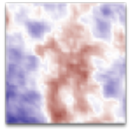
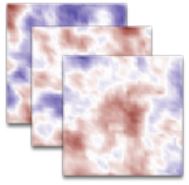
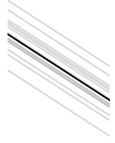
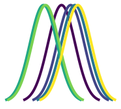
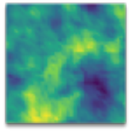
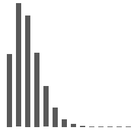
Model component	Illustration	Description	Example	Notation	Example code

Main effects		Linear, smoother, or breakpoint effects	Linear temperature, spline of depth, or breakpoint effect of oxygen on abundance	$\boldsymbol{X}^{\text{main}}_{\boldsymbol{s},t}\boldsymbol{\beta}$	`formula = y ~ x`
					`formula = y ~ s(x)`
					`formula = y ~ breakpt(x)`

Spatial random effects		All spatially correlated effects from variables that are constant in time but are omitted from the model (or a model without a time element)	Depth, latitude, or substrate effects if omitted from model	$\omega_{\boldsymbol{s}} \sim \text{MVN}(\boldsymbol{0}, \boldsymbol{\Sigma}_{\omega})$	`spatial = 'on'` `spatial = 'off'`

Spatiotemporal random effects		All spatially correlated effects from variables that change through time but are omitted from the model	Temperature, oxygen, prey abundance effects if omitted from the model	$\epsilon_{\boldsymbol{s},t} \sim \text{MVN}(\boldsymbol{0}, \boldsymbol{\Sigma}_{\epsilon})$	`spatiotemporal = 'iid'`
					`spatiotemporal = 'ar1'`
					`spatiotemporal = 'rw'`
					`spatiotemporal = 'off'`

IID random intercepts		Group-level effects that are constrained by normal distributions	Transect ID, vessel ID	$\alpha_g \sim \text{N}(0, \sigma^2_{\alpha})$	`formula = y ~ (1|g)`
Time-varying effects		Effects that vary though time	Relationship between depth and fish abundance changes through time	$\boldsymbol{X}^{\text{tvc}}_{\boldsymbol{s},t}\gamma_t$ $\gamma_t \sim \text{N}(\gamma_{t-1}, \sigma^2_{\gamma})$	`time_varying = ~ 0 + x` `time_varying = ~ 1`
Spatially varying effects		Effects ('slopes') that vary in space	(1) Local trends in abundance over time; (2) spatial distribution depends on a climate index	$\boldsymbol{X}^{\text{svc}}_{\boldsymbol{s},t}\zeta_{\boldsymbol{s}}$ $\zeta_{\boldsymbol{s}} \sim \text{MVN}(\boldsymbol{0}, \boldsymbol{\Sigma}_{\zeta})$	`spatial_varying = ~ x`

Observation error		Error from observing or sampling the process	Counting birds or fish in a survey; recording presence/ absence in a quadrat		`family = binomial(link = "logit")`
					`family = nbinom2(link = "log")`
					`family = tweedie(link = "log")`