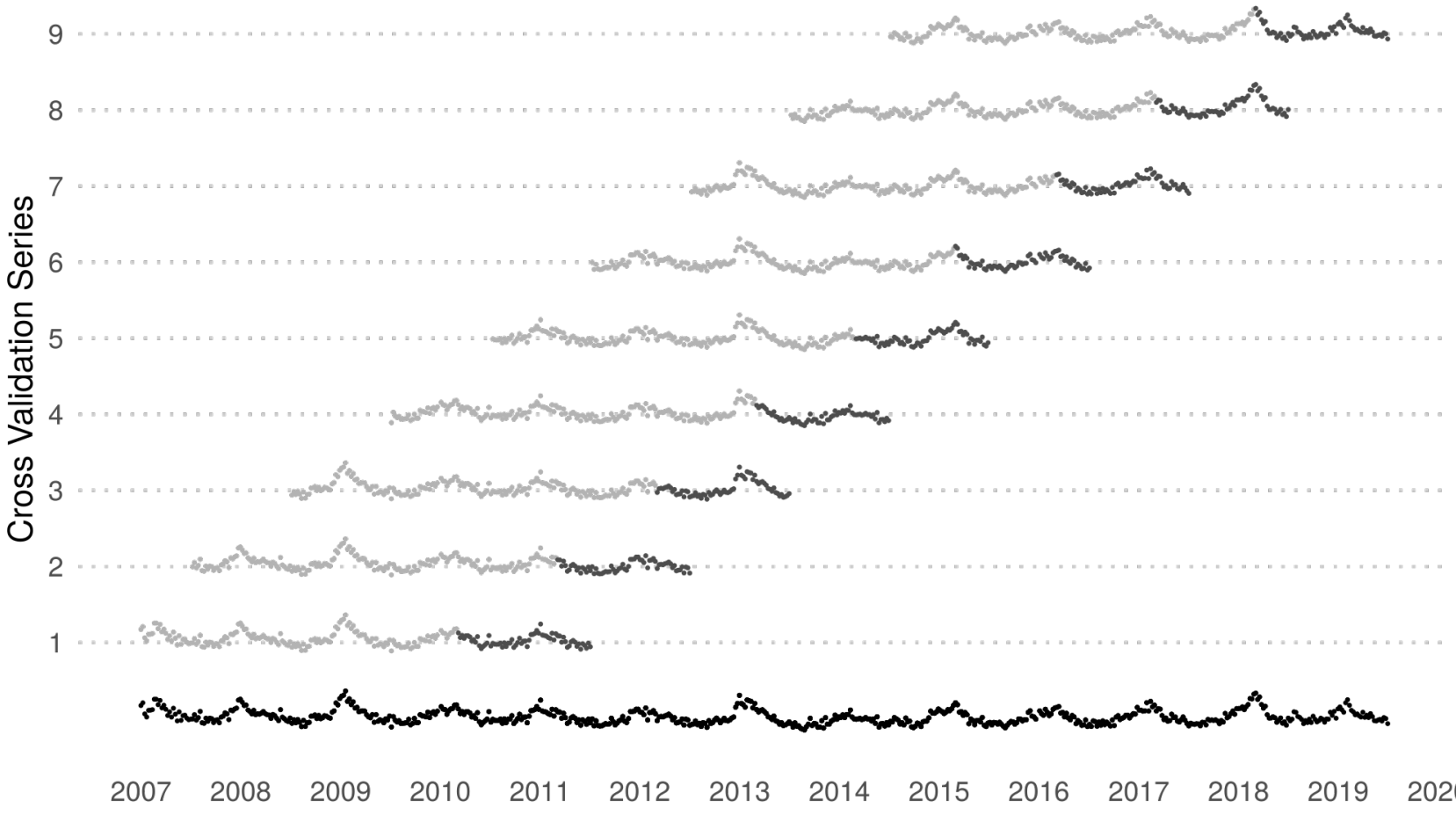
# Training-test split of time-series


**Weekly death counts**
Denmark.

Complete population.

Data: HMD.

# Training-test split of time-series

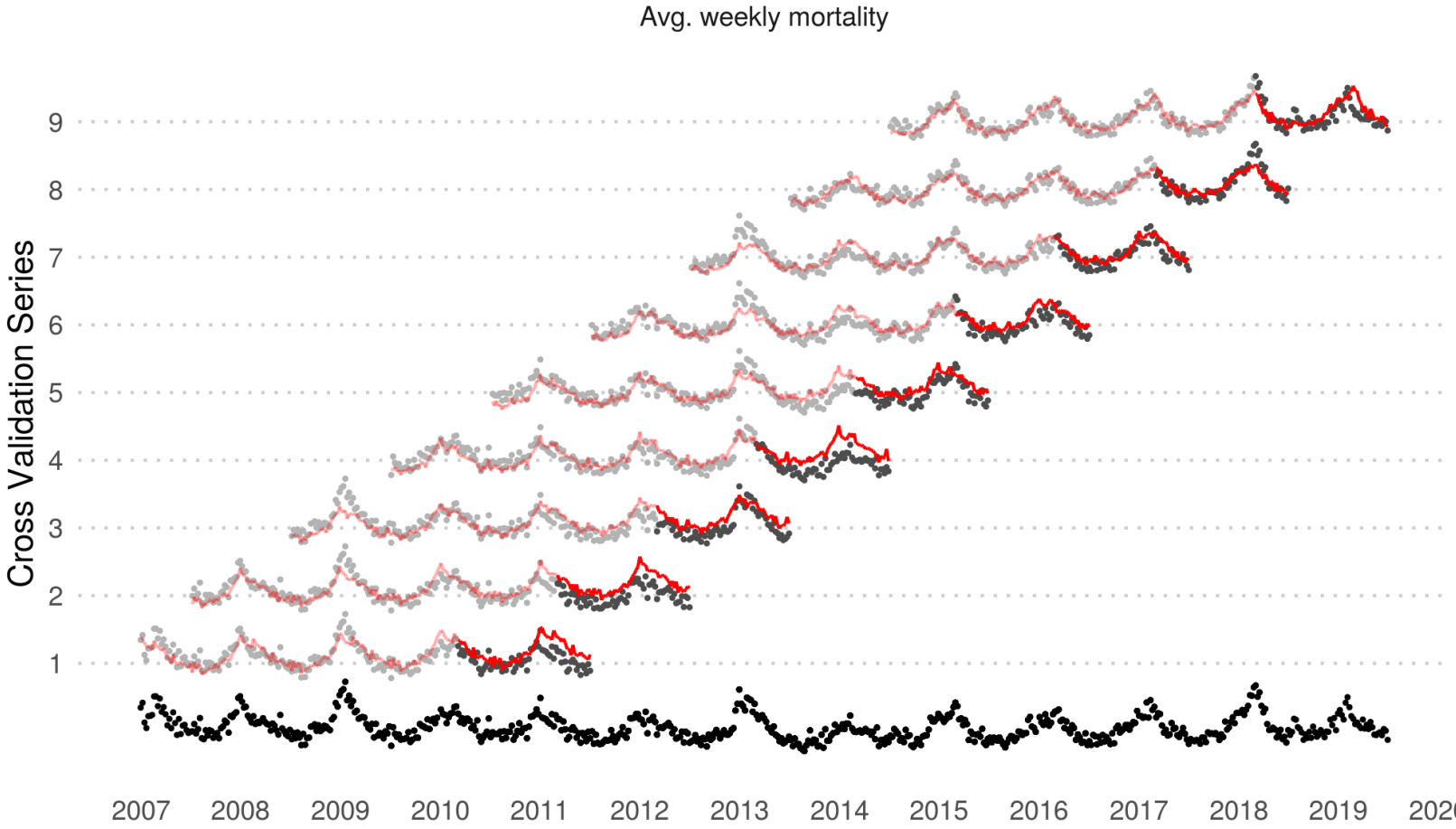



**Weekly death counts**
Denmark.

Complete population.

Data: HMD.

# The models




**Observed** vs. **predicted** weekly death counts Denmark.

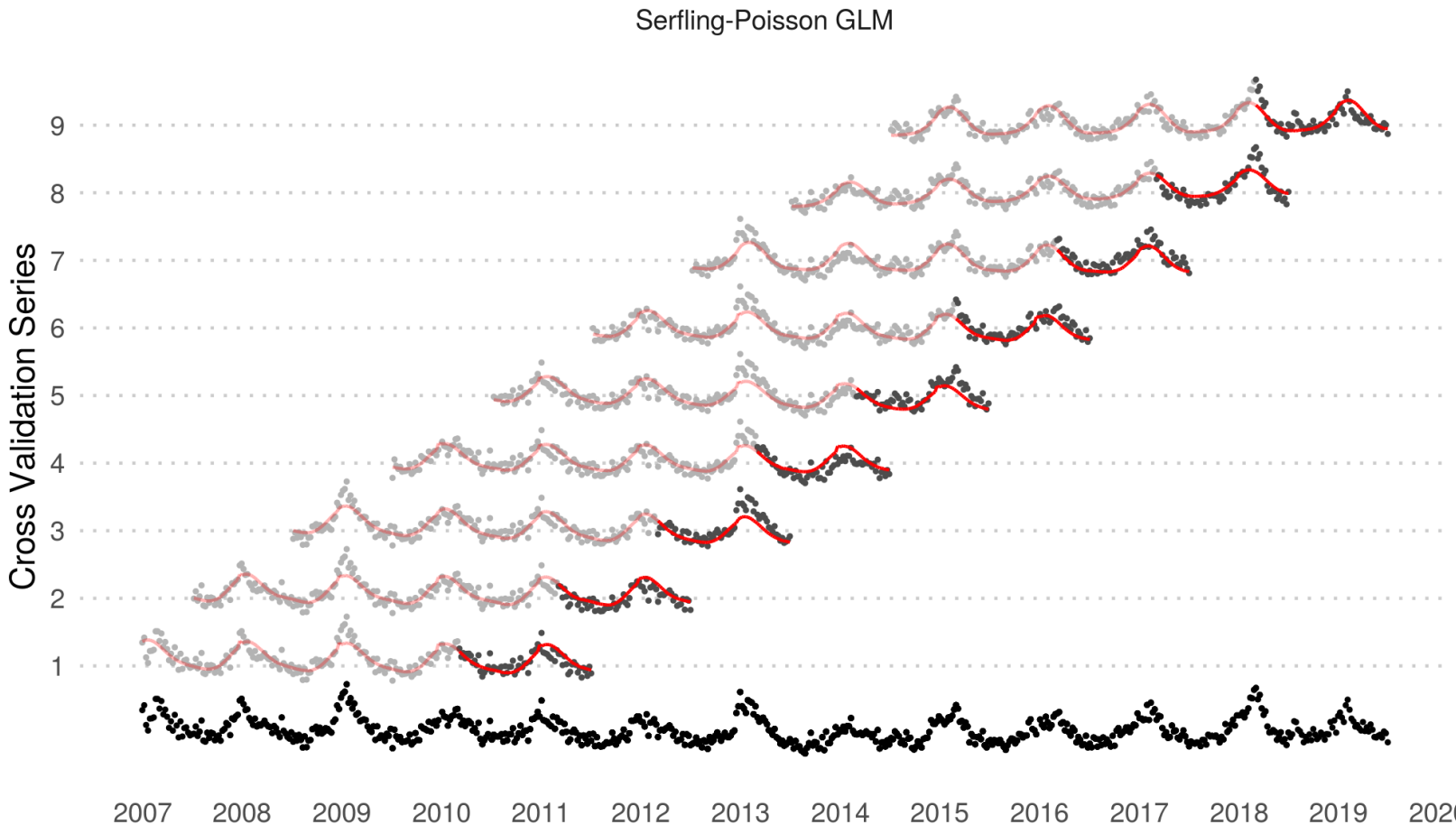
Complete population.

Data: HMD.

# The models

```
'Serfling-Poisson GLM', 'glm', list(
  formula = formula(
    observed_deaths ~
      # log linear long term trend
      weeks_since_origin*sex*age_group +
      # seasonality
      # full year period
      sin(2*pi*weeks_into_season_year/(365.25/7))*sex*age_group +
      cos(2*pi*weeks_into_season_year/(365.25/7))*sex*age_group +
      # half year period
      sin(2*pi*weeks_into_season_year/(365.25/2/7))*sex*age_group +
      cos(2*pi*weeks_into_season_year/(365.25/2/7))*sex*age_group +
      # adjustment for new years eve
      new_year*sex*age_group +
      # exposures
      offset(log(exposure))
  ),
  family = quasipoisson(link = 'log')
)
```

# The models




**Observed** vs. **predicted** weekly death counts Denmark.

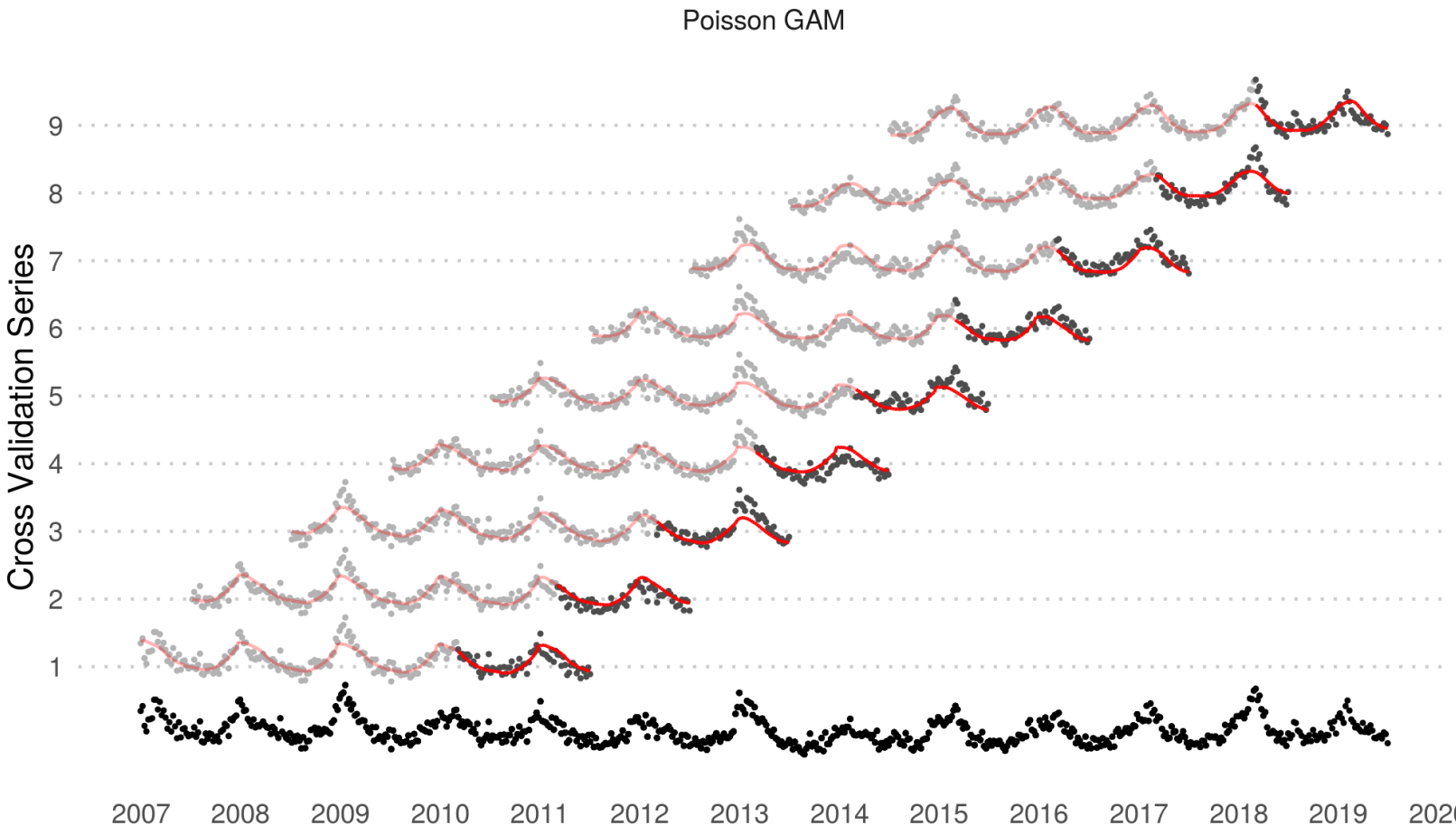
Complete population.

Data: HMD.

# The models

```
'Poisson GAM', 'gam', list(
  formula = formula(
    observed_deaths ~
      1 + sex + age_group +
      # log linear long term trend
      weeks_since_origin*sex_age_interaction +
      # penalized cyclic spline for seasonality
      s(weeks_into_season_year, bs = 'cp', k = 52, by = sex_age_interaction) +
      # adjustment for new years eve
      new_year*sex_age_interaction +
      # exposures
      offset(log(exposure))
  ),
  family = quasipoisson(link = 'log')
)
```

# The models




**Observed** vs. **predicted** weekly death counts Denmark.

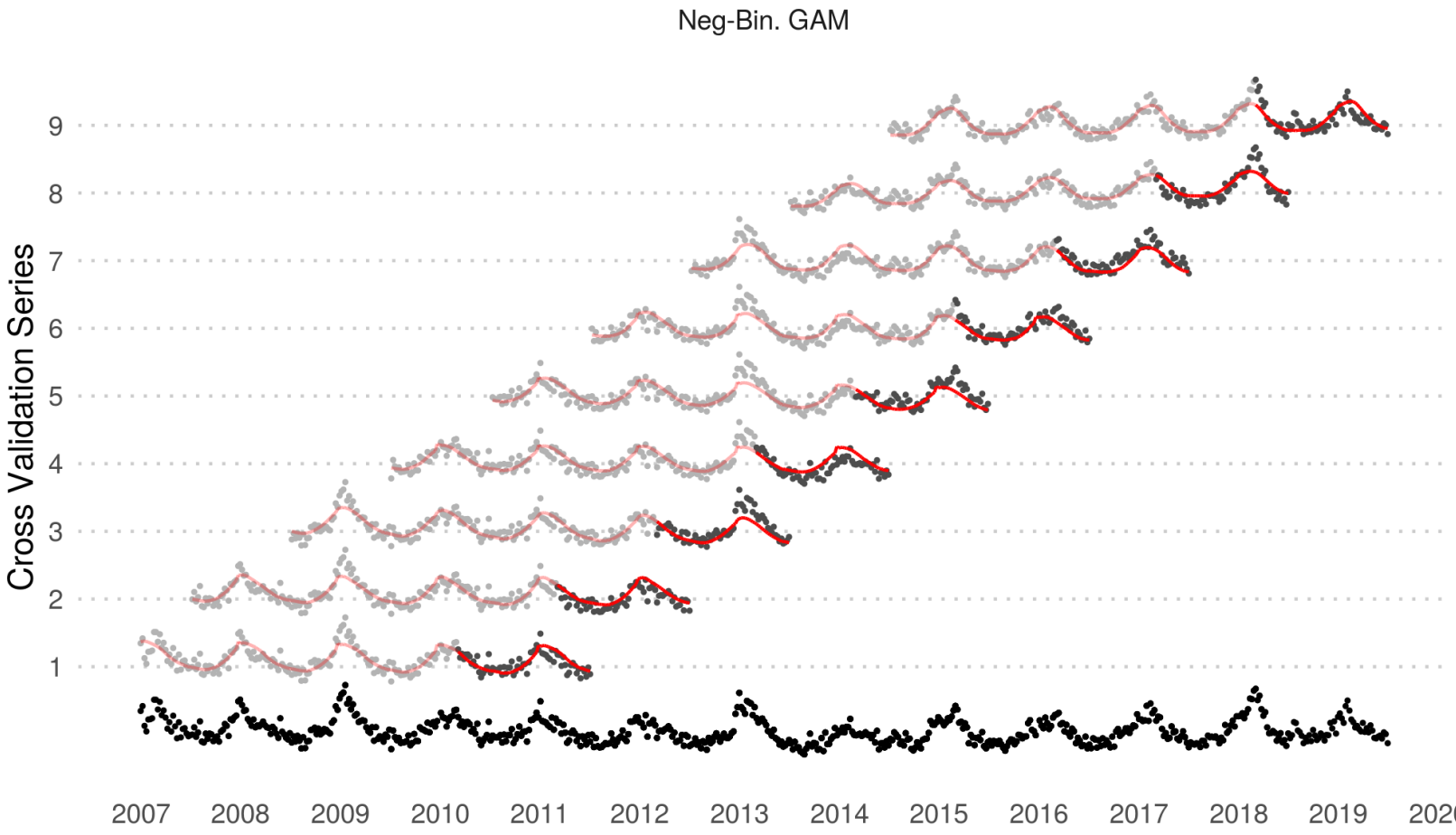
Complete population.

Data: HMD.

# The models

```
'Neg-Bin. GAM', 'gam', list(
  formula = formula(
    observed_deaths ~
      1 + sex + age_group +
      # log linear long term trend
      weeks_since_origin*sex_age_interaction +
      # penalized cyclic spline for seasonality
      s(weeks_into_season_year, bs = 'cp', k = 52, by = sex_age_interaction) +
      # adjustment for new years eve
      new_year*sex_age_interaction +
      # exposures
      offset(log(exposure))
  ),
  family = nb(link = 'log')
)
```

# The models




**Observed** vs. **predicted** weekly death counts Denmark.

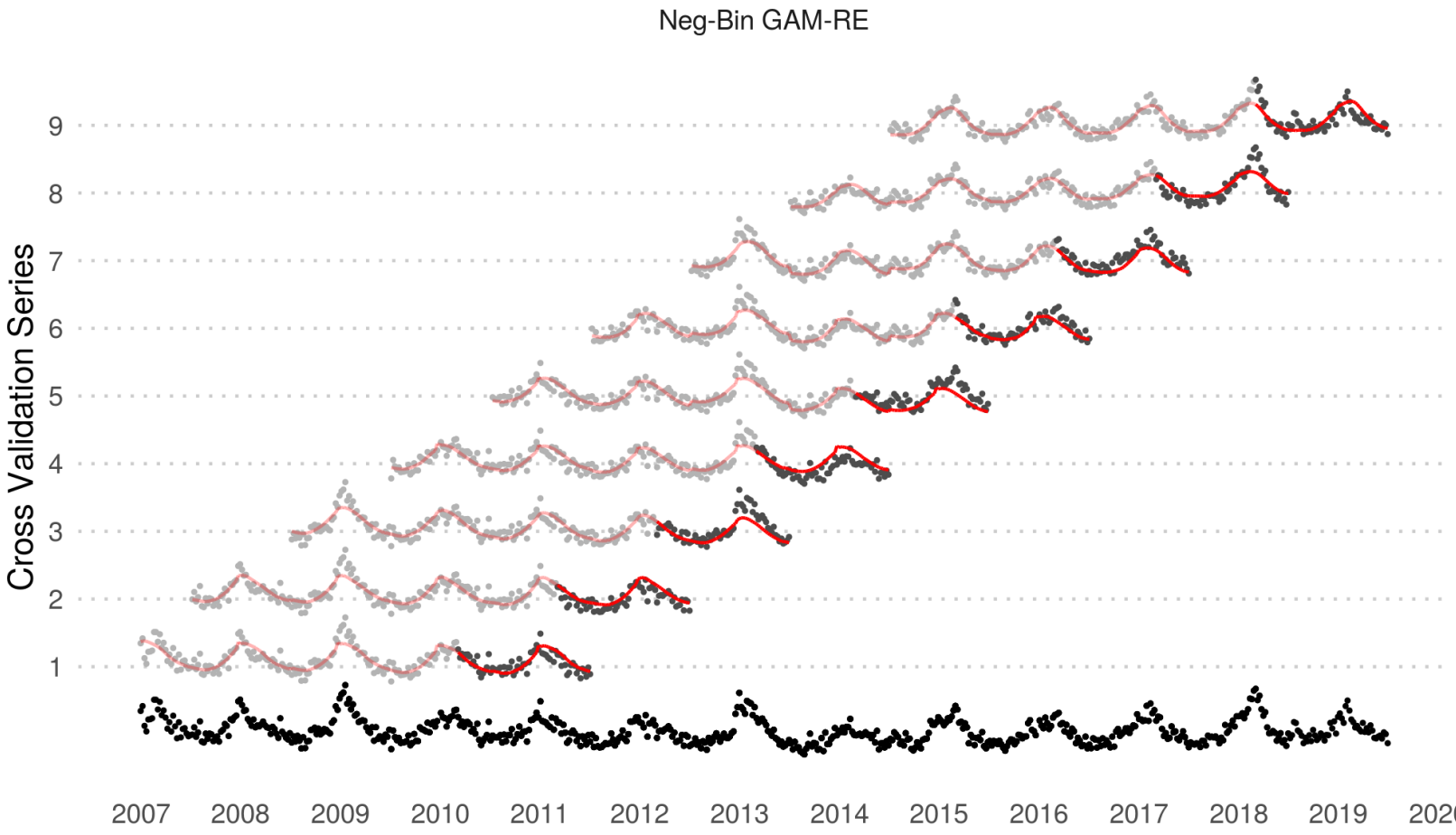
Complete population.

Data: HMD.

# The models

```
'Neg-Bin GAM-RE', 'gam', list(
  formula = formula(
    observed_deaths ~
      1 + sex + age_group +
      # log linear long term trend
      weeks_since_origin*sex_age_interaction +
      # penalized cyclic spline for seasonality
      s(weeks_into_season_year, bs = 'cp', k = 52, by = sex_age_interaction) +
      # adjustment for new years eve
      new_year*sex_age_interaction +
      # season year random effect adjustment
      s(season_year_sex_age_interaction, bs = 're') +
      # exposures
      offset(log(exposure))
  ),
  family = nb(link = 'log')
)
```

# The models

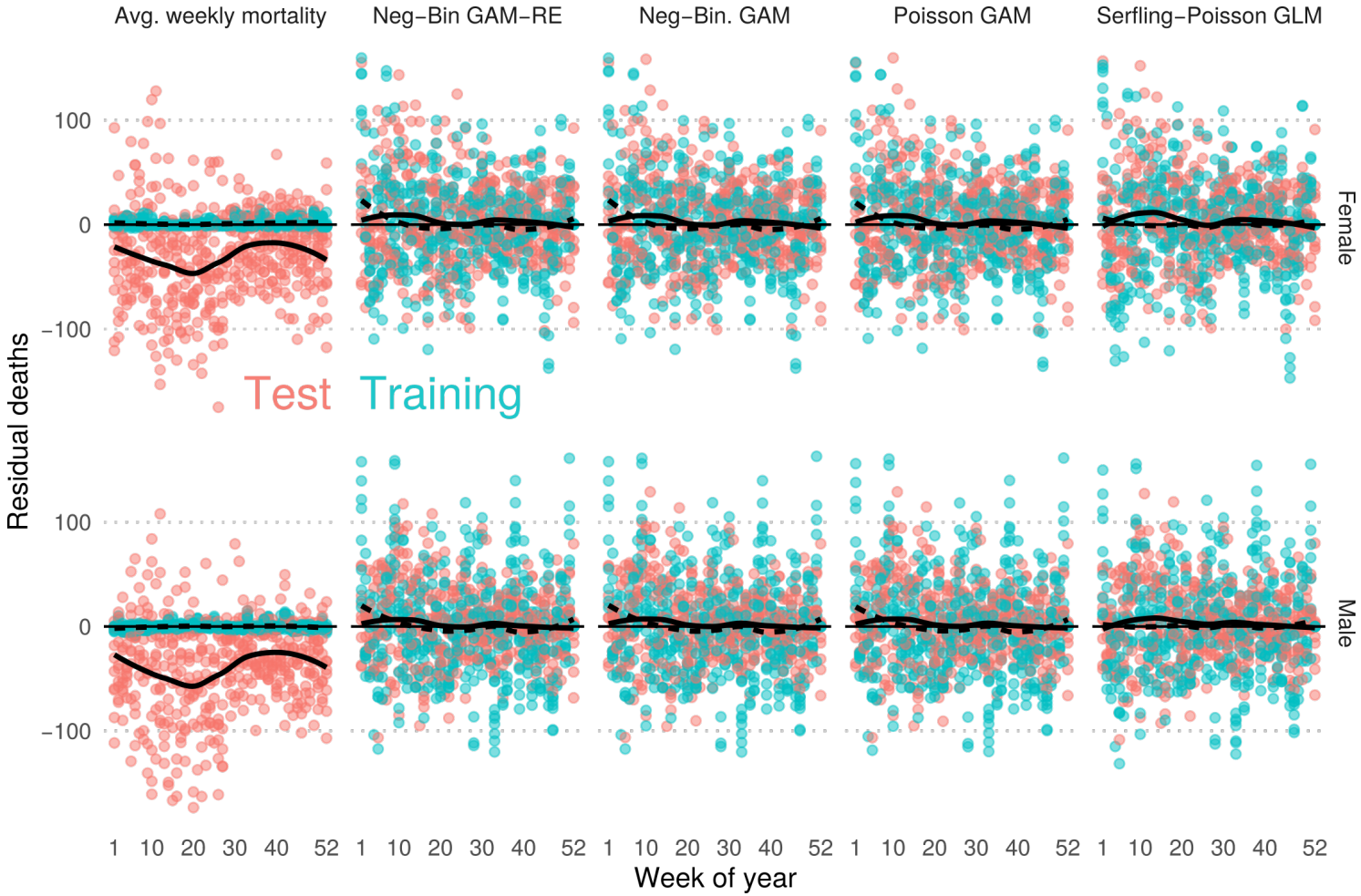



**Observed** vs. **predicted** weekly death counts Denmark.

Complete population.

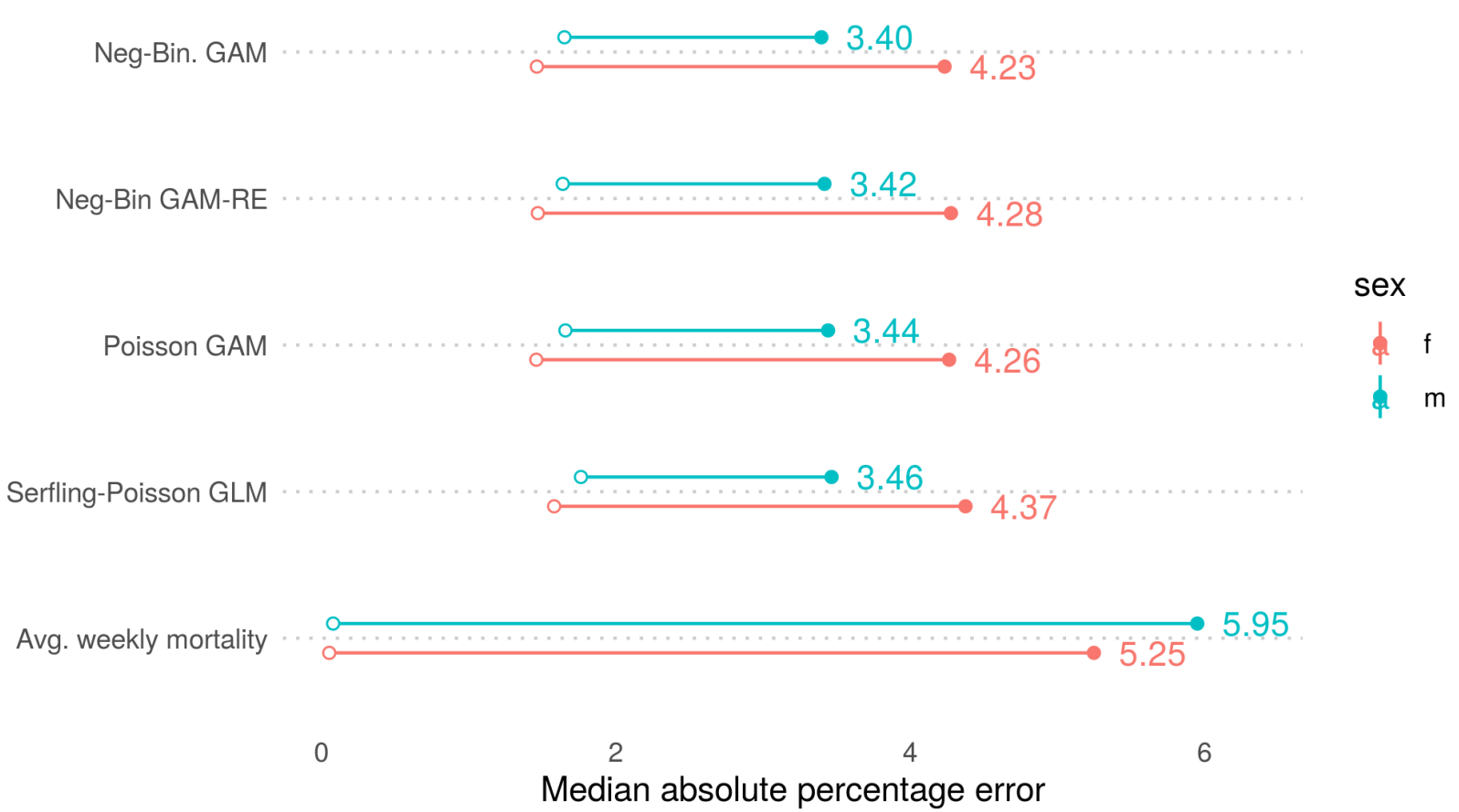
Data: HMD.

# Absolute weekly prediction error over test sets




**Observed** minus **predicted** weekly death counts Denmark.

# Median absolute prediction error




**Median absolute prediction error** of **death counts** on test set.

Complete Danish population by sex.

# Reproducible analysis

github.com/jschoeley

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