

Supplementary Information (SI) for
**Forecasting size-at-maturity shifts under global warming: A case study on European hake, a
widely distributed species**

Reviews in Fish Biology and Fisheries

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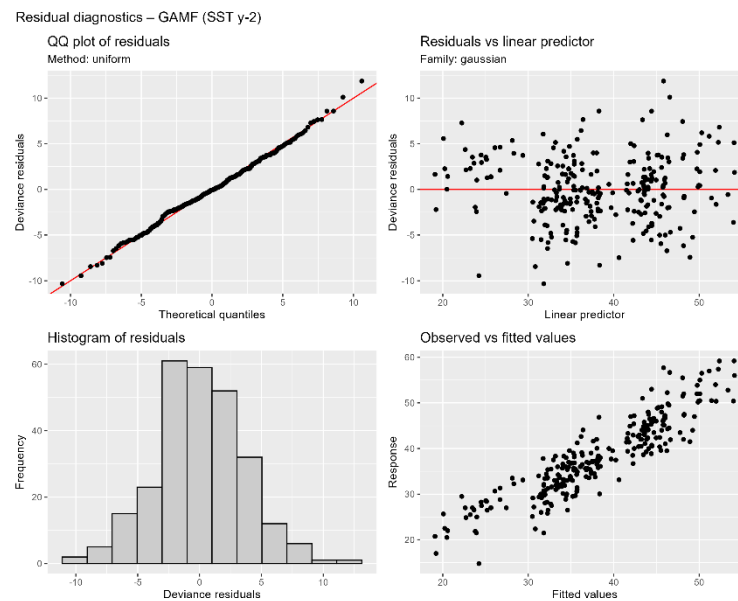
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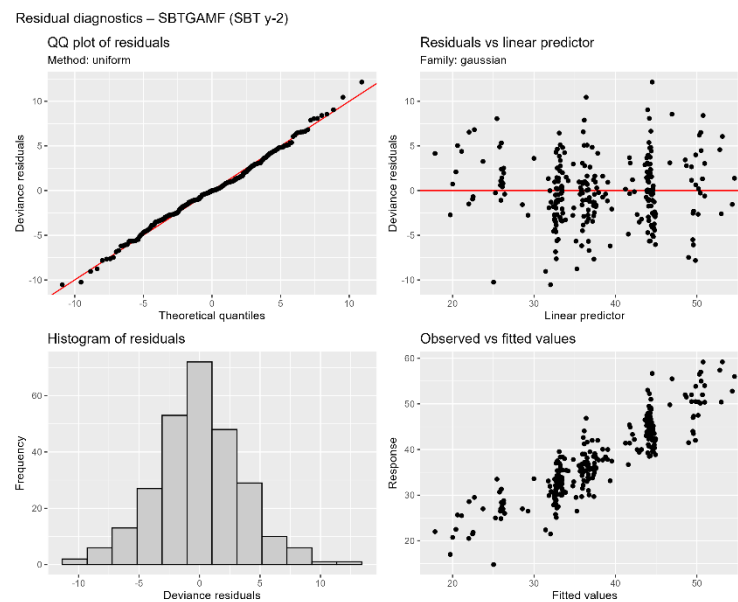
- **Online Resource 10** Diagnostic graphs and spatial patterns of generalised additive models (GAMs). A comprehensive diagnostic and interpretative visualisation of the two final generalised additive models (GAMs) is presented: one incorporating sea surface temperature with a two-year lag (SST_{y-2} , referred to as GAMF) and another using seabed temperature (SBT_{y-2} , referred to as SBTGAMF). All plots were generated using the R packages *gratia*, *ggplot2*, and *patchwork*.

Online Resource 10 Diagnostic graphs and spatial patterns of generalised additive models (GAMs). A comprehensive diagnostic and interpretative visualisation of the two final generalised additive models (GAMs) is presented: one incorporating sea surface temperature with a two-year lag (SST_{y-2} , referred to as GAMF) and another using seabed temperature (SBT_{y-2} , referred to as SBTGAMF). All plots were generated using the R packages *gratia*, *ggplot2*, and *patchwork*.

- Residual diagnostic plots of the final GAM (GAMF) with SST_{y-2} (from left to right and top to bottom): QQ plot of deviance residuals, residuals vs. linear predictor, histogram of residuals, and observed vs. fitted values. These plots assess distributional assumptions and potential heteroscedasticity.



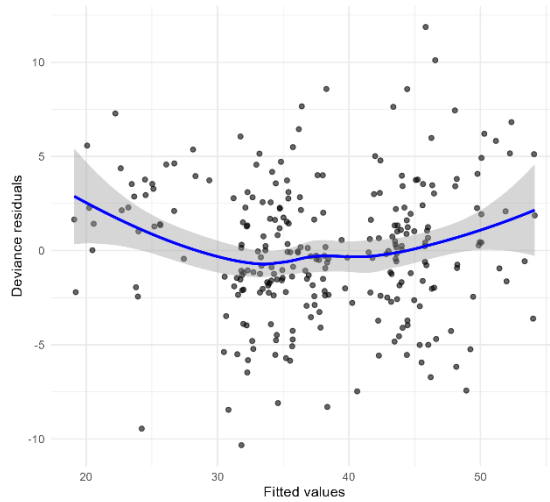
- Residual diagnostic plots of the alternative GAM (SBTGAMF) with SBT_{y-2} (from left to right and top to bottom): QQ plot of deviance residuals, residuals vs. linear predictor, histogram of residuals, and observed vs. fitted values. These plots assess distributional assumptions and potential heteroscedasticity.



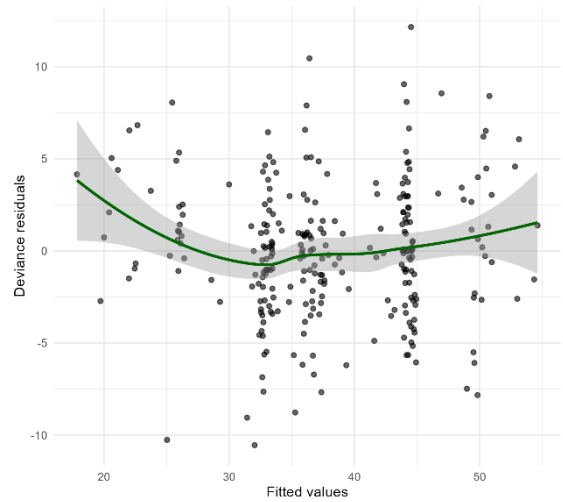
- Plots of smoothed deviance residuals versus fitted values: left panel shows the final GAM (GAMF) with SST_{y-2} , right panel the alternative GAM (SBTGAMF) with SBT_{y-2} . These diagnostic plots help identify non-linearity, heteroscedasticity, or other signs of model misspecification.

Residuals vs Fitted using geom_smooth()

Residuals vs Fitted – GAMF (SST y-2)



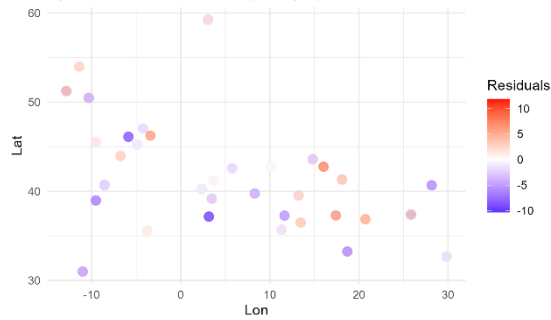
Residuals vs Fitted – SBTGAMF (SBT y-2)



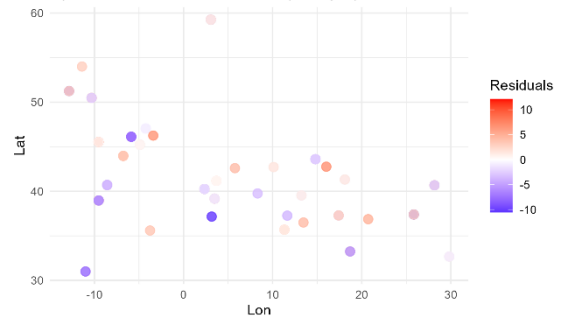
- Spatial plots of deviance residuals: left, final GAM (GAMF) with SSTy-2; right, alternative GAM (SBTGAMF) with SBTy-2. Residuals are colour-mapped from blue (negative) to red (positive), highlighting spatial patterns that may indicate localized model misfit.

Spatial distribution of deviance residuals

Spatial residuals – GAMF (SST y-2)



Spatial residuals – SBTGAMF (SBT y-2)



- Spatial smooth effects estimated for the two models: left, final GAM (GAMF) with SSTy-2; right, alternative GAM (SBTGAMF) with SBTy-2. The partial effect of the spatial term (tensor product smooth) is shown on the link scale, highlighting residual geographic variation in size-at-maturity beyond temperature and sex.

Partial effects of spatial smooth $te(Lon, Lat)$

