

# Package ‘EcoEnsemble’

July 21, 2025

**Title** A General Framework for Combining Ecosystem Models

**Version** 1.1.2

**Description** Fit and sample from the ensemble model described in Spence et al (2018): ``A general framework for combining ecosystem models"<[doi:10.1111/faf.12310](https://doi.org/10.1111/faf.12310)>.

**License** GPL (>= 3)

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**URL** <https://github.com/CefasRepRes/EcoEnsemble>

**BugReports** <https://github.com/CefasRepRes/EcoEnsemble/issues>

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**Imports** methods, Rcpp, matrixcalc, RcppParallel (>= 5.0.1), rstan (>= 2.26.0), rstantools (>= 2.1.1), dplyr, ggplot2, reshape2, tibble, cowplot

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'DiscrepancyPrior-IndSTPrior-class.R'  
'DiscrepancyPrior-ShaSTPrior-class.R'  
'DiscrepancyPrior-TruthPrior-class.R' 'EcoEnsemble-package.R'  
'EnsemblePrior-class.R' 'EnsembleData-class.R'  
'EnsembleFit-class.R' 'EnsembleSample-class.R'  
'Prior\_sampling.R' 'RcppExports.R' 'data.R' 'fit\_ensemble.R'  
'fit\_ensemble\_withdrivers.R' 'generate\_simulator\_stan\_data.R'  
'generate\_simulator\_stan\_data\_withdrivers.R'

'get\_stan\_outputs.R' 'get\_stan\_outputs\_withdrivers.R'  
 'plot\_functions.R' 'plot\_functions\_withdrivers.R'  
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 'validation\_prior\_functions.R'

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EcoEnsemble-package	<i>A general framework for combining ecosystem models</i>
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**Description**

The EcoEnsemble package implements the framework for combining ecosystem models laid out in Spence et al (2018).

**Details**

The ensemble model can be implemented in three main stages:

1. Eliciting priors on discrepancy terms: This is done by using the EnsemblePrior constructor.
2. Fitting the ensemble model: Using fit\_ensemble\_model with simulator outputs, observations and prior information. The ensemble model can be fit, obtaining either the point estimate, which maximises the posterior density, or running Markov chain Monte Carlo to generate a sample from the posterior density of the ensemble model.
3. Sampling the latent variables from the fitted model: Using generate\_sample with the fitted ensemble object, the discrepancy terms and the ensemble's best guess of the truth can be generated. Similarly to fit\_ensemble\_model, this can either be a point estimate or a full sample.

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**References**

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>

Spence, M. A., J. L. Blanchard, A. G. Rossberg, M. R. Heath, J. J. Heymans, S. Mackinson, N. Serpetti, D. C. Speirs, R. B. Thorpe, and P. G. Blackwell. 2018. "A General Framework for Combining Ecosystem Models." Fish and Fisheries 19: 1013-42. <https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12310>

**See Also**

Useful links:

- <https://github.com/CefasRepRes/EcoEnsemble>
- Report bugs at <https://github.com/CefasRepRes/EcoEnsemble/issues>

---

EnsembleData

*Constructor for the EnsembleData class*


---

**Description**

A constructor for the EnsembleData class. This is used to convert input data into the required form for `fit_ensemble_model`.

**Usage**

```
EnsembleData(observations, simulators, priors, drivers = FALSE, MMod)
```

**Arguments**

observations	A list of length 2 containing observations and a covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving observations of each output of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $d \times d$ matrix where $d$ is the number of columns of the observations data frame / matrix. This matrix is the covariance matrix of the observations.
simulators	A list with length equal to the number of simulators. For each simulator, there is a list of 2 objects containing the simulator output and covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving a simulator outputs of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $n_k \times n_k$ matrix where $n_k$ is the number of columns of the simulators output data frame / matrix. This matrix is the covariance matrix of the simulator outputs.
priors	An <code>EnsemblePrior</code> object specifying the prior distributions for the ensemble.
drivers	A logical indicating whether drivers have been used in combination with simulators. Default value is <code>FALSE</code> .
MMod	Not currently implemented.

**Value**

An object of class `EnsembleData`

**See Also**

[EnsembleData](#), [EnsemblePrior](#), [fit\\_ensemble\\_model](#)

**Examples**

```
ensemble_data <- EnsembleData(observations = list(SSB_obs, Sigma_obs),
                              simulators = list(list(SSB_ewe, Sigma_ewe, "EwE"),
                                                  list(SSB_fs, Sigma_fs, "FishSUMS"),
                                                  list(SSB_lm, Sigma_lm, "LeMans"),
                                                  list(SSB_miz, Sigma_miz, "mizer")),
                              priors = EnsemblePrior(4))
```

---

EnsembleData-class      *A class to hold the Ensemble data*

---

**Description**

A class that holds the observation data, simulator outputs, and prior information to convert into the required form for `fit_ensemble_model`.

**Slots**

`stan_input` A list of parameters in the correct form to fit the ensemble model in Stan.

`observations` A list of length 2 containing observations and a covariance matrix. The first element is a `data.frame` or `matrix` with each column giving observations of each output of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is the covariance matrix of the observations.

`simulators` A list with length equal to the number of simulators. For each simulator, there is a list of 2 objects containing the simulator output and covariance matrix. The first element is a `data.frame` or `matrix` with each column giving a simulator outputs of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is the covariance matrix of the simulator outputs.

`priors` An `EnsemblePrior` object specifying the prior distributions for the ensemble.

**See Also**

[EnsembleData](#), [EnsemblePrior](#), [fit\\_ensemble\\_model](#)

---

EnsembleFit      *The constructor for the EnsembleFit object*

---

**Description**

The constructor for an `EnsembleFit` object. This function need not be called as an `EnsembleFit` object is constructed automatically by the `fit_ensemble_model` function. The `samples` slot contains the samples from the MCMC if a full sampling was completed, otherwise the `point_estimate` slot contains information about a point estimate.

**Usage**

```
EnsembleFit(ensemble_data, samples = NULL, point_estimate = NULL)
```

**Arguments**

`ensemble_data` An EnsembleData object encapsulating the data used to fit the ensemble model.

`samples` A stanfit object containing the samples drawn from the fitted model. The default value is NULL.

`point_estimate` A list output of the optimised model. The default value is NULL.

**Value**

An object of class EnsembleFit

**References**

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>

**See Also**

[EnsembleFit](#), [fit\\_ensemble\\_model](#),

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EnsembleFit-class	<i>A class to hold the samples or point estimates from the ensemble model.</i>
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**Description**

An EnsembleFit object is returned by the `fit_ensemble_model` function. The object contains a slot for the EnsembleData object originally used to fit the ensemble model. The `samples` slot contains the samples from the MCMC if a full sampling was completed, otherwise the `point_estimate` slot contains information about a point estimate.

**Slots**

`ensemble_data` An EnsembleData object encapsulating the data used to fit the ensemble model.

`samples` A stanfit object containing the samples drawn from the fitted model. The default value is NULL.

`point_estimate` A list output of the optimised model. The default value is NULL.

**References**

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>

**See Also**

[EnsembleFit](#), [fit\\_ensemble\\_model](#), [generate\\_sample](#)

---

EnsemblePrior-class     *A class to hold the priors for the ensemble model.*

---

**Description**

An EnsemblePrior object encapsulates the prior information for the ensemble model.

**Slots**

- d A numeric specifying the number of variables of interest in the ensemble.
- ind\_st\_params A list containing a prior specification for the individual short-term discrepancies  $z_k^{(t)}$ . See details of the EnsemblePrior() constructor.
- ind\_lt\_params A list containing a prior specification for the individual long-term discrepancies  $\gamma_k$ . See details of the EnsemblePrior() constructor.
- sha\_st\_params A list containing a prior specification for the shared short-term discrepancies  $\eta^{(t)}$ . See details of the EnsemblePrior() constructor.
- sha\_lt\_params A numeric containing the standard deviations for the normal prior used on the shared short-term discrepancy  $\mu$ . If a single value is supplied, this is repeated for each variable
- truth\_params A list containing a prior specification for the processes on the truth  $y^{(t)}$ . See details of the EnsemblePrior() constructor. The default value is TruthPrior(d).
- priors\_stan\_input A list containing the prior data in the correct form to fit the model in Stan. This information is automatically generated by the constructor.

**References**

- Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>
- Lewandowski, Daniel, Dorota Kurowicka, and Harry Joe. 2009. “Generating Random Correlation Matrices Based on Vines and Extended Onion Method.” Journal of Multivariate Analysis 100: 1989–2001.

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EnsembleSample	<i>A constructor for the EnsembleSample object</i>
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### Description

A constructor for the EnsembleSample class. These objects are generated automatically using the generate\_sample function.

### Usage

```
EnsembleSample(ensemble_fit, mle, samples)
```

### Arguments

**ensemble\_fit** An EnsembleFit object containing the fitted ensemble model.

**mle** An array of dimension  $T \times (M + 2) \times N_{sample}$  containing MLE point estimates from the ensemble\_fit object, where  $T$  is the total time,  $M$  is the number of simulators and  $N_{sample}$  is the number of samples. For each time step, the  $t$ th element of the array is a matrix where each column is a sample and the rows are the variables:

$$\left( y^{(t)}, \eta^{(t)}, z_1^{(t)}, z_2^{(t)}, \dots, z_M^{(t)} \right)'$$

where  $y^{(t)}$  is the ensemble model's prediction of the latent truth value at time  $t$ ,  $\eta^{(t)}$  is the shared short-term discrepancy at time  $t$ ,  $z_i^{(t)}$  is the individual short-term discrepancy of simulator  $i$  at time  $t$ .

**samples** An array of dimension  $T \times (M + 2) \times N_{sample}$  containing samples from the ensemble\_fit object, where  $T$  is the total time,  $M$  is the number of simulators and  $N_{sample}$  is the number of samples. For each time step, the  $t$ th element of the array is a matrix where each column is a sample and the rows are the variables:

$$\left( y^{(t)}, \eta^{(t)}, z_1^{(t)}, z_2^{(t)}, \dots, z_M^{(t)} \right)'$$

where  $y^{(t)}$  is the ensemble model's prediction of the latent truth value at time  $t$ ,  $\eta^{(t)}$  is the shared short-term discrepancy at time  $t$ ,  $z_i^{(t)}$  is the individual short-term discrepancy of simulator  $i$  at time  $t$ .

### Value

An object of class EnsembleSample

### See Also

[EnsembleSample](#), [generate\\_sample](#)



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EnsembleSample-class    *A class to hold samples of the ensemble model*

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### Description

EnsembleSample objects are generated using the `generate_sample` function.

### Slots

`ensemble_fit` An EnsembleFit object containing the fitted ensemble model.

`mle` An array of dimension  $T \times (M + 2) \times N_{sample}$  containing MLE point estimates from the `ensemble_fit` object, where  $T$  is the total time,  $M$  is the number of simulators and  $N_{sample}$  is the number of samples. For each time step, the  $t$ th element of the array is a matrix where each column is a sample and the rows are the variables:

$$\left( y^{(t)}, \eta^{(t)}, z_1^{(t)}, z_2^{(t)}, \dots, z_M^{(t)} \right)'$$

where  $y^{(t)}$  is the ensemble model's prediction of the latent truth value at time  $t$ ,  $\eta^{(t)}$  is the shared short-term discrepancy at time  $t$ ,  $z_i^{(t)}$  is the individual short-term discrepancy of simulator  $i$  at time  $t$ .

`samples` An array of dimension  $T \times (M + 2) \times N_{sample}$  containing samples from the `ensemble_fit` object, where  $T$  is the total time,  $M$  is the number of simulators and  $N_{sample}$  is the number of samples. For each time step, the  $t$ th element of the array is a matrix where each column is a sample and the rows are the variables:

$$\left( y^{(t)}, \eta^{(t)}, z_1^{(t)}, z_2^{(t)}, \dots, z_M^{(t)} \right)'$$

where  $y^{(t)}$  is the ensemble model's prediction of the latent truth value at time  $t$ ,  $\eta^{(t)}$  is the shared short-term discrepancy at time  $t$ ,  $z_i^{(t)}$  is the individual short-term discrepancy of simulator  $i$  at time  $t$ .

### See Also

[EnsembleSample](#), [generate\\_sample](#)

---

`fit_ensemble_model`    *Fits the ensemble model*

---

### Description

`fit_ensemble_model` runs an MCMC of the ensemble model. This process can take a long time depending on the size of the datasets.

**Usage**

```
fit_ensemble_model(
  observations,
  simulators,
  priors,
  full_sample = TRUE,
  control = list(adapt_delta = 0.95),
  drivers = FALSE,
  MMod,
  ...
)
```

**Arguments**

observations	A list of length 2 containing observations and a covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving observations of each output of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $d \times d$ matrix where $d$ is the number of columns of the observations data frame / matrix. This matrix is the covariance matrix of the observations.
simulators	A list with length equal to the number of simulators. For each simulator, there is a list of 2 objects containing the simulator output and covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving a simulator outputs of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $n_k \times n_k$ matrix where $n_k$ is the number of columns of the simulators output data frame / matrix. This matrix is the covariance matrix of the simulator outputs.
priors	An <code>EnsemblePrior</code> object specifying the prior distributions for the ensemble.
full_sample	A logical that runs a full sampling of the posterior density of the ensemble model if TRUE. If FALSE, returns the point estimate which maximises the posterior density of the ensemble model.
control	If creating a full sample, this is a named list of parameters to control Stan's sampling behaviour. See the documentation of the <code>stan()</code> function in the <code>rstan</code> package for details. The default value is <code>list(adapt_delta = 0.95)</code> . If optimizing, this value is ignored.
drivers	A logical indicating whether drivers have been used in combination with simulators. Default value is FALSE.
MMod	Not currently implemented.
...	Additional arguments passed to the function <code>rstan::sampling</code> or <code>rstan::optimizing</code> .

**Value**

An `EnsembleFit` object.

## References

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>

## See Also

[EnsembleFit](#), [EnsembleSample](#)

## Examples

```
fit <- fit_ensemble_model(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_ewe, Sigma_ewe, "EwE"),
    list(SSB_fs, Sigma_fs, "FishSUMS"),
    list(SSB_lm, Sigma_lm, "LeMans"),
    list(SSB_miz, Sigma_miz, "Mizer")),
  priors = EnsemblePrior(4,
    ind_st_params = IndSTPrior(parametrisation_form = "lkj",
      var_params= list(1,1), cor_params = 10, AR_params = c(2, 2))),
  full_sample = FALSE) #Only optimise in this case
```

---

generate_sample	<i>Generate samples from a fitted ensemble model.</i>
-----------------	---

---

## Description

Methods to generates samples of the latent variables from a fitted ensemble model.

## Usage

```
generate_sample(fit, num_samples = 1)

get_transformed_data(fit)

get_parameters(ex.fit, x = 1)

get_mle(x = 1, ex.fit, transformed_data, time)

gen_sample(x = 1, ex.fit, transformed_data, time)

get_transformed_data_dri(fit)
```

## Arguments

fit	An EnsembleFit object.
num_samples	A numeric specifying the number of samples to be generated. The default is 1.

<code>ex.fit</code>	A list containing the samples / point estimate from the EnsembleFit object.
<code>x</code>	A numeric specifying which sample from the posterior to use. The default is 1.
<code>transformed_data</code>	A list of transformed input data.
<code>time</code>	A numeric specifying the time for which the ensemble model was run.

## Details

The samples are created using the methods described in Strickland et. al. (2009) and Durbin and Koopman (2002).

## Value

`generate_sample` gives a list of length 2, the first element being the MLE of latent variables and the second element being a set of samples of the latent variables.

- If `fit` is a sampling of the ensemble model parameters, then:
  - `mle` is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array, where  $M$  is the number of simulators and `num_samples` is the number of samples from the ensemble model, giving the MLE of the latent variables for each available sample from the ensemble model.
  - `sample` is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array, giving a sample of the latent variables for each available sample of the ensemble model.
- If `fit` is a point estimate of the ensemble model parameters, then:
  - `mle` is a  $\text{time} \times (3M + 2) \times 1$  array giving the MLE of the latent variables for the point estimate of the ensemble model.
  - `sample` is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array, giving `num_samples` samples of the latent variables for the single point estimate of the ensemble model.

`get_transformed_data` gives a list of transformed input data.

`get_parameters` gives a list of ensemble parameters from the requested sample.

`get_mle` If `fit` is a sampling of the ensemble model parameters, then this is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array. If `fit` is a point estimate of the ensemble model parameters, then this is a  $\text{time} \times (3M + 2) \times 1$  array giving the MLE of the latent variables for the point estimate of the ensemble model.

`gen_sample` If `fit` is a sampling of the ensemble model parameters, then this is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array, giving a sample of the latent variables for each available sample of the ensemble model. If `fit` is a point estimate of the ensemble model parameters, then this is a  $\text{time} \times (3M + 2) \times \text{num\_samples}$  array.

## References

- J. Durbin, S. J. Koopman (2002) A simple and efficient simulation smoother for state space time series analysis *Biometrika*, Volume 89, Issue 3, August 2002, Pages 603–616,
- Chris M.Strickland, Ian. W.Turner, Robert Denhamb, Kerrie L.Mengersena. Efficient Bayesian estimation of multivariate state space models *Computational Statistics & Data Analysis* Volume 53, Issue 12, 1 October 2009, Pages 4116-4125

**Examples**

```
fit <- fit_ensemble_model(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_ewe, Sigma_ewe, "EwE"),
    list(SSB_fs, Sigma_fs, "FishSUMS"),
    list(SSB_lm, Sigma_lm, "LeMans"),
    list(SSB_miz, Sigma_miz, "Mizer")),
  priors = EnsemblePrior(4,
    ind_st_params = IndSTPrior(parametrisation_form = "lkj",
      var_params= list(1,1), cor_params = 10, AR_params = c(2, 2))),
  full_sample = FALSE) #Only optimise in this case
samples <- generate_sample(fit, num_samples = 2000)
```

---

```
get_mcmc_ensemble_model
```

*Return the compiled ensemble model Stan object.*

---

**Description**

Gets the unfit, compiled stanmodel object encoding the ensemble model. This allows for manual fitting of the ensemble model directly using `rstan::sampling`.

**Usage**

```
get_mcmc_ensemble_model(priors, likelihood = TRUE, drivers = FALSE)
```

**Arguments**

priors	An EnsemblePrior object specifying the prior distributions for the ensemble for which the compiled stanmodel object will be obtained.
likelihood	A logical that returns the compiled stanmodel object including the likelihood (the Kalman filter) for given priors if TRUE. If FALSE returns the compiled stanmodel object without the likelihood for sampling from the prior.
drivers	A logical indicating whether drivers have been used in combination with simulators. Default value is FALSE.

**Value**

The stanmodel object encoding the ensemble model.

**Examples**

```
priors <- EnsemblePrior(4)
mod <- get_mcmc_ensemble_model(priors)

ensemble_data <- EnsembleData(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_ewe, Sigma_ewe, "EwE"),
    list(SSB_fs, Sigma_fs, "FishSUMS"),
```

```

        list(SSB_lm, Sigma_lm, "LeMans"),
        list(SSB_miz, Sigma_miz, "mizer")),
      priors = priors)

out <- rstan::sampling(mod, ensemble_data@stan_input, chains = 1)

```

---

IndLTPrior

*Constructor for the EnsemblePrior class*


---

## Description

Constructors for the EnsemblePrior class and related classes. These functions are used to encode prior information for the ensemble model. The IndSTPrior, IndLTPrior, ShaSTPrior, and TruthPrior constructors encapsulate prior information.

## Usage

```

IndLTPrior(
  parametrisation_form = "lkj",
  var_params = list(1, 1),
  cor_params = 1
)

IndSTPrior(
  parametrisation_form = "hierarchical",
  var_params = list(-3, 1, 8, 4),
  cor_params = list(0.1, 0.1, 0.1, 0.1),
  AR_params = c(2, 2)
)

ShaSTPrior(
  parametrisation_form = "lkj",
  var_params = list(1, 10),
  cor_params = 1,
  AR_params = c(2, 2)
)

TruthPrior(
  d,
  initial_mean = 0,
  initial_var = 100,
  rw_covariance = list(2 * d, diag(d))
)

EnsemblePrior(
  d,

```

```

ind_st_params = IndSTPrior(),
ind_lt_params = IndLTPrior(),
sha_st_params = ShaSTPrior(),
sha_lt_params = 5,
truth_params = TruthPrior(d)
)

```

## Arguments

parametrisation_form	The parametrisation by which the covariance matrix of the noise of the AR process (in the case of IndSTPrior and ShaSTPrior objects or the covariance of the distribution of long-term discrepancies for IndLTPrior objects) is decomposed. The default is hierarchical for IndSTPrior objects, and lkj otherwise. See details.
var_params	The parameters characterising the variance of the AR process (in the case of IndSTPrior and ShaSTPrior objects or the variance of the distribution of long-term discrepancies for IndLTPrior objects) on the discrepancy. The default value is <code>list(-3, 1, 8, 4)</code> for IndSTPrior objects, <code>list(1, 1)</code> for IndLTPrior objects, and <code>list(1, 10)</code> for ShaSTPrior objects. See details.
cor_params	The parameters characterising the correlations of the AR process (or the distribution of long-term discrepancies) on the short-term discrepancies. The default value in this case is to use <code>list(0.1, 0.1, 0.1, 0.1)</code> for IndSTPrior objects, and 1 for IndLTPrior and ShaSTPrior objects. See details.
AR_params	The parameters giving the beta parameters for the prior distribution on the autoregressive parameter of the AR(1) process. The default is <code>c(2, 2)</code> . See details.
d	A numeric specifying the number of variables of interest in the ensemble.
initial_mean	A numeric giving the mean of the normal distribution giving the prior on the initial value of the random walk. This is the same value for each variable. Default value is 0.
initial_var	A numeric giving the variance of the normal distribution giving the prior on the initial value of the random walk. This is the same value for each variable. Default value is 100.
rw_covariance	A list of length 2 containing the inverse-Wishart parameters for the covariance of the random walk of the truth. The default value is <code>list(2*d, diag(d))</code> .
ind_st_params	An IndSTPrior object specifying priors for the individual short-term discrepancies $z_k^{(t)}$ . The default value is <code>IndSTPrior("hierarchical", list(-3, 1, 8, 4), list(0.1, 0.1, 0.1, 0.1), c(2, 2))</code> .
ind_lt_params	An IndLTPrior object specifying priors for the individual long-term discrepancies $\gamma_k$ . The default value is <code>IndLTPrior("lkj", list(1, 1), 1)</code> .
sha_st_params	A ShaSTPrior object specifying priors for the shared short-term discrepancies $\eta^{(t)}$ . The default value is <code>ShaSTPrior("lkj", list(1, 10), 1, c(2, 2))</code> .
sha_lt_params	A numeric of length d or 1 containing the standard deviations for the normal prior used on the shared short-term discrepancy $\mu$ . If a single value is supplied, this is repeated for each variable of interest. The default value is 5.
truth_params	A TruthPrior object specifying priors for the processes on the truth $y^{(t)}$ . The default value is <code>TruthPrior(d)</code> .

## Details

IndSTPrior and ShaSTPrior discrepancy prior parameter objects contain 4 slots corresponding to:

1. `parametrisation_form` - A character specifying how the priors are parametrised. Currently supported priors are 'lkj', 'inv\_wishart', 'beta', 'hierarchical', or 'hierarchical\_beta\_conjugate' ('hierarchical' and 'hierarchical\_beta\_conjugate' are only supported for IndSTPrior objects).
2. `var_params` - The prior parameters for the discrepancy variances, either a list of length 2 or a numeric of length 4. See below.
3. `cor_params` - The correlation matrix parameters, either a list of length 2, a numeric of length 3 or a numeric of length 4. See below.
4. `AR_params` - Parameters for the autoregressive parameter as a numeric of length 2.

IndLTPrior discrepancy prior parameter objects contain the slots `parametrisation_form`, `var_params`, and `cor_params`.

There are currently five supported prior distributions on covariance matrices. As in Spence et. al. (2018), the individual and shared short-term discrepancy covariances,  $\Lambda_k$  and  $\Lambda_\eta$ , as well as the individual long-term discrepancy covariance,  $\Lambda_\gamma$ , are decomposed into a vector of variances and a correlation matrix

$$\Lambda = \sqrt{\text{diag}(\pi)} P \sqrt{\text{diag}(\pi)},$$

where  $\pi$  is the vector of variances for each variable of interest (VoI), and  $P$  is the correlation matrix.

Selecting 'lkj', 'inv\_wishart', 'beta', 'hierarchical' or 'hierarchical\_beta\_conjugate' refers to setting LKJ, inverse Wishart, beta or hierarchical (with gamma-distributed hyperparameters or beta-conjugate-distributed hyperparameters) prior distributions on the covariance matrix respectively. The variance parameters should be passed through as the `var_params` slot of the object and the correlation parameters should be passed through as the `cor_params`. For 'lkj', 'inv\_wishart', and 'beta' selections, variances are parameterised by gamma distributions, so the `var_params` slot should be a list of length two, where each element gives the shape and rate parameters for each VoI (either as a single value which is the same for each VoI or a numeric with the same length as the number of VoI). For example, setting `var_params = list(c(5,6,7,8), c(4,3,2,1))` would correspond to a  $\text{Gamma}(5, 4)$  prior on the variance of the first VoI, a  $\text{Gamma}(6, 3)$  prior on the variance of the second VoI, etc... The correlations should be in the following form:

- If 'lkj' is selected, then `cor_params` should be a numeric  $\eta$  giving the LKJ shape parameter, such that the probability density is given by (Lewandowski et. al. 2009)

$$f(\Sigma|\eta) \propto \det(\Sigma)^{\eta-1}.$$

Variances are parameterised by gamma distributions.

- If 'inv\_wishart' is selected, then `cor_params` should be a list containing a scalar value  $\eta$  (giving the degrees of freedom) and a symmetric, positive definite matrix  $S$  (giving the scale matrix). The dimensions of  $S$  should be the same as the correlation matrix it produces (i.e.  $d \times d$  where  $d$  is the number of VoI). The density of an inverse Wishart is given by

$$f(W|\eta, S) = \frac{1}{2^{\eta d/2} \Gamma_N\left(\frac{\eta}{2}\right)} |S|^{\eta/2} |W|^{-(\eta+d+1)/2} \exp\left(-\frac{1}{2} \text{tr}(SW^{-1})\right),$$



where  $\Gamma_N$  is the multivariate gamma function and  $\text{tr}(X)$  is the trace of  $X$ . Note that inverse Wishart distributions act over the space of all covariance matrices. When used for a correlation matrix, only the subset of valid covariance matrices that are also valid correlation matrices are considered. Variances are parameterised by gamma distributions.

- If 'beta' is selected, then `cor_params` should be a list containing two symmetric  $d \times d$  matrices  $A$  and  $B$  giving the prior success parameters and prior failure parameters respectively. The correlation between the  $i$ th and  $j$ th VoI is  $\rho_{i,j}$  with

$$\frac{1}{\pi} \tan^{-1} \frac{\rho_{i,j}}{\sqrt{1 - \rho_{i,j}^2}} + \frac{1}{2} \sim \text{beta}(A_{i,j}, B_{i,j}).$$

Variances are parameterised by gamma distributions.

- If 'hierarchical' or 'hierarchical\_beta\_conjugate' is selected, then variances are parameterised by log-normal distributions:

$$\log \pi_{k,i} \sim N(\mu_i, \sigma_i^2)$$

with priors

$$\begin{aligned} \mu_i &\sim N(\alpha_\pi, \beta_\pi), \\ \sigma_i^2 &\sim \text{InvGamma}(\gamma_\pi, \delta_\pi). \end{aligned}$$

The `var_params` slot should then be a numeric of length 4, giving the  $\alpha_\pi, \beta_\pi, \gamma_\pi, \delta_\pi$  hyperparameters respectively. Correlations ( $\rho_{k,i,j}$  where  $\rho_{k,i,j}$  is the correlation between VoI  $i$  and  $j$  for the  $k$ th simulator) are parameterised by hierarchical beta distributions.

$$\frac{\rho_{k,i,j} + 1}{2} \sim \text{beta}(c_{k,i,j}, d_{k,i,j})$$

with priors

$$\begin{aligned} c_{k,i,j} &\sim \text{gamma}(\alpha_\rho, \beta_\rho), \\ d_{k,i,j} &\sim \text{gamma}(\gamma_\rho, \delta_\rho). \end{aligned}$$

NOTE: These options is only supported for the individual short-term discrepancy terms.

- If 'hierarchical' is selected, then the `cor_params` slot should be a numeric of length 4 giving the  $\alpha_\rho, \beta_\rho, \gamma_\rho, \delta_\rho$  hyperparameters. respectively. NOTE: This option is only supported for the individual short-term discrepancy terms.
- If 'hierarchical\_beta\_conjugate' is selected, then the `cor_params` slot should be a numeric of length 3. Denoting the values by  $r, s, k$ , they map to the hyperparameters  $p, q, k$  of the beta conjugate distribution via  $k = k, p^{-1/k} = (1 + e^{-s})(1 + e^{-r})$  and  $q^{1/k} = e^{-r}(1 + e^{-s})^{-1}(1 + e^{-r})^{-1}$ . The density of the beta conjugate distribution is defined up to a constant of proportionality by

$$p(\alpha_\rho, \beta_\rho | p, q, k) \propto \frac{\Gamma(\alpha_\rho + \beta_\rho)^k p^{\alpha_\rho} q^{\beta_\rho}}{\Gamma(\alpha_\rho)^k \Gamma(\beta_\rho)^k}.$$

NOTE: This option is only supported for the individual short-term discrepancy terms. Priors may also be specified for the autoregressive parameters for discrepancies modelled using autoregressive processes (i.e. for IndSTPrior and ShaSTPrior objects). These are parametrised via beta distributions such that the autoregressive parameter  $R \in (-1, 1)$  satisfies

$$\frac{R + 1}{2} \sim \text{Beta}(\alpha, \beta)$$

In addition to priors on the discrepancy terms, it is also possible to add prior information on the truth. We require priors on the truth at  $t = 0$ . By default, a  $N(0, 10)$  prior is used on the initial values., however this can be configured by the `truth_params` argument. The covariance matrix of the random walk of the truth  $\Lambda_y$  can be configured using an inverse-Wishart prior. The `truth_params` argument should be a `TruthPrior` object.

## Value

`EnsemblePrior` returns an object of class `EnsemblePrior`. `IndSTPrior` returns an object of class `IndSTPrior`. `IndLTPrior` returns an object of class `IndLTPrior`. `ShaSTPrior` returns an object of class `ShaSTPrior`. `TruthPrior` returns an object of class `TruthPrior`.

## References

Spence et. al. (2018). A general framework for combining ecosystem models. *Fish and Fisheries*, 19(6):1031-1042.

## Examples

```
##### Different forms of the individual long term discrepancy priors
#LKJ(10) priors on correlation matrices and gamma(5, 3) priors on the variances
ist_lkj <- IndSTPrior("lkj", list(5, 3), 10)#

#Same as above but with an additional beta(2, 4) prior on
#the autoregressive parameter of the AR process.
ist_lkj <- IndSTPrior("lkj", list(5, 3), 10, AR_params = c(2, 4))

#Same as above but with different variance priors for 5 different variables of interest.
#This encodes that there is a gamma(1, 1) prior on the variance of the first variable,
#a gamma(23, 1) on the second variable etc...
ist_lkj <- IndSTPrior("lkj", list(c(1,23,24,6,87), c(1,1,1,1,5)), 10, AR_params = c(2, 4))

#Hierarchical priors with gamma(1,2) and gamma(10, 1) on the variance hyperparameters and
#gamma(3,4), gamma(5,6) on the correlation hyperparameters
ist_hie <- IndSTPrior("hierarchical", list(1,2,10,1), list(3,4,5,6))

#Hierarchical priors with gamma(1,2) and gamma(10, 1) on the variance hyperparameters and
#the beta conjugate prior with parameters (p = 0.75, q = 0.75, k = 0.2) on the
#correlation hyperparameters
ist_hie_beta_conj <- IndSTPrior("hierarchical_beta_conjugate",
list(1,2,10,1), list(0.75,0.75,0.2))

#Inverse Wishart correlation priors. Gamma(2, 1/3) priors are on the variances and
#inv-Wishart(5, diag(5)) on the correlation matrices.
ist_inW <- IndSTPrior("inv_wishart", list(2, 1/3),list(5, diag(5)))

##### TruthPrior
#Simple default truth prior with 7 variables of interest
truth_def <- TruthPrior(7)
# A more fine-tuned truth prior for an ensemble with 7 species.
truth_cus <- TruthPrior(7, initial_mean = 2, initial_var = 10, rw_covariance = list(10, diag(7)))
```

```

#The default priors for an ensemble with 8 variables of interest
priors <- EnsemblePrior(8)

#With 4 variables of interest.
priors <- EnsemblePrior(4)

#Defining custom priors for a model with 4 species.
num_species <- 5
priors <- EnsemblePrior(
  d = num_species,
  ind_st_params = IndSTPrior("lkj", list(3, 2), 3, AR_params = c(2,4)),
  ind_lt_params = IndLTPrior(
    "beta",
    list(c(10,4,8, 7,6),c(2,3,1, 4,4)),
    list(matrix(5, num_species, num_species),
          matrix(0.5, num_species, num_species))
  ),
  sha_st_params = ShaSTPrior("inv_wishart",list(2, 1/3),list(5, diag(num_species))),
  sha_lt_params = 5,
  truth_params = TruthPrior(d = num_species, initial_mean = 5, initial_var = 10,
                             rw_covariance = list(10, diag(10)))
)

```

---

IndLTPrior-class	<i>A class to hold the priors for the ensemble model.</i>
------------------	---

---

## Description

An IndLTPrior object encapsulates the prior information for the long-term discrepancies of the individual simulators within the ensemble model.

## Details

Individual long-term discrepancies  $\gamma_k$  are drawn from a distribution

$$\gamma_k \sim N(0, C_\gamma).$$

Accepted parametrisation forms for this discrepancy are lkj, beta, or inv\_wishart. See details of the EnsemblePrior() constructor for more details.

## Slots

**parametrisation\_form** The parametrisation by which the covariance matrix of the noise of the AR process is decomposed.

**var\_params** The parameters characterising the variance of the distribution of the individual long-term discrepancy.

**cor\_params** The parameters characterising the correlations of the distribution of the individual long-term discrepancy.

**See Also**

[IndSTPrior](#), [ShaSTPrior](#), [TruthPrior](#),

---

IndSTPrior-class

*A class to hold the priors for the ensemble model.*

---

**Description**

An IndSTPrior object encapsulates the prior information for the short-term discrepancies of the individual simulators within the ensemble model.

**Details**

Individual short-term discrepancies  $z_k^{(t)}$  are modelled as an AR(1) process so that

$$z_k^{(t+1)} \sim N(R_k z_k^{(t)}, \Lambda_k).$$

Accepted parametrisation forms for this discrepancy are lkj, beta, inv\_wishart, hierarchical or hierarchical\_beta\_conjugate. See details of the EnsemblePrior() constructor for more details.

**Slots**

AR\_param The parameters giving the beta parameters for the autoregressive parameter of the AR(1) process.

parametrisation\_form The parametrisation by which the covariance matrix of the noise of the AR process is decomposed.

var\_params The parameters characterising the variance of the AR process on the individual short-term discrepancy.

cor\_params The parameters characterising the correlations of the AR process on the individual short-term discrepancy. .

**See Also**

[IndLTPrior](#), [ShaSTPrior](#), [TruthPrior](#),

---

KalmanFilter_back	<i>Backwards Kalman filter</i>
-------------------	--------------------------------

---

**Description**

Finds the most likely path through a dynamical linear model.

**Usage**

```
KalmanFilter_back(rhos, dee, R, Q, C, P, xhat, Time, y, obs)
```

**Arguments**

rhos	A numeric containing the diagonal elements of the transition matrix of the evolution equation.
dee	A numeric of the same length as rho containing the discrepancies or biases in the observation process.
R	A numeric representing the variances of the observation process.
Q	A matrix of dimensions length(rho) and length(rho) representing the covariance of the evolution process.
C	A a matrix of dimensions length(rho) and length(R) representing the observation operator of the observation process.
P	A matrix of dimensions length(rho) and length(rho) representing the covariance matrix of the first state of the evolution process.
xhat	A numeric of the same length as rho representing the expectation of the first state of the evolution process.
Time	A numeric The length of time of the dynamical linear model.
y	A matrix of dimensions Time and length(R) of observations of the observation process.
obs	A matrix of dimensions Time and length(R). 1 means in the i,jth element means that the jth output is observed at tim i.

**Details**

For the model with the evolution process

$$x_{t+1} \sim N(\rho \cdot x_t, Q)$$

and observation process

$$y_t \sim N(\rho(x_t + \delta), \text{diag}(R))$$

.

Using the sequential Kalman filter, the function gives the mostly path of  $x_t$  for all  $t$ .

**Value**

A matrix with dimensions `nrow(time)` and `length(xhat)` representing the most likely values of the latent variables.

**References**

Chui, C.K. & Chen, G. (2009) Kalman Filtering with Real-Time Applications. Springer, Berlin, Heidelberg, Fourth Edition.

Kalman, R. E. (1960) A new approach to linear filtering and prediction problems. Trans. ASME, J. Basic Eng., 82, pp. 35-45.

**Examples**

```
fit <- fit_ensemble_model(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_ewe, Sigma_ewe, "EwE"),
    list(SSB_fs, Sigma_fs, "FishSUMS"),
    list(SSB_lm, Sigma_lm, "LeMans"),
    list(SSB_miz, Sigma_miz, "Mizer")),
  priors = EnsemblePrior(4,
    ind_st_params = IndSTPrior(parametrisation_form = "lkj",
      var_params= list(1,1), cor_params = 10, AR_params = c(2, 2))),
  full_sample = FALSE) #Only optimise in this case
transformed_data <- get_transformed_data(fit)
ex.fit <- fit@point_estimate$par
params <- get_parameters(ex.fit)
ret <- KalmanFilter_back(params$AR_params, params$lt_discrepancies,
  transformed_data$all_eigenvalues_cov, params$SIGMA,
  transformed_data$bigM, params$SIGMA_init, params$x_hat,
  fit@ensemble_data@stan_input$time, transformed_data$new_data,
  transformed_data$observation_available)
```

---

`plot.EnsembleSample`     *Plot the ensemble output*

---

**Description**

Plots the latent variables predicted by the ensemble model, along with simulator outputs and observations.

**Usage**

```
## S3 method for class 'EnsembleSample'
plot(x, variable = NULL, quantiles = c(0.05, 0.95), ...)
```

**Arguments**

<code>x</code>	An EnsembleSample object.
<code>variable</code>	The name of the variable to plot. This can either be a character string in the same form as the observation variable, or an index for the column in the observations data frame.
<code>quantiles</code>	A numeric vector of length 2 giving the quantiles for which to plot ribbons if doing a full sampling of the ensemble model. The default is <code>c(0.05, 0.95)</code> .
<code>...</code>	Other arguments passed on to methods. Not currently used.

**Value**

The ggplot object.

**Examples**

```
priors <- EnsemblePrior(4)
prior_density <- prior_ensemble_model(priors, M = 4)
samples <- sample_prior(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_miz, Sigma_miz),
    list(SSB_ewe, Sigma_ewe),
    list(SSB_fs, Sigma_fs),
    list(SSB_lm, Sigma_lm)),
  priors = priors,
  sam_priors = prior_density)
plot(samples) #Plot the prior predictive density.
plot(samples, variable="Herring")
```

---

`prior_ensemble_model`    *Generate samples of parameters from prior distribution*

---

**Description**

Methods to generates samples of the parameters from the prior distribution of the ensemble model.

**Usage**

```
prior_ensemble_model(
  priors,
  M = 1,
  MM = NULL,
  full_sample = TRUE,
  control = list(adapt_delta = 0.95),
  ...
)
```

**Arguments**

priors	An EnsemblePrior object specifying the prior distributions for the ensemble.
M	A numeric that represents the number of simulators. The default is 1.
MM	A numeric that represents the number of drivers. The default is NULL.
full_sample	A logical that runs a full sampling of the prior density of the ensemble model if TRUE. If FALSE, returns the point estimate which maximises the prior density of the ensemble model.
control	If creating a full sample, this is a named list of parameters to control Stan's sampling behaviour. See the documentation of the stan() function in the rstan package for details. The default value is list(adapt_delta = 0.95). If optimizing, this value is ignored.
...	Additional arguments passed to the function rstan::sampling or rstan::optimizing.

**Value**

A list containing two items named `samples` and `point_estimate`. If `full_sample==TRUE`, `samples` is a `stanfit` and `point_estimate` is a `NULL` object, else `samples` is a `NULL` and `point_estimate` is a list object. It is possible to generate a point estimate for the prior if the individual short-term discrepancy prior follows a hierarchical parameterisation.

**References**

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.2. <https://mc-stan.org>

**See Also**

[EnsembleFit](#)

**Examples**

```
priors <- EnsemblePrior(4)
prior_density <- prior_ensemble_model(priors, M = 4)
```

---

sample\_prior

*Generate samples of latent variables from prior predictive distribution*

---

**Description**

Methods to generate samples of the latent variables from the prior predictive distribution of the ensemble model.



**Usage**

```
sample_prior(
  observations,
  simulators,
  priors,
  sam_priors,
  num_samples = 1,
  full_sample = TRUE,
  drivers = FALSE,
  ...
)
```

**Arguments**

observations	A list of length 2 containing observations and a covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving observations of each output of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $d \times d$ matrix where $d$ is the number of columns of the observations data frame / matrix. This matrix is the covariance matrix of the observations.
simulators	A list with length equal to the number of simulators. For each simulator, there is a list of 2 objects containing the simulator output and covariance matrix. The first element is a <code>data.frame</code> or <code>matrix</code> with each column giving a simulator outputs of interest and each row a time. Rows should be named with the times and columns should be named the variables. The second element is a $n_k \times n_k$ matrix where $n_k$ is the number of columns of the simulators output data frame / matrix. This matrix is the covariance matrix of the simulator outputs.
priors	An <code>EnsemblePrior</code> object specifying the prior distributions for the ensemble.
sam_priors	A list containing two items named <code>samples</code> and <code>point_estimate</code> . <code>samples</code> is either a <code>NULL</code> or a <code>stanfit</code> object containing the samples drawn from the prior distribution of the ensemble model and <code>point_estimate</code> is either a <code>NULL</code> or a list object containing the optimised prior distribution of the ensemble model. If this object is missing then <code>sample_prior</code> generates it.
num_samples	A numeric specifying the number of samples to be generated. The default is 1.
full_sample	A logical that runs a full sampling of the prior density of the ensemble model if <code>TRUE</code> . If <code>FALSE</code> , returns the point estimate which maximises the prior density of the ensemble model.
drivers	A logical indicating whether drivers have been used in combination with simulators. Default value is <code>FALSE</code> .
...	Additional arguments passed to the function <code>rstan::sampling</code> or <code>rstan::optimizing</code> .

**Details**

The samples are created using the methods described in Strickland et. al. (2009) and Durbin and Koopman (2002).

**Value**

An EnsembleSample object.

**References**

J. Durbin, S. J. Koopman (2002) A simple and efficient simulation smoother for state space time series analysis Biometrika, Volume 89, Issue 3, August 2002, Pages 603-616,

Chris M.Strickland, Ian. W.Turner, RobertDenhamb, Kerrie L.Mengersena. Efficient Bayesian estimation of multivariate state space models Computational Statistics & Data Analysis Volume 53, Issue 12, 1 October 2009, Pages 4116-4125

**See Also**

[EnsembleFit](#), [EnsembleSample](#), [generate\\_sample](#), [prior\\_ensemble\\_model](#)

**Examples**

```
priors <- EnsemblePrior(4)
prior_density <- prior_ensemble_model(priors, M = 4)
samples <- sample_prior(observations = list(SSB_obs, Sigma_obs),
  simulators = list(list(SSB_miz, Sigma_miz),
    list(SSB_ewe, Sigma_ewe),
    list(SSB_fs, Sigma_fs),
    list(SSB_lm, Sigma_lm)),
  priors = priors,
  sam_priors = prior_density)
plot(samples) #Plot the prior predictive density.
```

---

ShaSTPrior-class

*A class to hold the priors for the ensemble model.*

---

**Description**

An ShaSTPrior object encapsulates the prior information for the short-term discrepancies of the shared discrepancy of the ensemble model.

**Details**

Shared short-term discrepancies  $\eta^{(t)}$  are modelled as an AR(1) process so that

$$\eta^{(t+1)} \sim N(R_{\eta}\eta, \Lambda_{\eta}).$$

Accepted parametrisation forms for this discrepancy are lkj, beta, or inv\_wishart. See details of the EnsemblePrior() constructor for more details.

Slots

- AR\_param The parameters giving the beta parameters for the main parameter of the AR(1) process.
- parametrisation\_form The parametrisation by which the covariance matrix of the noise of the AR process is decomposed.
- var\_params The parameters characterising the variance of the AR process on the shared short-term discrepancy.
- cor\_params The parameters characterising the correlations of the AR process on the shared short-term discrepancy.

---

Sigma_ewe	<i>Ecopath with EcoSim Sigma</i>
-----------	----------------------------------

---

Description

A 4x4 covariance matrix quantifying the parameter uncertainty of Ecopath with EcoSim

Usage

Sigma\_ewe

Format

A 4x4 matrix.

References

Mackinson, S., Platts, M., Garcia, C., and Lynam, C. (2018). Evaluating the fishery and ecological consequences of the proposed North Sea multi-annual plan. PLOS ONE, 13(1), 1–23.

---

Sigma_fs	<i>FishSUMS Sigma</i>
----------	-----------------------

---

Description

A 3x3 covariance matrix quantifying the parameter uncertainty of FishSUMS

Usage

Sigma\_fs

Format

A 3x3 matrix.

References

Spence, M. A., Blanchard, J. L., Rossberg, A. G., Heath, M. R., Heymans, J. J., Mackinson, S., Serpetti, N., Speirs, D. C., Thorpe, R. B., and Blackwell, P. G. (2018). A general framework for combining ecosystem models. *Fish and Fisheries*, 19(6), 1031–1042.

---

Sigma_lm	<i>LeMans Sigma</i>
----------	---------------------

---

Description

LeMans Sigma

Usage

Sigma\_lm

Format

A 4x4 matrix. A 4x4 covariance matrix quantifying the parameter uncertainty of LeMans

References

Thorpe, R. B., Le Quesne, W. J. F., Luxford, F., Collie, J. S., and Jennings, S. (2015). Evaluation and management implications of uncertainty in a multispecies size-structured model of population and community responses to fishing. *Methods in Ecology and Evolution*, 6(1), 49–58.

---

Sigma_miz	<i>mizer Sigma</i>
-----------	--------------------

---

Description

mizer Sigma

Usage

Sigma\_miz

Format

A 4x4 matrix. A 4x4 covariance matrix quantifying the parameter uncertainty of mizer

References

Spence, M. A., Blackwell, P. G., and Blanchard, J. L. (2016). Parameter uncertainty of a dynamic multispecies size spectrum model. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(4), 589–59

Sigma\_obs

*Stock assessment Sigma***Description**

A 4x4 covariance matrix quantifying the covariances of the stock assessment estimates of biomass.

**Usage**

Sigma\_obs

**Format**

A 4x4 matrix.

**References**

Herring Assessment Working Group for the Area South of 62 N (HAWG). Technical report, ICES Scientific Reports. ACOM:07. 960 pp, ICES, Copenhagen.

Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak. Technical report, ICES Scientific Reports. ACOM:22.pp, ICES, Copenhagen.

SSB\_ewe

*Ecopath with EcoSim SSB***Description**

A dataset containing the predictions for spawning stock biomass of Norway Pout, Herring, Cod, and Sole in the North Sea between 1991-2050 under an MSY fishing scenario from EcoPath with EcoSim.

**Usage**

SSB\_ewe

**Format**

A data.frame with 60 rows and 4 variables:

N.pout Spawning stock biomass of Norway Pout, in log tonnes.

Herring Spawning stock biomass of Herring, in log tonnes.

Cod Spawning stock biomass of Cod, in log tonnes.

Sole Spawning stock biomass of Sole, in log tonnes.

## References

ICES (2016). Working Group on Multispecies Assessment Methods (WGSAM). Technical report, International Council for Exploration of the Seas.

---

SSB\_fs

*FishSUMS SSB*


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## Description

A data frame containing the predictions for spawning stock biomass of Norway Pout, Herring, and Cod in the North Sea between 1984-2050 under an MSY fishing scenario from FishSUMS. Note that FishSUMS does not produce outputs for Sole.

## Usage

SSB\_fs

## Format

A data.frame with 67 rows and 3 variables:

N.pout Spawning stock biomass of Norway Pout, in log tonnes.

Herring Spawning stock biomass of Herring, in log tonnes.

Cod Spawning stock biomass of Cod, in log tonnes.

## References

Speirs, D., Greenstreet, S., and Heath, M. (2016). Modelling the effects of fishing on the North Sea fish community size composition. *Ecological Modelling*, 321, 35–45

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SSB\_lm

*LeMans SSB*


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## Description

A data.frame containing the predictions for spawning stock biomass of Norway Pout, Herring, Cod, and Sole in the North Sea between 1986-2050 under an MSY fishing scenario from the LeMaRns package.

## Usage

SSB\_lm

**Format**

A data.frame with 65 rows and 4 variables:

N.pout Spawning stock biomass of Norway Pout, in log tonnes.

Herring Spawning stock biomass of Herring, in log tonnes.

Cod Spawning stock biomass of Cod, in log tonnes.

Sole Spawning stock biomass of Sole, in log tonnes.

**References**

Thorpe, R. B., Le Quesne, W. J. F., Luxford, F., Collie, J. S., and Jennings, S. (2015). Evaluation and management implications of uncertainty in a multispecies size-structured model of population and community responses to fishing. *Methods in Ecology and Evolution*, 6(1), 49–58.

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SSB\_miz

*mizer SSB*


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**Description**

A data.frame containing the predictions for spawning stock biomass of Norway Pout, Herring, Cod, and Sole in the North Sea between 1984-2050 under an MSY fishing scenario from mizer.

**Usage**

```
SSB_miz
```

**Format**

A data frame with 67 rows and 4 variables:

N.pout Spawning stock biomass of Norway Pout, in log tonnes.

Herring Spawning stock biomass of Herring, in log tonnes.

Cod Spawning stock biomass of Cod, in log tonnes.

Sole Spawning stock biomass of Sole, in log tonnes.

**References**

Blanchard, J. L., Andersen, K. H., Scott, F., Hintzen, N. T., Piet, G., and Jennings, S. (2014). Evaluating targets and trade-offs among fisheries and conservation objectives using a multispecies size spectrum model. *Journal of Applied Ecology*, 51(3), 612–622

SSB\_obs

*Stock assessment SSB***Description**

A data.frame containing the single species stock assessment estimates of spawning stock biomass of Norway Pout, Herring, Cod, and Sole in the North Sea between 1984-2017.

**Usage**

SSB\_obs

**Format**

A data frame with 34 rows and 4 variables:

N.pout Spawning stock biomass of Norway Pout, in log tonnes.

Herring Spawning stock biomass of Herring, in log tonnes.

Cod Spawning stock biomass of Cod, in log tonnes.

Sole Spawning stock biomass of Sole, in log tonnes.

**References**

Herring Assessment Working Group for the Area South of 62 N (HAWG)(2020). Technical report, ICES Scientific Reports. ACOM:07. 960 pp, ICES, Copenhagen.

Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (2020). Technical report, ICES Scientific Reports. ACOM:22.pp, ICES, Copenhagen.

TruthPrior-class

*A class to hold the priors for the truth model in the ensemble framework***Description**

An TruthPrior object encapsulates the prior information for the short-term discrepancies of the shared discrepancy of the ensemble model.

**Details**

The truth  $\mathbf{y}^{(t)}$  is modelled as a random walk such that

$$\mathbf{y}^{(t+1)} \sim N(\mathbf{y}^{(t)}, \Lambda_y).$$

The covariance matrix  $\Lambda_y$  is parameterised by an inverse Wishart distribution (contained in the rw\_covariance slot) and the initial value is modelled as drawn from a normal distribution.



**Slots**

- `d` A numeric giving the number of variables of interest in the ensemble model.
- `initial_mean` A numeric giving the standard deviation of the normal prior on the initial mean value of the random walk. This is the same standard deviation for each variable of interest.
- `initial_var` A list of length 2 containing the shape and scale parameters (respectively) for the gamma priors on the variance of the initial value of the truth.
- `rw_covariance` A list of length 2 containing the inverse-Wishart parameters for the covariance of the random walk of the truth.

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