# *StrathE2E2*: an R package for modelling the dynamics of marine food webs and fisheries

# Technical manual – documentation of input and output R-objects and file structures

# Version 3.2.0

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Package information

From an R-session:
library(StrathE2E2)

Package overview:
help(StrathE2E2)

CheatSheet:
vignette("StrathE2E2_CheatSheet")

131 Outputs from sensitivity analysis
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# MODEL CONFIGURATION AND INPUTS

## Folder structure for model input files

The data which define a model (parameters and driving data) are held in a specific folder structure for each implementation. The R-package has a demonstration model of the North Sea embedded in it which can be used as a template for user-defined models. The location of the North Sea demonstration model data within the folder structure of the R-package is shown in Figure 1, and the structure expected for any user-defined models in Figure 2.

The North Sea demonstration model is read-only within the folder structure of the R-package. The basic functions of the package will operate perfectly well from these folders, but the more advanced optimization functions require to write data back into the Parameter sub-folders. To use these function it wil be necessary to create an editable copy of the demonstartion models in a local work-space. Copies of the North Sea model can also be used as a template for development new models. This can be done using using any file manager or the e2e_copy() function provided with the package:

```
e2e_copy ("North_Sea", "1970-1999")
```

The above example copies the default NorthSea model variant “1970-1999” and the associated documentation which are provided within the package, to a folder “Models” in the current user workspace, creating the folder if necessary.

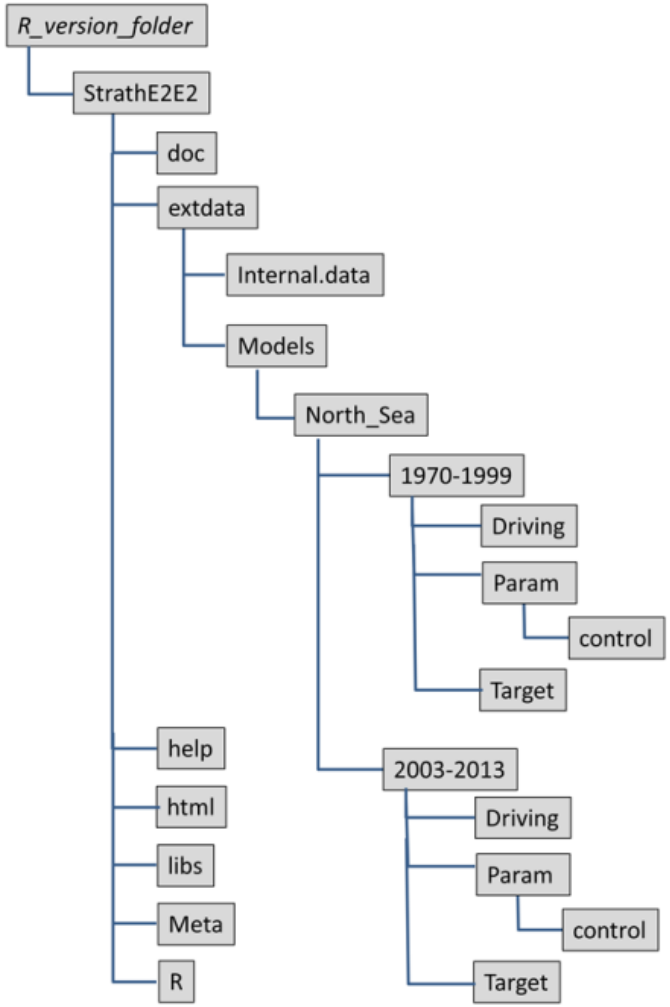


**Figure 1. Locations of the definition data folders for the North Sea demonstration model and its two variants in the structure of the R-package.**

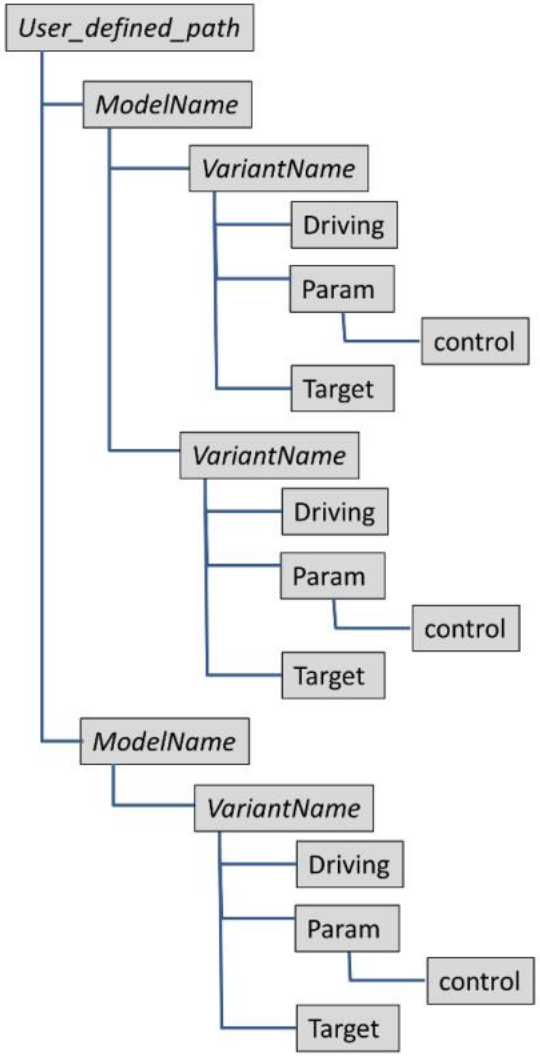


**Figure 2. Organisation of model definition data folders in any user-defined work-space. Italicised folder names are free for user specification.**

## Model configuration file

The configuration of a model run is managed at the highest level by a comma-separated (*.csv*) setup file which resides in the '*version*' sub-folder of each '*model_region*' folder. This must have the name "*MODEL_SETUP.csv*" in every case. User created "*MODEL_SETUP.csv*" can be edited in e.g. Excel or any text-editor.

The *MODEL_SETUP* file contains details of the 24 *.csv* parameter and data files that are required to define the ecology and fishing fleet models and provide the driving conditions for the system. These files must reside in three sub-directories of the model version folder, as listed in Table 1. Names for most of the files may be user defined, within the constraint that each must contain at least a core text-string (Table 2). The setup file also includes a free-text column for users to store brief details of e.g. the origins of data contained in each *,csv* file (Table 3).

**Table 1**. Expected locations of "*.csv*" data files in the folder structure hierarchy of a model setup, and details of which sub-folders and file-names are editable without breaking the dataflow through the model functions. The contents of all "*.csv*" files are editable.

| Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Names editable |
|---|---|---|---|---|---|
| Model folder | | | | | Yes |
| | Version sub-folders | | | | Yes |
| | | "*MODEL_SETUP.csv*" file | | | No |
| | | "*Driving*" sub-folder | | | No |
| | | | Driving data files (*.csv*) | | Yes |
| | | "*Param*" sub-folder | | | No |
| | | | Parameter data files (*.csv*) | | Yes |
| | | | "*control*" sub-folder | | No |
| | | | | control files (*.csv*) | No |
| | | "*Target*" sub-folder | | | No |
| | | | Target data files (*.csv*) | | Yes |

**Table 2**. Description, mandatory sub-directory location, and mandatory core text string required for the file-name of each of the *.csv* parameter and data files defining the model.

| **Brief description** | **Expected sub-directory of model version folder** | **Mandatory text string in file name** |
|---|---|---|
| Physical parameters (areas thickness and sediments) | */Param* | *physical_parameters* |
| Physics drivers (ocean inflows temperature etc) | */Driving* | *physics* |
| Chemistry drivers (boundary nutrients etc) | */Driving* | *chemistry* |
| Initial state of each state variable | */Param* | *Initial_values* |
| Biological event timing parameters | */Param* | *event_timing* |
| Fixed parameters for consumer guilds | */Param* | *fixed_consumers* |
| Fixed miscellaneous parameters (Q10s etc) | */Param* | *fixed_ miscellaneous* |
| Fitted prey preference matrix | */Param* | *fitted_ preference_matrix* |
| Fitted uptake and mortality parameters | */Param* | *fitted_ uptake_mort_rates* |
| Fitted microibiology and other parameters | */Param* | *fitted_ microbiology_ others* |
| Fishing fleet basic parameters | */Param* | *fishing_fleet* |
| Fishing activity and seabed abrasion rates for each gear | */Param* | *fishing_activity* |
| Fishing power parameters for each gear and guild | */Param* | *fishing_power* |
| Discard rates for each gear and guild | */Param* | *fishing_discards* |
| Processing at sea ratyes for each gear and guild | */Param* | *fishing_processing* |
| Spatial distribution of activity rates across habitats | */Param* | *fishing_distribution* |
| Gear activity multipliers (used to define fishing scenarios) | */Param* | *fishing_gear_multiplier* |
| Harvest ratio multipliers (used to define fishing scenarios) | */Param* | *harvest_ratio_multiplier* |
| Food web flow matrix template | */Param* | *food_web_flow_matrix_template* |
| Relationships between gear activity rates over time | */Param* | *fishing_gear_linkages* |
| Annual observational target data | */Target* | *annual_observed* |
| Monthly observational target data | */Target* | *monthly_observed* |
| Independently estimates guild harvest ratios (whole domain) | */Target* | *regional_harvest_r* |
| Inshore and offshore harvest ratios from a prior model run | */Target* | *zonal_harvest_r* |

**Table 3**. Example of a *MODEL_SETUP.csv* file for the 2003-2013 version of the North Sea model included with the package.

| Filename | Expected_subdir | Description | Comments |
|---|---|---|---|
| *physical_parameters_NORTH_SEA.csv* | *Param* | Physical parameters (areas thickness and sediments) | North Sea model data |
| *physics_ NORTH_SEA_2003-2013.csv* | *Driving* | Physics drivers (ocean inflows temperature etc) | North Sea 2003-2013 data from NEMO-ERSEM and elsewhere |
| *chemistry_NORTH_SEA_2003-2013.csv* | *Driving* | Chemistry drivers (boundary nutrients etc) | North Sea 2003-2013 data from NEMO-ERSEM World Ocean Atlas and elsewhere |
| *initial_values_NORTH_SEA_2003-2013.csv* | *Param* | Initial state of each state variable | Data exported from end of run for stationary state North Sea 2003-2013 model |
| *event_timing_ NORTH_SEA_2003-2013.csv* | *Param* | Biological event timing parameters | North Sea spawning recruitment and mackerel migrations in the 2003-2013 period |
| *fixed_ consumers_NORTH_SEA_2003-2013.csv* | *Param* | Fixed parameters for consumer guilds | Mostly generic parameters for European temperate waters with minor variation in harvestable fraction for carniv zoo for 2003-2013 |
| *fixed_ miscellaneous.csv* | *Param* | Fixed miscellaneous parameters (Q10s etc) | Miscellaneous fixed parameters for European temperate waters |
| *fitted_ preference_matrix_NORTH_SEA.csv* | *Param* | Fitted prey preference matrix | North Sea preference matrix generic for both 1970-1999 and 2003-2013 periods |
| *fitted_ uptake_ mort_rates_NORTH_SEA.csv* | *Param* | Fitted uptake and mortality parameters | North Sea parameters generic for both 1970-1999 and 2003-2013 periods |
| *fitted_ microbiology_ others_NORTH_SEA.csv* | *Param* | Fitted microibiology and other parameters | North Sea parameters generic for both 1970-1999 and 2003-2013 periods |
| *fishing_fleet_ NORTH_SEA_2003-2013.csv* | *Param* | Fishing fleet basic parameters | North Sea fleet parameters for the 2003-2013 period (uses demersal discard rates from csv file) |
| *fishing_activity_ NORTH_SEA_2003-2013.csv* | *Param* | Fishing activity and seabed abrasion rates | North Sea gear activity rates from STECF and Norway for the 2003- |

| | | | |
|---|---|---|---|
| | | for each gear | 2013 period |
| *fishing_power_ NORTH_SEA.csv* | *Param* | Fishing power parameters for each gear and guild | North Sea power parameters derived from 2003-2013 STECF data - used generically for both 1970-1999 and 2003-2013 periods |
| *fishing_discards_NORTH_SEA.csv* | *Param* | Discard rates for each gear and guild | North Sea discard rates from 2003-2013 STECF data - used generically for both 1970-1999 and 2003-2013 - EXCEPT for demersal fish rates need to be set to internally derived in 1970-1999 |
| *fishing_processing _NORTH_SEA.csv* | *Param* | Processing at sea ratyes for each gear and guild | North Sea processing-at-sea rates generic for both 1970-1999 and 2003-2013 periods |
| *fishing_distribution _NORTH_SEA.csv* | *Param* | Spatial distribution of activity rates across habitats | North Sea gear activity distributions from 2003-2013 STECF data - used generically for both the 1970-1999 and 2003-2013 periods |
| *fishing_gear_multiplier_NORTH_SEA.csv* | *Param* | Gear activity multipiers | Multipliers to be applied to activity rates of gears used in the North Sea (values >=0) |
| *harvest_ratio_multiplier.csv* | *Param* | Harvest ratio multipliers | Multipliers to be applied to guild harvest ratios (values >=0) |
| *food_web_flow_matrix_template.csv* | *Param* | Food web flow matrix template | Template file for the creation of a mass flow matrix for the final year of the model run – should never be edited. |
| *fishing_ gear_linkages.csv* | *Param* | Relationships between gear activity rates over time | North Sea estimates _ only required by utility programme to seek activity rates generating given patterns of harvest ratios |
| *annual_observed_NORTH_SEA_2003-2013.csv* | *Target* | Annual target data | Compilation of annual observational data on the mean state of the North Sea during 2003-2013 |
| *monthly_observed_NORTH_SEA_2003-2013.csv* | *Target* | Monthly target data | Compilation of monthly |

| | | | |
|---|---|---|---|
| | | | observational data on the mean state of the North Sea during 2003-2013 |
| *regional_harvest_r_2003-2013.csv* | *Target* | Independently estimates guild harvest ratios | North Sea 2003-2013 guild HRs from ICES stock assessments and survey data and regional ecosystem review - only required by utility programme to calculate HRscale parameters given known regional harvest ratios |
| *zonal_harvest_r_2003-2013.csv* | *Target* | Inshore and offshore harvest ratios | North Sea 2003-2013 inshore and offshore harvest ratios genertaed by a prior run of the model - only required by utility programme to seek activity rates generating given patterns of harvest ratios |

## Parameter and data input files

Tables 4-30 provide details of all of the input files which are listed in the configuration file *MODEL_SETUP.csv*

Table 4. Details of the physical configuration file for the ecology model ("*physical_parameters*.csv*"). The file consists of two columns of data, the first being data values, second being a descriptive text field. Each row corresponds to a different parameter.

| Row number (excl. header) | Units | Description of each data row |
|---|---|---|
| 1 | m | Offshore zone upper layer thickness |
| 2 | m | Offshore zone lower layer thickness |
| 3 | m | Inshore zone thickness |
| 4 | m | Bottom boundary layer thickness for benthos (must be less than the thicknesses of offshore zone lower layer and inshore zone) |
| 5 | | Whole model domain area-proportion of inshore rock habitat s0 (sum of all 8 habitat areas must=1) |
| 6 | | Whole model domain area-proportion of inshore sediment habitat s1 (sum of all 8 habitat areas must=1) |
| 7 | | Whole model domain area-proportion of inshore sediment habitat s2 (sum of all 8 habitat areas must=1) |
| 8 | | Whole model domain area-proportion of inshore sediment habitat s3 (sum of all 8 habitat areas must=1) |
| 9 | | Whole model domain area-proportion of offshore rock habitat d0 (sum of all 8 habitat areas must=1) |
| 10 | | Whole model domain area-proportion of offshore sediment habitat d1 (sum of all 8 habitat areas must=1) |
| 11 | | Whole model domain area-proportion of offshore sediment habitat d2 (sum of all 8 habitat areas must=1) |
| 12 | | Whole model domain area-proportion of offshore sediment habitat d3 (sum of all 8 habitat areas must=1) |
| 13 | mm | Inshore sediment s1 median grain size (muddy sediment, if set to 0 denotes rock) |
| 14 | mm | Inshore sediment s2 median grain size (sandy sediment, if set to 0 denotes rock) |
| 15 | mm | Inshore sediment s3 median grain size (gravelly sediment, if set to 0 denotes rock) |
| 16 | mm | Offshore sediment d1 median grain size (muddy sediment, if set to 0 denotes rock) |
| 17 | mm | Offshore sediment d2 median grain size (sandy sediment, if set to 0 denotes rock) |
| 18 | mm | Offshore sediment d3 median grain size (gravelly sediment, if set to 0 denotes rock) |
| 19 | mm | Reference grain size for baseline geochemisty rates |
| 20 | | Parameter p1 for relationship between porosity and grainsize<br>10^( p3+p4*(1/(1+exp(-($\log_{10}$(grainsize)-p1)/p2)))) |
| 21 | | Parameter p2 for relationship between porosity and grainsize<br>10^( p3+p4*(1/(1+exp(-($\log_{10}$(grainsize)-p1)/p2)))) |

| | | |
|---|---|---|
| 22 | | Parameter p3 for relationship between porosity and grainsize 10^( p3+p4*(1/(1+exp(-($\log_{10}$(grainsize)-p1)/p2)))) |
| 23 | | Parameter p4 for relationship between porosity and grainsize 10^( p3+p4*(1/(1+exp(-($\log_{10}$(grainsize)-p1)/p2)))) |
| 24 | | Parameter p1 for relationship between permeability and grainsize (10^p1)*(grainsize^p2) |
| 25 | | Parameter p2 for relationship between permeability and grainsize (10^p1)*(grainsize^p2) |
| 26 | | Parameter p1 for relationship between mud% and grainsize (10^p1)*(grainsize^p2) |
| 27 | | Parameter p2 for relationship between mud% and grainsize (10^p1)*(grainsize^p2) |
| 28 | | Parameter p1 for relationship between Total Nitrogen as a percentage if dry weight (Total Nitrogen% )and mud percentage by dry weight (mud%) (10^p1)*(mud%^p2) |
| 29 | | Parameter p2 for relationship between Total Nitrogen as a percentage if dry weight (Total Nitrogen% ) and mud percentage by dry weight (mud%) (10^p1)*(mud%^p2) |
| 30 | | Ratio of inshore zone Total Nitrogen % in sediments to whole domain Total Nitrogen% at any given grain size |
| 31 | | Ratio of offshore zone Total Nitrogen % in sediments to whole domain Total Nitrogen% at any given grain size |
| 32 | | Proportion of measured sediment Total Nitrogen estimated to be refractory |
| 33 | | SWITCH to determine how sediment porosity is provided (0=calculated from parameterised relationship / 1=defined below as values) |
| 34 | | Defined porosity of inshore sediment s1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 35 | | Defined porosity of inshore sediment s2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 36 | | Defined porosity of inshore sediment s3 if not calculated internally (gravlly sediment, if set to 0 denotes rock) |
| 37 | | Defined porosity of offshore sediment d1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 38 | | Defined porosity of offshore sediment d2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 39 | | Defined porosity of offshore sediment d3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 40 | | SWITCH to determine how sediment permeability is provided (0=calculated from parameterised relationship / 1=defined below as values) |
| 41 | $m^{-2}$ | Defined permeability of inshore sediment s1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 42 | $m^{-2}$ | Defined permeability of inshore sediment s2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 43 | $m^{-2}$ | Defined permeability of inshore sediment s3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 44 | $m^{-2}$ | Defined permeability of offshore sediment d1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 45 | $m^{-2}$ | Defined permeability of offshore sediment d2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 46 | $m^{-2}$ | Defined permeability of offshore sediment d3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 47 | | SWITCH to determine how sediment Total Nitrogen% is provided (0=calculated from parameterised relationship / 1=defined below as values) |
| 48 | | Defined Total Nitrogen% of inshore sediment s1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 49 | | Defined Total Nitrogen% of inshore sediment s2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |

| | | |
|---|---|---|
| 50 | | Defined Total Nitrogen% of inshore sediment s3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 51 | | Defined Total Nitrogen% of offshore sediment d1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 52 | | Defined Total Nitrogen% of offshore sediment d2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 53 | | Defined Total Nitrogen% of offshore sediment d3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 54 | | SWITCH to determine how sediment layer thicknesses are provided (0=calculated from parameterised relationship (RECOMMENDED) / 1=defined below as values (RISKS TRIGGERING SHORT TIME STEPS)) |
| 55 | m | Defined thickness of inshore sediment s1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 56 | m | Defined thickness of inshore sediment s2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 57 | m | Defined thickness of inshore sediment s3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 58 | m | Defined thickness of offshore sediment d1 if not calculated internally (muddy sediment, if set to 0 denotes rock) |
| 59 | m | Defined thickness of offshore sediment d2 if not calculated internally (sandy sediment, if set to 0 denotes rock) |
| 60 | m | Defined thickness of offshore sediment d3 if not calculated internally (gravelly sediment, if set to 0 denotes rock) |
| 61 | m | Penetration depth of benthos infauna burrows into the sediments |
| 62 | m | Penetration depth of natural erosion scour into the sediment (m) |
| 63 | | Parameter p1 of relationship between light attenuation coefficient (base e) and suspended particulate matter (SPM; $mg.m^{-3}$) Attenuation = p1 + (p2*SPM) |
| 64 | | Parameter p2 of relationship between light attenuation coefficient (base e) and suspended particulate matter (SPM; $mg.m^{-3}$) Attenuation = p1 + (p2*SPM) |
| 65 | | Proportion of inshore zone water column depth layer occupied by phytoplankton (set a value less than or equal to 1.0) |
| 66 | | Proportion of inshore water column layer thickness in the rock (macrophyte) habitat (set a value less than or equal to 1.0) |

**Table 5**. Details of the file specifying the time-dependent physical driving data file for the ecology model ("*physics *.csv*"). The data are presented as a rectangular matrix with the rows (1-12) being months of a repeating annual cycle, and the columns corresponding to different monthly resolution data time-series.

| Column header | Units | Description |
|---|---|---|
| Month | | Values 1 – 12 |
| Slight | $E.m^{-2}.d^{-1}$ | Daily integrated sea surface irradiance |
| SO_LogeSPM | $mg.m^{-3}$ | $Log_e$ transformed suspended particulate matter concentration in the offshore zone upper layer |
| SI_LogeSPM | $mg.m^{-3}$ | $Log_e$ transformed suspended particulate matter concentration in the inshore zone |
| SO_temp | °C | Monthly mean temperature in the offshore zone upper layer |
| D_temp | °C | Monthly mean temperature in the offshore zone lower layer |
| SI_temp | °C | Monthly mean temperature in the inshore zone |
| Rivervol_SI | $d^{-1}$ | Daily river outflow into the inshore zone as a proportion of inshore zone volume |
| log10Kvert | $m^2.s^{-1}$ | $Log_{10}$ transformed vertical diffusion coefficient per unit length at the interface between the lower and upper layers in the offshore zone |
| mixLscale | | Length scale over which vertical diffusion acts in the offshore zone (equivalent to the thickness of the pycnocline layer) as a proportion of offshore zone depth (values between 0 and 1) |
| Upwelling | $d^{-1}$ | Daily upwelling volume in the inshore zone as a proportion of the upper layer volume |
| SO_OceanIN | $d^{-1}$ | Daily volume flux across the ocean boundary into the offshore zone upper layer, as a proportion of the layer volume |
| D_OceanIN | $d^{-1}$ | Daily volume flux across the ocean boundary into the offshore zone lower layer, as a proportion of the layer volume |
| SI_OceanIN | $d^{-1}$ | Daily volume flux into the inshore zone from across the adjacent shelf boundary, as a proportion of the inshore volume |
| SI_OceanOUT | $d^{-1}$ | Daily volume flux out of the inshore zone across the adjacent shelf boundary, as a proportion of the inshore volume |
| SO_SI_flow | $d^{-1}$ | Daily volume flux from the offshore zone into the inshore zone, as a proportion of the inshore volume |
| habS1_pdist | $d^{-1}$ | Inshore zone sediment habitat 1; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| habS2_pdist | $d^{-1}$ | Inshore zone sediment habitat 2; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| habS3_pdist | $d^{-1}$ | Inshore zone sediment habitat 3; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| habD1_pdist | $d^{-1}$ | Offshore zone sediment habitat 1; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| habD2_pdist | $d^{-1}$ | Offshore zone sediment habitat 2; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| habD3_pdist | $d^{-1}$ | Offshore zone sediment habitat 3; daily area-proportion disturbed by natural bed shear stress (see Wilson et al. 2018) |
| Inshore_waveheight | m | Monthly mean significant wave height in the inshore zone |

**Table 6**. Details of the file specifying the time-dependent chemical boundary driving data file for the ecology model ("*chemistry*.csv*"). The data are presented as a rectangular matrix with the rows (1-12) being months of a repeating annual cycle, and the columns corresponding to different monthly resolution data time-series.

| Column header | Units | Description |
|---|---|---|
| Month | | Values 1 – 12 |
| SO_nitrate | $mMN.m^{-3}$ | Flow-weighted monthly mean nitrate concentration at the ocean boundary of the offshore zone upper layer |
| SO_ammonia | $mMN.m^{-3}$ | Flow-weighted monthly mean ammonia concentration at the ocean boundary of the offshore zone upper layer |
| SO_phyt | $mMN.m^{-3}$ | Flow-weighted monthly mean phytoplankton concentration at the ocean boundary of the offshore zone upper layer |
| SO_detritus | $mMN.m^{-3}$ | Flow-weighted monthly mean suspended detritus concentration at the ocean boundary of the offshore zone upper layer |
| D_nitrate | $mMN.m^{-3}$ | Flow-weighted monthly mean nitrate concentration at the ocean boundary of the offshore zone lower layer |
| D_ammonia | $mMN.m^{-3}$ | Flow-weighted monthly mean ammonia concentration at the ocean boundary of the offshore zone lower layer |
| D_phyt | $mMN.m^{-3}$ | Flow-weighted monthly mean phytoplankton concentration at the ocean boundary of the offshore zone lower layer |
| D_detritus | $mMN.m^{-3}$ | Flow-weighted monthly mean suspended detritus concentration at the ocean boundary of the offshore zone lower layer |
| SI_nitrate | $mMN.m^{-3}$ | Flow-weighted monthly mean nitrate concentration at the adjacent shelf boundary of the infshore zone |
| SI_ammonia | $mMN.m^{-3}$ | Flow-weighted monthly mean ammonia concentration at the adjacent shelf boundary of the infshore zone |
| SI_phyt | $mMN.m^{-3}$ | Flow-weighted monthly mean phytoplankton concentration at the adjacent shelf boundary of the infshore zone |
| SI_detritus | $mMN.m^{-3}$ | Flow-weighted monthly mean suspended detritus concentration at the adjacent shelf boundary of the infshore zone |
| RIV_nitrate | $mMN.m^{-3}$ | Flow-weighted monthly mean nitrate concentration in rivers flowing into the inshore zone |
| RIV_ammonia | $mMN.m^{-3}$ | Flow-weighted monthly mean ammonia concentration in rivers flowing into the inshore zone |
| RIV_detritus | $mMN.m^{-3}$ | Flow-weighted monthly mean suspended detritus concentration in rivers flowing into the inshore zone |
| SO_ATM_nitrate_flux | $mMN.m^{-2}.d^{-1}$ | Monthly mean atmospheric deposition rate of oxidised nitrogen to the offshore zone |
| SO_ATM_ammonia_flux | $mMN.m^{-2}.d^{-1}$ | Monthly mean atmospheric deposition rate of reduced nitrogen to the offshore zone |
| SI_ATM_nitrate_flux | $mMN.m^{-2}.d^{-1}$ | Monthly mean atmospheric deposition rate of oxidised nitrogen to the inshore zone |
| SI_ATM_ammonia_flux | $mMN.m^{-2}.d^{-1}$ | Mointhly mean atmospheric deposition rate of reduced nitrogen to the inshore zone |
| SI_other_nitrate_flux | $mMN.m^{-2}.d^{-1}$ | Monthly mean emission rate of oxidised nitrogen to the inshore zone from other sources, e.g. industry |
| SI_other_ammonia_flux | $mMN.m^{-2}.d^{-1}$ | Monthly mean emission rate of reduced nitrogen to the inshore zone from other sources, e.g. industry |

**Table 7**. Details of the initial conditions file ("*initial_values*.csv*") setting starting values for each state variable in the model (units mMN in the model domain, scaled to a whole-domain sea surface area of $1m^2$). The file comprises two columns, with no header row. The first column contains the variable name within the model code; the second column contains the initial values. Each row represents a different model variable. xxxx indicates that an numeric value is expected. The grey shaded column is included here to provide a description of each variable and is not present in the operational filke. In practice this file would rarely ever be manually created by the user but created automatically at the end of a stationary state model run using the function e2e_extract_start() provided with the package.

| **Variable name within the model code** | **Numeric value** | **Variable description** |
|---|---|---|
| detritus_so | xxxx | Offshore zone upper layer suspended detritus |
| detritus_d | xxxx | Offshore zone lower layer suspended detritus |
| x_detritus_s1 | xxxx | Labile sediment detritus inshore zone habitat 1 |
| x_detritus_s2 | xxxx | Labile sediment detritus inshore zone habitat 2 |
| x_detritus_s3 | xxxx | Labile sediment detritus inshore zone habitat 3 |
| x_detritus_d1 | xxxx | Labile sediment detritus offshore zone habitat 1 |
| x_detritus_d2 | xxxx | Labile sediment detritus offshore zone habitat 2 |
| x_detritus_d3 | xxxx | Labile sediment detritus offshore zone habitat 3 |
| xR_detritus_s1 | xxxx | Refractory sediment detritus inshore zone habitat 1 |
| xR_detritus_s2 | xxxx | Refractory sediment detritus inshore zone habitat 2 |
| xR_detritus_s3 | xxxx | Refractory sediment detritus inshore zone habitat 3 |
| xR_detritus_d1 | xxxx | Refractory sediment detritus offshore zone habitat 1 |
| xR_detritus_d2 | xxxx | Refractory sediment detritus offshore zone habitat 2 |
| xR_detritus_d3 | xxxx | Refractory sediment detritus offshore zone habitat 3 |
| discard_o | xxxx | Fishery discards in the offshore zone |
| corpse_s1 | xxxx | Seabed corpses in the inshore zone habitat 1 |
| corpse_s2 | xxxx | Seabed corpses in the inshore zone habitat 2 |
| corpse_s3 | xxxx | Seabed corpses in the inshore zone habitat 3 |
| corpse_d1 | xxxx | Seabed corpses in the offshore zone habitat 1 |
| corpse_d2 | xxxx | Seabed corpses in the offshore zone habitat 2 |
| corpse_d3 | xxxx | Seabed corpses in the offshore zone habitat 3 |
| ammonia_so | xxxx | Water column ammonia in the offshore zone upper layer |
| ammonia_d | xxxx | Water column ammonia in the offshore zone lower layer |

| | | |
|---|---|---|
| x_ammonia_s1 | xxxx | Porewater ammonia in the inshore zone habitat 1 |
| x_ammonia_s2 | xxxx | Porewater ammonia in the inshore zone habitat 2 |
| x_ammonia_s3 | xxxx | Porewater ammonia in the inshore zone habitat 3 |
| x_ammonia_d1 | xxxx | Porewater ammonia in the offshore zone habitat 1 |
| x_ammonia_d2 | xxxx | Porewater ammonia in the offshore zone habitat 2 |
| x_ammonia_d3 | xxxx | Porewater ammonia in the offshore zone habitat 3 |
| nitrate_so | xxxx | Water column nitrate in the offshore zone upper layer |
| nitrate_d | xxxx | Water column nitrate in the offshore zone lower layer |
| x_nitrate_s1 | xxxx | Porewater nitrate in the inshore zone habitat 1 |
| x_nitrate_s2 | xxxx | Porewater nitrate ia in the inshore zone habitat 2 |
| x_nitrate_s3 | xxxx | Porewater nitrate  in the inshore zone habitat 3 |
| x_nitrate_d1 | xxxx | Porewater nitrate in the offshore zone habitat 1 |
| x_nitrate_d2 | xxxx | Porewater nitrate  in the offshore zone habitat 2 |
| x_nitrate_d3 | xxxx | Porewater nitrate in the offshore zone habitat 3 |
| phyt_so | xxxx | Phytoplankton in the offshore zone upper layer |
| phyt_d | xxxx | Phytoplankton in the offshore zone lower layer |
| omni_o | xxxx | Omnivorous zooplankton in the offshore zone |
| carn_o | xxxx | Carnivorous zooplankton in the offshore zone |
| benthslar_o | xxxx | Larvae of susp/dep feeding benthis in the offshore zone |
| benths_o | xxxx | Susp/dep feeding benthos in the offshore zone |
| benthclar_o | xxxx | Larvae of carn/scav feeding benthis in the offshore zone |
| benthc_o | xxxx | Carn/scav feeding benthos in the offshore zone |
| fishp_o | xxxx | Planktivorous fish in the offshore zone |
| fishplar_o | xxxx | Larvae of planktivorous fish in the offshore zone |
| fishd_o | xxxx | Demersal fish in the offshore zone |
| fishdlar_o | xxxx | Larvae of demersal fish in the offshore zone |
| fishm_o | xxxx | Migratoryl fish in the offshore zone |
| bird_o | xxxx | Birds in the offshore zone |
| detritus_si | xxxx | Suspended detritus in the inshore zone |
| ammonia_si | xxxx | Water column ammonia in the inshore zone |

| | | |
|---|---|---|
| nitrate_si | xxxx | Water column nitrate in the inshore zone |
| phyt_si | xxxx | Phytoplankton in the inshore zone |
| benthslar_i | xxxx | Larvae of susp/dep feeding benthos in the inshore zone |
| benthclar_i | xxxx | Larvae of carn/scav feeding benthos in the inshore zone |
| benths_i | xxxx | Susp/dep feeding benthos in the inshore zone |
| benthc_i | xxxx | Carn/scav feeding benthos in the inshore zone |
| discard_i | xxxx | Discards in the inshore zone |
| omni_i | xxxx | Omnivorous zooplankton in the inshore zone |
| carn_i | xxxx | Carnivorous zooplankton in the inshore zone |
| fishplar_i | xxxx | Larvae of planktivorous fish in the inshore zone |
| fishdlar_i | xxxx | Larvae of demersal fish in the inshore zone |
| fishp_i | xxxx | Planktivorous fish in the inshore zone |
| fishm_i | xxxx | Migratory fish in the inshore zone |
| fishd_i | xxxx | Demersal fish in the inshore zone |
| bird_i | xxxx | Birds in the inshore zone |
| seal_o | xxxx | Pinnipeds in the offshore zone |
| seal_i | xxxx | Pinnipeds in the inshore zone |
| ceta_o | xxxx | Cetaceans in the offshore zone |
| ceta_i | xxxx | Cetaceans in the inshore zone |
| corpse_s0 | xxxx | Seabed corpses in the inshore zone habitat 0 (exposed rock) |
| corpse_d0 | xxxx | Seabed corpses in the offshore zone habitat 0 (exposed rock) |
| kelpC | xxxx | Macrophyte carbon mass |
| kelpN | xxxx | Macrophyte nitrogen mass |
| Kelpdebris | xxxx | Macrophyte debris nitrogen mass |

**Table 8.** Layout of the input file defining timings of biological events in the ecology model ("*event_timing *.csv*"). Each row corresponds to a different parameter with a numeric value and a text description field. Day-of-the-year assumes a 360-day year of 30 days per month. xxxx indicates that a numeric value is expected. The grey-shaded columns are provided here to aid clairity and are not present in the operational file.

| Value | Description | Units | Additional description |
|---|---|---|---|
| xxxx | Planktivorous_fish_spawning_start_day | Day of the year | Start date of spawning by planktivorous fish |
| xxxx | Planktivorous _fish_spawning_duration_(days) | Days | Duration of spawning by planktivorous fish |
| xxxx | Planktivorous _fish_recruitment_start_day | Day of the year | Start date of recruitment of planktivorous fish larvae to the adult guild |
| xxxx | Planktivorous _fish_recruitment_duration_(days) | Days | Duration of recruitment to the planktivorous fish guild |
| xxxx | Demersal_fish_spawning_start_day | Day of the year | Start date of spawning by demersal fish |
| xxxx | Demersal_fish_spawning_duration_(days) | Days | Duration of spawning by demersal fish |
| xxxx | Demersal_fish_recruitment_start_day | Day of the year | Start date of recruitment of demersal fish larvae to the adult guild |
| xxxx | Demersal_fish_recruitment_duration_(days) | Days | Duration of recruitment to the demersal fish guild |
| xxxx | Susp/dep_benthos_spawning_start_day | Day of the year | Start date of spawning by suspension/deposit feeding benthos |
| xxxx | Susp /dep_benthos_spawning_duration_(days) | Days | Duration of spawning by suspension/deposit feeding benthos |
| xxxx | Susp /dep_benthos_recruitment_start_day | Day of the year | Start date of recruitment of suspension/deposit feeding benthos larvae to the settled guild |
| xxxx | Susp /dep_benthos_recruitment_duration_(days) | Days | Duration of recruitment to the suspension/deposit feeding benthos guild |
| xxxx | Carn/scav_benthos_spawning_start_day | Day of the year | Start date of spawning by carnivore/scavenge feeding benthos |
| xxxx | Carn/scav_benthos_spawning_duration_(days) | Days | Duration of spawning by carnivore/scavenge feeding benthos |
| xxxx | Carn/scav_benthos_recruitment_start_day | Day of the year | Start date of recruitment of carnivore/scavenge feeding benthos larvae to the settled guild |
| xxxx | Carn/scav_benthos_recruitment_duration_(days) | Days | Duration of recruitment to the carnivore/scavenge feeding benthos guild |
| xxxx | Migratory_fish_switch_(0=off_1=on) | | Switch to enable or disable external boundary migrations of migratory fish |
| xxxx | Migratory_fish_ocean_biomass_(Tonnes_wet_weight) | Tonnes wet weight | 'Global' stock biomass of migratory fish, a proportion of which may be enabled to enter the model domain |
| xxxx | Migratory_fish_carbon_to_wet_weight_(g/g) | $g.g^{-1}$ | Carbon content of migratory fish as a proportion of wet weight |
| xxxx | Model_domain_sea_surface_area_(km2) | $km^2$ | Sea surface atrea of the whole model domain |
| xxxx | Propn_of_ocean_population_entering_model_domain_each_year | | Proportion of the 'global' stock of migratory fish entering the model domain each year |
| xxxx | Immigration_start_day | Day of the year | Start date of the annual immigration of migratory fish into the model domain |

| | | | |
|---|---|---|---|
| xxxx | Immigration_end_day_(must_be_later_than_start_day_even_if_migration_disabled) | Day of the year | End date of the annual immigration of migratory fish into the model domain |
| xxxx | Propn_of_peak_popn_in_model_domain_which_remains_and_does_not_emigrate | | Proportion of the peak annual biomass of migratory fish in the model domain which remains behind after the end-of-emigration date |
| xxxx | Emigration_start_day | Day of the year | End date of the annual emigration of migratory fish from the model domain |
| xxxx | Emigration_end_day_(must_be_later_than_start_day_even_if_migration_disabled) | Day of the year | End date of the annual emigration of migratory fish from the model domain |

**Table 9.** Layout of the fixed parameters input file for each guild in the ecology model ("*fixed_consumers*.csv*"). These data are not affected by the simulated annealing optimization function provided with the package, and must be manually edited by a user. Rows = ecology model guilds, columns = parameter types. The grey-shaded column is provided here to aid clairity and is not present in the operational file. NA indicates a non-functional guild/parameter combination; xxxx indicates that a numeric value is required. Exponential format is acceptable for numeric values, e.g. x.xxxE-x. Annual weight specific fecundity is the proportion by weight of each guild shed annually as eggs. Units of the "threshold exploitable biomass" and "minimum inedible biomass" parameters are $mMN.m^{-2}$.

| Model guild | consumer | assimilation_efficiency | background_metabolic_rate | annual_weight_specific_fecundity | threshold_exploitable_biomass | minimum_inedible_biomass |
|---|---|---|---|---|---|---|
| Macrophytes | kelp | NA | NA | NA | xxxx | NA |
| Phytoplankton | phyt | NA | NA | NA | NA | NA |
| Omnivorous zooplankton | omnivzoo | xxxx | xxxx | NA | NA | NA |
| Carnivorous zooplankton | carnzoo | xxxx | xxxx | NA | xxxx | xxxx |
| Larvae of planktivorous fish | fishplar | xxxx | xxxx | NA | NA | NA |
| Larvae of demersal fish | fishdlar | xxxx | xxxx | NA | NA | NA |
| Planktivorous fish | fishp | xxxx | xxxx | xxxx | xxxx | NA |
| Migratory fish | fishm | xxxx | xxxx | NA | xxxx | NA |
| Demersal fish | fishd | xxxx | xxxx | xxxx | xxxx | NA |
| Larvae of | benthslar | xxxx | xxxx | NA | NA | NA |

| | | | | | | |
|---|---|---|---|---|---|---|
| suspension/deposit feeding benthos | | | | | | |
| Larvae of carnivorous/ scavenge feeding benthos | benthclar | xxxx | xxxx | NA | NA | NA |
| Suspension/ deposit feeding benthos | benths | xxxx | xxxx | xxxx | xxxx | NA |
| Carnivorous/ scavenge feeding benthos | benthc | xxxx | xxxx | xxxx | xxxx | NA |
| Birds | bird | xxxx | xxxx | NA | xxxx | NA |
| Pinnipeds | seal | xxxx | xxxx | NA | xxxx | NA |
| Cetaceans | ceta | xxxx | xxxx | NA | xxxx | NA |

**Table 10.** Layout of the miscellaneous fixed parameters input file for the ecology model ("*fixed_ miscellaneous*.csv*"). The file is not affected by the simulated annealing optimization function provided with the package, and must be manually edited by a user. Each row corresponds to a different parameter with a numeric value and a text description field ; xxxx indicates that a numeric value is required. Exponential format is acceptable for numeric values, e.g. x.xxxE-x. The grey-shaded columns are provided here to aid clairity and are not present in the operational file.

| Value | Description | **Units** | **Additional description** |
|---|---|---|---|
| xxxx | Irradiance_at_maximum_carbon_uptake_by_kelp | $E.m^{-2}.d^{-1}$ | Applies to macrophytes |
| xxxx | Minimum_NC_ratio_for_kelp | Molar nitrogen to carbon ratio | Applies to macrophytes |
| xxxx | Maximum_NC_ratio_for_kelp | Molar nitrogen to carbon ratio | Applies to macrophytes |
| xxxx | Irradiance_at_maximum_nutrient_uptake_by_phytoplankton | $E.m^{-2}.d^{-1}$ | Applies tro phytoplankton |
| xxxx | Autotroph_Q10_value | $(10°C)^{-1}$ | $Q_{10}$ for maximum uptake rates of phytoplanktion and macrophytes |
| xxxx | Heterotroph_uptake_Q10_value | $(10°C)^{-1}$ | $Q_{10}$ for maximum uptake rates for all claases of zooplankton, benthos and their larvae, fish and their larvae. Also applied as an inverse $Q_{10}$ effect on metabolic rates of birds, pinnipeds and cetaceans. Maximum uptake erates of birds, pinnipeds and cetaceans are independent of temperature |
| xxxx | Metabolic_and_bacterial_Q10_value | $(10°C)^{-1}$ | $Q_{10}$ for metabolic rates of all living guilds except macrophytes and phytoplankton, birds, pinnipeds and cetaceans |
| xxxx | Q10_reference_temperature | °C | $Q_{10}$ reference temperature for temperature dependent processes in the model |

**Table 11.** Details of the preference matrix input file for the ecology model ("*fitted_ preference_matrix*.csv*"). The file is structured as a rectangular table with rows = source terms, columns = consumers. Values in each column (consumers) must sum to 1. The grey-shades columns/rows shown here are provided to aid clairity and are not present in the operational file. Also, the column names in the operational file are the text row names 8 – 23, rather than the numeric ID's shown here. NA indicates a non-functional source-consumer link; x.xxx indicates a numeric value ≤1 is required, which may be 0., The file is generated automatically by the simulated annealing optimization function, and would not normally be manually edited by a user.

| | | | Consumers | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Description** | **ID** | **Row name** | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Water column ammonia | 1 | ammonia | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Water column nitrate | 2 | nitrate | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Suspended detritus | 3 | suspdet | NA | NA | **x.xxx** | NA | NA | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA |
| Sediment detritus | 4 | seddet | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.478 | NA | NA | NA | NA |
| Macrophyte debris | 5 | kelpdebris | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA |
| Corpses | 6 | corpses | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA |
| Fishery discards | 7 | discards | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |
| Macrophytes | 8 | kelp | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA |
| Phytoplankton | 9 | phyt | NA | NA | **x.xxx** | NA | NA | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA |
| Omnivorous zooplankton | 10 | omnivzoo | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA | **x.xxx** |
| Carnivorous zooplankton | 11 | carnzoo | NA | NA | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |
| Larvae of planktivorous fish | 12 | fishplar | NA | NA | NA | **x.xxx** | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA |
| Larvae of demersal fish | 13 | fishdlar | NA | NA | NA | **x.xxx** | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA |
| Planktivorous fish | 14 | fishp | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |
| Migratory fish | 15 | fishm | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |
| Demersal fish | 16 | fishd | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |
| Larvae of suspension/deposit feeding benthos | 17 | benthslar | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA | NA |
| Larvae of carnivorous/scavenge feeding benthos | 18 | benthclar | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** | NA | NA | NA | NA | NA | NA | NA | NA |
| Suspension/deposit feeding benthos | 19 | benths | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** | **x.xxx** |
| Carnivorous/scavenge feeding benthos | 20 | benthc | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | NA | NA | NA | NA | **x.xxx** | **x.xxx** | **x.xxx** |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Birds | 21 | Bird | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** | **x.xxx** |
| Pinnipeds | 22 | seal | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | **x.xxx** |
| Cetaceans | 23 | Ceta | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

**Table 12**. Layout of the uptake and mortality rate parameter file for the ecology model ("*fitted_ uptake_ mortality_rates*.csv*"). The file is generated automatically by the simulated annealing optimization function, but can also be manually edited by a user. Rows = living guilds in the model network, columns = different parameter types. The grey-shades columns/rows shown here are provided to aid clairity and are not present in the operational file. NA indicates a non-functional guild/parameter combination; xxxx indicates that a numeric value is required. Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| **Consumer guild** | **Row name** | **Maximum carbon uptake rate** | **Density dependent carbon exudation rate** | **Maximum nitrogen uptake rate** | **Nitrogen uptake half-saturation coefficient** | **Beddington-DeAngelis parameter** | **Density dependent mortality coefficient** | **Active migration coefficient** | **Maximum exploitable fraction of the stock** |
|---|---|---|---|---|---|---|---|---|---|
| **Column name** | **Consumer** | **Cumax** | **Cddexud** | **Numax** | **Nhsat** | **BdeApar** | **Ddmort** | **migration_coef** | **max_exploitable_f** |
| Macrophytes | Kelp | xxxx | xxxx | xxxx | xxxx | NA | xxxx | NA | xxxx |
| Phytoplankton - shallow | phyt_s | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Phytoplankton - deep | phyt_d | NA | NA | NA | NA | NA | xxxx | NA | NA |
| Omnivorous zooplankton | Omnivzoo | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Carnivorous zooplankton | Carnzoo | NA | NA | xxxx | xxxx | NA | xxxx | NA | xxxx |
| Larvae of planktivorous fish | Fishplar | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Larvae of demersal fish | Fishdlar | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Planktivorous fish | Fishp | NA | NA | xxxx | xxxx | NA | xxxx | xxxx | xxxx |
| Migratory fish | Fishm | NA | NA | xxxx | xxxx | NA | xxxx | xxxx | xxxx |
| Demersal fish | Fishd | NA | NA | xxxx | xxxx | NA | xxxx | xxxx | xxxx |
| Larvae of suspension/deposit feeding benthos | Benthslar | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Larvae of carnivorous/scavenge feeding benthos | Benthclar | NA | NA | xxxx | xxxx | NA | xxxx | NA | NA |
| Suspension/deposit feeding benthos | Benths | NA | NA | xxxx | xxxx | NA | xxxx | NA | xxxx |
| Carnivorous/scavenge | Benthc | NA | NA | xxxx | xxxx | NA | xxxx | NA | xxxx |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| feeding benthos | | | | | | | | | |
| Birds | Bird | NA | NA | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Pinnipeds | Seal | NA | NA | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Cetaceans | Ceta | NA | NA | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |

**Table 13**. Layout of the microbiology and other parameters file for the ecology model ("*fitted_ microbiology_ others*.csv*").. The file is generated automatically by the simulated annealing optimization function, but can also be manually edited by a user. Each row corresponds to a specific parameter and includes a numeric value and a text description field. The grey-shades columns shown here are provided to aid clairity and are not present in the operational file. xxxx indicates that a numeric value is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| Value | Description | Units | Additional description |
|---|---|---|---|
| xxxx | water_column_detritus_mineralisation_rate | $d^{-1}$ | Proportion of suspended detritus converted to ammonia per day at the $Q_{10}$ reference temperature |
| xxxx | upper_layer_water_column_nitrification_rate | $d^{-1}$ | Proportion of upper layer ammonia converted to nitrate per day at the $Q_{10}$ reference temperature |
| xxxx | upper_layer_water_column_denitrification_rate | $d^{-1}$ | Proportion of upper layer nitrate converted to nitrogen gas per day at the $Q_{10}$ reference temperature |
| xxxx | lower_layer_water_column_nitrification_rate | $d^{-1}$ | Proportion of lower layer ammonia converted to nitrate per day at the $Q_{10}$ reference temperature |
| xxxx | lower_layer_water_column_denitrification_rate | $d^{-1}$ | Proportion of lower layer nitrate converted to nitrogen gas per day at the $Q_{10}$ reference temperature |
| xxxx | proportion_of_detritus_or_corpses_converted_to_refractory_material_max_0.5 | | Proportion of sediment detritus or corpses converted to refractory detritus during the mineralisation or disintegration process (capped at 0.5) |
| xxxx | mineralisation_rate_scaling_parameter_for_refractory_detritus | | Mineralisation rate of refractory detritus is a fixed proportion of the ambient rate for labile sediment detritus |
| xxxx | proportion_of_refractory_detritus_digestible_by_benthos | | Proportion of ingested refractory detritus digestible by benthos - refractory detritus is less efficiently digested by suspension and deposit feeding benthos than labile detritus |
| xxxx | sediment_detritus_mineralisation_rate | $d^{-1}$ | Proportion of sediment labile detritus converted to ammonia per day at the $Q_{10}$ reference temperature and the reference value of median grain size specified in the physical configuration file |
| -xxxx | grain_size_sensitivity_for_sediment_detritus_mineralisation_rate | $mm^{-1}$ | Sensitivity parameter for the relationship between labile sediment detritus mineralisation rate and sediment median grain size. **Expecting a negative number here.** |

| | | | |
|---|---|---|---|
| xxxx | sediment_ nitrification_rate | $d^{-1}$ | Proportion of sediment porewater ammonia converted to nitrate per day at the $Q_{10}$ reference temperature and the reference value of median grain size specified in the physical configuration file |
| -xxxx | grain_size_sensitivity_for_sediment_ nitrification_rate | $mm^{-1}$ | Sensitivity parameter for the relationship between sediment detritus nitrification rate and sediment median grain size. **Expecting a negative number here.** |
| xxxx | sediment_ denitrification_rate | $d^{-1}$ | Proportion of sediment porewater nitrate converted to nitrogen gas per day at the $Q_{10}$ reference temperature and the reference value of median grain size specified in the physical configuration file |
| xxxx | grain_size_sensitivity_for_sediment_ denitrification_rate | $mm^{-1}$ | Sensitivity parameter for the relationship between sediment denitrification rate and sediment median grain size |
| xxxx | conversion_rate_of_discards_to_corpses | $d^{-1}$ | Proportion of discards concerted to seabed corpses per day at the $Q_{10}$ reference temperature |
| xxxx | conversion_rate_of_corpses_to_sediment_detritus | $d^{-1}$ | Proportion of seabed corpses converted to sediment detritus per day at the $Q_{10}$ reference temperature |
| xxxx | conversion_rate_of_kelp_debris_to_detritus | $d^{-1}$ | Proportion of macrophyte debris converted to sediment detritus per day at the $Q_{10}$ reference temperature |
| xxxx | detritus_sinking_rate_in_the_upper_layers | $d^{-1}$ | Proportion of offshore zone upper layer supended detritus sinking into the lower layer per day |
| xxxx | detritus_sinking_rate_in_the_lower_layer | $d^{-1}$ | Proportion of offshore zone lower layer and inshore zone supended detritus sinking onto the seabed per day |
| xxxx | density_dependent_self_shading_parameter_for_kelp | $(mMN.m^{-2})^{-1}$ | Attenuation rate of light available to macrophytes as a function of macrophyte biomass |
| xxxx | Wave_dependent_beach_cast_rate_for_kelp_debris | $m^{-1}$ | Proportion of macrophyte debris exported from the model as beach-cast per metre of significant wave height |
| xxxx | fitting_parameter_for_undersize_demersal_fish_function | | Fitting parameter aligning the biomass-dependent undersize fraction of demersal fish in model catches to those observed in reality – expected to be close to 1.0 |

**Table 14**. Gear-independent parameters for the fishing fleet model ("*fishing_fleet *.csv*"). Each row corresponds to a specific parameter and includes a numeric value and a text description field. xxxx indicates that a numeric value is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x . The grey-shaded column shown here is provided to aid clairity and is not present in the operational file.

| Value | Description | Additional description |
|---|---|---|
| xxxx | parameter_a_in_Pdemersal_catch_NONQUOTA= a*exp(-b*(1stJan_demersal_biomass)))_set_to_0_and_all_demfish_treated_as_quota_limited | Parameter value in the empirically based relationship between proportion of non-quota demersal species in commercial catches and demersal biomass |
| xxxx | parameter_b_in_Pdemersal_catch_NONQUOTA=a* exp(-b*(1stJan_demersal_biomass))) | Parameter value in the empirically based relationship between proportion of non-quota demersal species in commercial catches and demersal biomass |
| xxxx | parameter_a_in_Pundersize_NONQUOTA = a*exp(-b*1stJan_demersal_biomass)) | Parameter value in the empirically based relationship between proportion of non-quota demersal species in commercial catches which are undersize and demersal biomass |
| xxxx | parameter_b_in_Pundersize_NONQUOTA = a*exp(-b*1stJan_demersal_biomass)) | Parameter value in the empirically based relationship between proportion of non-quota demersal species in commercial catches which are undersize and demersal biomass |
| xxxx | parameter_a_in_Pundersize_QUOTA = a*exp(-b*1stJan_demersal_biomass)) | Parameter value in the empirically based relationship between proportion of quota-limiteddemersal species in commercial catches which are undersize and demersal biomass |
| xxxx | parameter_b_in_Pundersize_QUOTA = a*exp(-b*1stJan_demersal_biomass)) | Parameter value in the empirically based relationship between proportion of quota-limiteddemersal species in commercial catches which are undersize and demersal biomass |
| xxxx | DF_HR_SWITCH_(0=use_externally_defined_DFharvestratio/1=improved_selectivity_ie_reduce_Dfharvestratio_to_match_no_undersize_catch) | Switch to select alternative demersal harvest ratio selectivity scenarios – **see separate table below for details** |
| xxxx | DF_DISC_SWITCH_(0=use_internally_derived_density_dependent_DF_discard_rates/1=use_DF_discard_rates_from_parameter_file/2=only_discard_undersize_NQDF/3=no_DF_discards_ie_land_everything) | Switch to select alternative demersal discard rate scenarios – **see separate table below for details** |
| xxxx | Seabed_penetration_depth_of_gears_(m) | Depth to which towed gears which abrade the seabed penetrate into the sediment |
| xxxx | Mortality_inflicted_per_seabed_contact_trawl_pass_on_susp/deposit_feeding_benthos | Proportion of suspension/deposit feeding benthos biomass conveted to corpses as a result of a pass-over by a seabed-contact gear |
| xxxx | Mortality_inflicted_per_seabed_contact_trawl_pass_on_carnivore/scavenge_feeding_benthos | Proportion of carnivore/scavenge feeding benthos biomass conveted to corpses as a result of a pass-over by a seabed-contact gear |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Planktivorous_fish | Parameter linking planktivorous fish effort-density integrated across all gears to harvest ratio |

| | | |
|---|---|---|
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Demersal_fish | Parameter linking demersal fish effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Migratory_fish | Parameter linking migratory fish effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Susp/deposit_feeding_benthos | Parameter linking suspension/deposit feeding benthos effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Carnivore/scavenge_feeding_benthos | Parameter linking carnivore/scavenge feeding benthos effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Carnivorous_zooplankton | Parameter linking carnivorous zooplankton effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Birds | Parameter linking seabird effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Seals | Parameter linking pinniped effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Cetaceans | Parameter linking cetacean effort-density integrated across all gears to harvest ratio |
| xxxx | Scaling_between_effort_per_day_and_harvest_ratio_per_day_Kelp | Parameter linking macrophyte effort-density integrated across all gears to harvest ratio |
| xxxx | Offal_as_proportion_of_live_weight_of_fish_and_shellfish | Proportion of live weight which is regarded as offal during at-sea processing |

**Table 15**. Configuration scenarios for the fishing fleet model as a result of the range of possible combinations of settings for the demersal fish harvest ratio switch (DF_HR_SWITCH) and discarding switch (DF_DISC_SWITCH) in the fishing fleet model parameter file *fishing_fleet*.csv*

| DF_HR_SWITCH | DF_DISC_SWITCH | Harvest ratio action | Discard rate action |
|---|---|---|---|
| 0 | 0 | Harvest ratios for demersal fish according to the external data on gear activity and power (selectivity), as processed by the fleet model. | Discard rates for demersal fish set internally by the ecology model to equal the undersize fractions of quota-limited and non-quota fractions, overriding the externally supplied discard rates. |
| 1 | 0 | Implicit changes in gear selectivity to minimise catches of undersize fish - the externally set harvest ratios for demersal fish are attenuated by a factor equal to the lesser of the proportion of undersize quota-limited and non-quota fish in catches, as derived by the ecology model. | Discard rates for demersal fish set internally by the ecology model, overriding the externally supplied discard rates. But, due to the implicit changes in selectivity, there are no undersize catches of either quota-limited or non-quota demersal fish so discard rates are set to zero. |
| 0 | 1 | Harvest ratios for demersal fish according to the external data on gear activity and power (selectivity), as processed by the fleet model. | Discard rate of demersal fish set according to the external data in the discard rate parameter file for the fleet model. The ecology model first attempts to meet this rate by discarding the internally derived undersize fractions of quota-limited and non-quota fish. If this is insufficient to meet the external rate then the code increases discards of quota-limited fish - i.e. implicitly representing high-grading or over-quota discards. If the external rate is less than the internal rate arising from undersize quota-limited and non-quota fish then the code reduce discards of non-quota fish until to overall rate equals the externally set value. |

| | | | |
|---|---|---|---|
| 1 | 1 | Implicit changes in gear selectivity to minimise catches of undersize fish - the externally set harvest ratios for demersal fish are attenuated by a factor equal to the lesser of the proportion of undersize quota-limited and non-quota fish in catches, as derived by the ecology model. | Discard rate of demersal fish set according to the external data in the discard rate parameter file for the fleet model. But as a result of the implicit changes in selectivity there are no catches of undersize fish. So the implication is that all discards represent high-grading or over-quota discarding. Hence, the ecology model attempts to meet the externally defined overall discard rate first by increasing the discard rate of quota-limited fish, and if this is insufficient then by increasing the discard rate of non-quota fish. |
| 0 | 2 | Harvest ratios for demersal fish according to the external data on gear activity and power (selectivity), as processed by the fleet model. | Discard rates for non-quota demersal fish are set internally by the ecology model to equal the undersize fraction. Discard rates for quota-limited demersal fish are set to zero regardless of external data or the internally derived undersize fraction - i.e. this forces all the catch of quota-limited to be landed including undersize fish. This option mimics the EU Common Fisheries Policy Landing Obligation. |
| 1 | 2 | Implicit changes in gear selectivity to minimise catches of undersize fish - the externally set harvest ratios for demersal fish are attenuated by a factor equal to the lesser of the proportion of undersize quota-limited and non-quota fish in catches, as derived by the ecology model. | This has the same effect as setting discard rate switch to 0, i.e. due to the implicit changes in selectivity, there are no undersize catches of either quota-limited or non-quota demersal fish so discard rates are set to zero. |
| 0 | 3 | Harvest ratios for demersal fish according to the external data on gear activity and power (selectivity), as processed by the fleet model. | Discard rates for both quota-limited and non-quota demersal fish are set to zero regardless of external data or the internally derived undersize fractions - i.e. this forces all the catch of all demersal fish to be landed including undersize fish. |
| 1 | 3 | Implicit changes in gear selectivity so that there are no catches of undersize fish - the externally set harvest ratios for demersal fish are attenuated by an amount proportional to the undersize fractions of quota-limited and non-quota fish in catches, as derived by the ecology model. | This has the same effect as setting the discard rate switch to 0, i.e. due to the implicit changes in selectivity, there are no undersize catches of either quota-limited or non-quota demersal fish so discard rates are set to zero. |

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**Table 16**. Definitions of the gear types, their activity rates and seabed abrasion rates in the fishing fleet model ("*fishing_activity *.csv*"). Each gear is assigned a name, a short-code used in some plotting functions, and activity density (seconds of deployment. $m^{-2}.d^{-1}$), and a seabed abrasion (ploughing) rate ($m^2$ abraded.$s^{-1}$). The gear names and codes shown here are for the North Sea model included with the package; xxxx indicates that a numeric value is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| **Gear_name** | **Gear_code** | **Activity_(s/m$^2$/d)** | **Plough_rate_(m$^2$/s)** |
|---|---|---|---|
| Pelagic_Trawl+Seine | PTS | xxxx | xxxx |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | xxxx | xxxx |
| Longline_mackerel | LLm | xxxx | xxxx |
| Beam_Trawl_BT1+BT2 | BTf | xxxx | xxxx |
| Demersal_Seine | DS | xxxx | xxxx |
| Demersal_Otter_Trawl_TR1 | OT | xxxx | xxxx |
| Gill_Nets+Longline_demersal | LLd | xxxx | xxxx |
| Beam_Trawl_shrimp | BTs | xxxx | xxxx |
| Nephrops_Trawl_TR2 | NT | xxxx | xxxx |
| Creels | CR | xxxx | xxxx |
| Mollusc_Dredge | MD | xxxx | xxxx |
| Whaler | Wh | xxxx | xxxx |

**Table 17**. Catching power of each gear with respect to each of the harvestable resource guilds in the ecology model ("*fishing_power *.csv*"). Gear names and codes (rows) must correspond with those defined in the gear activity file. Numeric values along each row define the selectivity pattern of each gear. The grey-shaded row shown here is provided to aid clairity and is not present in the operational file. The gear names and codes shown here are for the North Sea model included with the package; xxxx indicates that a numeric value is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| **Guild definition** | | Planktivorous fish | Demersal fish | Migratory fish | Susp/dep feeding benthos | Carn/scav feeding benthos | Carniv. zooplankton | Birds | Pinnipeds | Cetaceans | Macrophytes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear_name | Gear_code | Power_PF | Power_DF | Power_MF | Power_FDB | Power_CSB | Power_CZ | Power_BD | Power_SL | Power_CT | Power_KP |
| Pelagic_Trawl+Seine | PTS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Longline_mackerel | LLm | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_BT1+BT2 | BTf | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Seine | DS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Otter_Trawl_TR1 | OT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Gill_Nets+Longline_demersal | LLd | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_shrimp | BTs | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Nephrops_Trawl_TR2 | NT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Creels | CR | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Mollusc_Dredge | MD | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Whaler | Wh | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |

**Table 18**. Discard rate (proportion of catch discarded) by each gear with respect to each of the harvestable resource guilds in the ecology model ("*fishing_discards*.csv*"). Gear names and codes (rows) must correspond with those defined in the gear activity file. Numeric values along each row define the selectivity pattern of each gear. The grey-shaded row shown here is provided to aid clairity and is not present in the operational file. The gear names and codes shown here are for the North Sea model included with the package; xxxx indicates that a numeric value ≤1 is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| **Guild definition** | | Planktivorous fish | Demersal fish | Migratory fish | Susp/dep feeding benthos | Carn/scav feeding benthos | Carniv. zooplankton | Birds | Pinnipeds | Cetaceans | Macrophytes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear_name | Gear_ code | Discardrate_PF | Discardrate_DF | Discardrate_MF | Discardrate_FDB | Discardrate_CSB | Discardrate_CZ | Discardrate_BD | Discardrate_SL | Discardrate_CT | Discardrate_KP |
| Pelagic_Trawl+Seine | PTS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Longline_mackerel | LLm | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_BT1+BT2 | BTf | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Seine | DS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Otter_Trawl_TR1 | OT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Gill_Nets+Longline_demersal | LLd | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_shrimp | BTs | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Nephrops_Trawl_TR2 | NT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Creels | CR | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Mollusc_Dredge | MD | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Whaler | Wh | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |

**Table 19**. Processing-at-sea rate (proportion of retained catch weight which is processed) for each gear with respect to each of the harvestable resource guilds in the ecology model ("*fishing_processing *.csv*"). Gear names and codes (rows) must correspond with those defined in the gear activity file. The grey-shaded row shown here is provided to aid clairity and is not present in the operational file. Gear names and codes shown here are for the North Sea model included with the package; xxxx indicates that a numeric value ≤1 is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| **Guild definition** | | Planktivorous fish | Demersal fish | Migratory fish | Susp/dep feeding benthos | Carn/scav feeding benthos | Carniv. zooplankton | Birds | Pinnipeds | Cetaceans | Macrophytes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear_name | Gear_ code | Propgutted_ PF | Propgutted_ DF | Propgutted_ MF | Propgutted_ FDB | Propguttede_ CSB | Propgutted_ CZ | Propgutted_ BD | Propgutted_ SL | Propgutted_ CT | Propgutted_ KP |
| Pelagic_Trawl+Seine | PTS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Longline_mackerel | LLm | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_BT1+BT2 | BTf | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Seine | DS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Otter_Trawl_TR1 | OT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Gill_Nets+Longline_demersal | LLd | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_shrimp | BTs | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Nephrops_Trawl_TR2 | NT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Creels | CR | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Mollusc_Dredge | MD | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Whaler | Wh | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |

**Table 20**. Spatial distributions of activity for each gear type in the fishing fleet model ("*fishing_distribution *.csv*"). Gear names and codes (rows) must correspond with those defined in the gear activity file. Numeric values in each row must sum to 1.0, and define the proportion of activity by each gear which is deployed over each of the seabed habitats defined in the model configuration. Habitats s0 and d0 are hard-wired to be seabed rock in the inshore (s) and offshore (d) zones respectively. Other habitats would typically be configured to represent sediment habitats. Gear names and codes shown here are for the North Sea model included with the package; xxxx indicates that a numeric value ≤1 is required; Exponential format is acceptable for numeric values, e.g. x.xxxE-x .

| Gear_name | Gear_code | Habitat_s0 | Habitat_s1 | Habitat_s2 | Habitat_s3 | Habitat_d0 | Habitat_d1 | Habitat_d2 | Habitat_d3 |
|---|---|---|---|---|---|---|---|---|---|
| Pelagic_Trawl+Seine | PTS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Longline_mackerel | LLm | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_BT1+BT2 | BTf | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Seine | DS | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Demersal_Otter_Trawl_TR1 | OT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Gill_Nets+Longline_demersal | LLd | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Beam_Trawl_shrimp | BTs | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Nephrops_Trawl_TR2 | NT | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Creels | CR | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Mollusc_Dredge | MD | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |
| Whaler | Wh | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx |

**Table 21**. Fishing gear activity multiplier file ("*fishing_gear_multiplier*.csv*"). Gear names and codes (rows) must correspond with those defined in the gear activity file. The multiplier values in the third column are automatically applied to the activity density values for each gear defined in the "*fishing_activity_parameters*.csv*" file before being piped into the ecology model. Hence the default values of 1.0 shown here have no effect on activity rates. Manual or programmed editing of the multiplier values is a convenient route to configuring fishing scenarios for the model. Gear names and codes shown here are for the North Sea model included with the package.

| **Gear_name** | **Gear_code** | **Multiplier_to_be_applied_to_activity** |
|---|---|---|
| Pelagic_Trawl+Seine | PTS | 1 |
| Sandeel+sprat_trawl(Otter30-70mm+TR3) | SST | 1 |
| Longline_mackerel | LLm | 1 |
| Beam_Trawl_BT1+BT2 | BTf | 1 |
| Demersal_Seine | DS | 1 |
| Demersal_Otter_Trawl_TR1 | OT | 1 |
| Gill_Nets+Longline_demersal | LLd | 1 |
| Beam_Trawl_shrimp | BTs | 1 |
| Nephrops_Trawl_TR2 | NT | 1 |
| Creels | CR | 1 |
| Mollusc_Dredge | MD | 1 |
| Whaler | Wh | 1 |

**Table 22.** Harvest ratio multiplier file ("*harvest_ratio_multiplier*.csv*"). The multiplier values in the second column are automatically applied to the integrated harvest ratios for each resource guild derived by the fleet model, before being piped into the ecology model. Hence the default values of 1.0 shown here have no effect on ecology model. Manual or programmed editing of the multiplier values is a convenient route to configuring fishing scenarios for the model, but note that this only changes the harvest ratios and not the other collateral effects of fishing such as seabed abrasion associated with gear activity.

| Guild | Harvest_ratio_multiplier |
|---|---|
| Planktivorous_fish | 1 |
| Demersal_fish | 1 |
| Migratory_fish | 1 |
| Benthos_susp-dep | 1 |
| Benthos_carn-scav | 1 |
| Zooplankton_carn | 1 |
| Birds | 1 |
| Pinnipeds | 1 |
| Cetaceans | 1 |
| Macrophytes | 1 |

**Table 23**. Details of the food web flow matrix template file ("*food web flow matrix template.csv*"). The flow-matrix defines all of the flows in the model from every source to every destination. The template file is populated with null values to acts as a template for the code which creates the whole-domain flow-matrix required by the NetIndices R-package to derive network indices for the final year of a model run. There should be no requirement for a user to edit the file. The rows of the matrix are all the sources of flows in the network - state variables and import sources to the model. The columns are all the destinations for flows in the network - state variables, import sources and export destinations for the model. The matrix contains additional columns (exports to fishery landings and exports to macrophyte beachcast) which are not represented in the rows.

| Row/column number | Row/column name | Description |
|---|---|---|
| 1 | Wcammonia | Water column ammonia |
| 2 | Sedammonia | Sediment porewater ammonia |
| 3 | Wcnitrate | Water column nitrate |
| 4 | Sednitrate | Sediment porewater nitrate |

| | | |
|---|---|---|
| 5 | Wcdetritus | Water column detritus and bacteria |
| 6 | Seddetritus | Sediment labile detritus and bacteria |
| 7 | seddetritusR | Sediment refractory detritus |
| 8 | kelpdebris | Macrophyte debris |
| 9 | corpses | Corpses |
| 10 | discards | Fishery discards |
| 11 | kelp | Macrophytes |
| 12 | phyt | Phytoplankton |
| 13 | omnivzoo | Omnivorous zooplankton |
| 14 | carnzoo | Carnivorous zooplankton |
| 15 | pfishlar | Larvae of planktivorous fish |
| 16 | dfishlar | Larvae of demersal fish |
| 17 | pfish | Planktivorous fish |
| 18 | mfish | Migratory fish |
| 19 | dfish | Demersal fish |
| 20 | benthslar | Larvae of susp/dep feeding benthos |
| 21 | benthclar | Larvae of carn/scav feeding benthos |
| 22 | benths | Susp/dep feeding benthos |
| 23 | benthc | Carn/scav feeding benthos |
| 24 | bird | Birds |
| 25 | seal | Pinnipeds |
| 26 | ceta | Cetaceans |
| 27 | ocean | External ocean outside the model domain |
| 28 | rivers | Rivers flowing into the model domain |
| 29 | atmosphere | Atmosphere above the model domain |
| 30 | seabed | Seabed sediments beneath the active modelled layer in the model |
| (31) | landings | Fishery landings (processed weight) (column-data only) |
| (32) | beachcast | Macrophyte beachcast (column-data ony) |

**Table 24.** Details of the fishing fleet gear linkages file (*fishing_ gear_linkages.csv*). The table shows an example for the North Sea. The file is required only by the simulated annealing function e2e_optimize_hr() to find the combination of gear activity scaling values producing the best fit of the harvest ratios generated the fleet model to prior estimate inshore and offshore values, given a known relative spatial distribution of each gear and known effort-harvest ratio scaling values. The table specifies which gear activity rates are forced to vary in concert during the fitting process, as opposed to varying independently. The value of the linkage coefficient defines the scaling of changes in the activity rate of a dependent gear relative to its linked independent gear – for example gear 8 is permitted to vary independently (value in column 3 and 4 = NA), but gear 9 is dependent on gear 8 – the activity rate of gear 9 = (0.645 ± some random variation) * (activity of gear 8). Similarly for gear 10.

| Gear_id | Gear name | Gear to which linked | Linkage coefficient | Comments |
|---|---|---|---|---|
| 1 | Pelagic_Trawl+Seine | NA | NA | Independent of other gears |
| 2 | Sandeel+sprat_trawl(Otter30-70mm+TR3) | 1 | 1.5 | Based on ICES ecosystem review |
| 3 | Longline_mackerel | 1 | 1 | Guess |
| 4 | Beam_Trawl_BT1+BT2 | NA | NA | Independent of other gears |
| 5 | Demersal_Seine | 6 | 1 | Based on ICES ecosystem review |
| 6 | Demersal_Otter_Trawl_TR1 | NA | NA | Independent of other gears |
| 7 | Gill_Nets+Longline_demersal | 6 | 1 | Guess |
| 8 | Beam_Trawl_shrimp | NA | NA | Independent of other gears |
| 9 | Nephrops_Trawl_TR2 | 8 | 0.645 | Based on ICES ecosystem review |
| 10 | Creels | 8 | 0.606 | Based on ICES ecosystem review |
| 11 | Mollusc_Dredge | NA | NA | Independent of other gears |
| 12 | Whaler | NA | NA | Independent of other gears |

**Table 25.** Column details in the database of observed annual-based indices of the state of the ecosystem in the model domain during the period corresponding to the physical and chemical driving data ("*annual_observed*.csv*"). The annual measures referred to in column 1 are listed in Table 26.

| Column number | Column name | Description | User editable |
|---|---|---|---|
| 1 | Annual_measure | Mean annual numeric value of the measure specified by the descriptior in column "Name". Missing values denoted by NA. | Yes |
| 2 | SD_of_measure | Standard deviation of the mean annual numeric value. Missing values denoted by NA. | Yes |
| 3 | Use1_0 | Switch setting to determine whether the measure is included in likelihood calculations (1 = yes, 0 = no) | Yes |
| 4 | Name | Name used to identify the measure in the model code | No |
| 5 | Units | Units of the annual measure | No |
| 6 | Description | Text describing each measure | No |
| 7 | Region | Free-text describing the region in which the observations were collected | Yes |
| 8 | Time_period | Free-text describing the time period over which the observations were collected | Yes |
| 9 | Source | Free-text describing the literature or data-centre source the observations | Yes |

**Table 26.** Row details in the database (Table 25) of observed annual-based indices of the state of the ecosystem in the model domain during the period corresponding to the physical and chemical driving data ("*annual_observed*.csv*").

| **Row number** | **Name in the model code** | **Units** | **Description** |
|---|---|---|---|
| 1 | Obs_TAPP | $mMN.m^{-2}.y^{-1}$ | Annual total primary production |
| 2 | Obs_NP | $mMN.m^{-2}.y^{-1}$ | Annual new production from depth integrated nitrate draw-down plus summer river and atmospheric inputs |
| 3 | Obs_KelpP | $gC.m^{-2}.y^{-1}$ | Annual within forest net production of macrophytes |
| 4 | Obs_OmnizooP | $mMN.m^{-2}.y^{-1}$ | Annual omnivorous zooplankton gross production |
| 5 | Obs_CarnzooP | $mMN.m^{-2}.y^{-1}$ | Annual carnivorous zooplankton gross production |
| 6 | Obs_PFishP | $mMN.m^{-2}.y^{-1}$ | Annual planktivorous fish gross production |
| 7 | Obs_DFishP | $mMN.m^{-2}.y^{-1}$ | Annual demersal fish gross production |
| 8 | Obs_BensuspP | $mMN.m^{-2}.y^{-1}$ | Annual suspensiondeposit feeding benthos gross production |
| 9 | Obs_BencarnP | $mMN.m^{-2}.y^{-1}$ | Annual carnivore/scavenge feeding benthos gross production |

| | | | |
|---|---|---|---|
| 10 | Obs_birdP | $mMN.m^{-2}.y^{-1}$ | Annual net production of birds |
| 11 | Obs_sealP | $mMN.m^{-2}.y^{-1}$ | Annual net production of pinnipeds |
| 12 | Obs_cetaP | $mMN.m^{-2}.y^{-1}$ | Annual net production of cetaceans |
| 13 | Obs_maxbenthslar | $mMN.m^{-3}$ | Annual monthly max concentration of benthos suspension/deposit feeder larvae |
| 14 | Obs_maxbenthclar | $mMN.m^{-3}$ | Annual monthly max concentration of benthos carnivore/scavenge feeder larvae |
| 15 | Obs_Conpfishfish | $mMN.m^{-2}.y^{-1}$ | Annual consumption of planktivorous fish by fish |
| 16 | Obs_Condfishfish | $mMN.m^{-2}.y^{-1}$ | Annual consumption of demersal fish by fish |
| 17 | Obs_Conzoofish | $mMN.m^{-2}.y^{-1}$ | Annual consumption of omnivorous zooplankton by fish and fish larvae |
| 18 | Obs_Conzoocarnz | $mMN.m^{-2}.y^{-1}$ | Annual consumption of omnivorous zooplankton by carnivorous zooplankton |
| 19 | Obs_Conbenfish | $mMN.m^{-2}.y^{-1}$ | Annual consumption of benthos by fish |
| 20 | Obs_Contotal_bird | $mMN.m^{-2}.y^{-1}$ | Annual food consumption by birds |
| 21 | Obs_Proppfishbird | Dimensionless | Proportion planktivorous fish in diet of birds |
| 22 | Obs_Propdfishbird | Dimensionless | Proportion demersal fish in diet of birds |
| 23 | Obs_Propmfishbird | Dimensionless | Proportion migratory fish in diet of birds |
| 24 | Obs_Propdiscbird | Dimensionless | Proportion discards in diet of birds |
| 25 | Obs_Contotal_seal | $mMN.m^{-2}.y^{-1}$ | Annual food consumption by pinnipeds |
| 26 | Obs_Proppfishseal | Dimensionless | Proportion planktivorous fish in diet of pinnipeds |
| 27 | Obs_Propdfishseal | Dimensionless | Proportion demersal fish in diet of pinnipeds |
| 28 | Obs_Propmfishseal | Dimensionless | Proportion migratory fish in diet of pinnipeds |
| 29 | Obs_Contotal_ceta | $mMN.m^{-2}.y^{-1}$ | Annual food consumption by cetaceans |
| 30 | Obs_Proppfishceta | Dimensionless | Proportion planktivorous fish in diet of cetaceans |
| 31 | Obs_Propdfishceta | Dimensionless | Proportion demersal fish in diet of cetaceans |
| 32 | Obs_Propmfishceta | Dimensionless | Proportion migratory fish in diet of cetaceans |
| 33 | Obs_Pland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual planktivorous fish landings (live weight) |
| 34 | Obs_Dland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual demersal fish landings (live weight) |
| 35 | Obs_Mland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual migratory fish landings (live weight) |
| 36 | Obs_Bsland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual suspension/deposit feeding benthos landings (live weight) |
| 37 | Obs_Bcland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual carnivore/scavenge feeding benthos landings (live weight) |
| 38 | Obs_Zcland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual carnivorous zooplankton landings (live weight) |
| 39 | Obs_Kland_livewt | $mMN.m^{-2}.y^{-1}$ | Annual macrophyte landings (live weight) |
| 40 | Obs_kelp_pb | $y^{-1}$ | Annual carbon gross PB ratio of macrophytes |

| | | | |
|---|---|---|---|
| 41 | Obs_benslar_pb | $y^{-1}$ | Annual gross PB ratio larvae of suspension/deposit feeding benthos |
| 42 | Obs_benclar_pb | $y^{-1}$ | Annual gross PB ratio larvae of carnivore/scavenge feeding benthos |
| 43 | Obs_bens_pb | $y^{-1}$ | Annual gross PB ratio suspension/deposit feeding benthos |
| 44 | Obs_benc_pb | $y^{-1}$ | Annual gross PB ratio carnivore/scavenge feeding benthos |
| 45 | Obs_omni_pb | $y^{-1}$ | Annual gross PB ratio omnivorous zooplankton |
| 46 | Obs_carn_pb | $y^{-1}$ | Annual gross PB ratio carnivorous zooplankton |
| 47 | Obs_fishplar_pb | $y^{-1}$ | Annual gross PB ratio larvae of planktivorous fish |
| 48 | Obs_fishdlar_pb | $y^{-1}$ | Annual gross PB ratio larvae of demersal fish |
| 49 | Obs_fishp_pb | $y^{-1}$ | Annual gross PB ratio planktivorous fish |
| 50 | Obs_fishd_pb | $y^{-1}$ | Annual gross PB ratio demersal fish |
| 51 | Obs_fishm_pb | $y^{-1}$ | Annual gross PB ratio migratory fish |
| 52 | Obs_bird_pb | $y^{-1}$ | Annual net PB ratio birds |
| 53 | Obs_seal_pb | $y^{-1}$ | Annual net PB ratio pinnipeds |
| 54 | Obs_ceta_pb | $y^{-1}$ | Annual net PB ratio cetaceans |
| 55 | Obs_exud_C_kelp | Dimensionless | Annual average proportion of macrophyte C uptake which is exuded |
| 56 | Obs_kelp_NC | Dimensionless | Annual average molar NC ratio of macrophytes |
| 57 | Obs_Denitrif | $mMN.m^{-2}.y^{-1}$ | Annual denitrification |
| 58 | Obs_Dfdiscardp | Dimensionless | Proportion of demersal fish catch discarded |
| 59 | Obs_s_x_ammonia | $mMN.m^{-3}$ | Annual average ammonia concentration in porewater of sand grain size 0.25mm |
| 60 | Obs_d_x_ammonia | $mMN.m^{-3}$ | Annual average ammonia concentration in porewater of mud grain size 0.12mm |
| 61 | Obs_s_x_nitrate | $mMN.m^{-3}$ | Annual average nitrate concentration in porewater of sand grain size 0.25mm |
| 62 | Obs_d_x_nitrate | $mMN.m^{-3}$ | Annual average nitrate concentration in porewater of mud grain size 0.12mm |
| 63 | Obs_s_x_TON | %N $(gN.(g\ dry\ sed)^{-1})$ | Annual average organic N content of sand grain size 0.25mm (0.19-0.43mm) |
| 64 | Obs_d_x_TON | %N $(gN.(g\ dry\ sed)^{-1})$ | Annual average organic N content of mud grain size 0.12mm (0.03-0.07mm) |
| 65 | Obs_NDJF_s_nitrate | $mMN.m^{-3}$ | Average winter (Nov-Feb) nitrate concentration shallow layer |
| 66 | Obs_MJJA_s_nitrate | $mMN.m^{-3}$ | Average summer (May-Aug) nitrate concentration shallow layer |
| 67 | Obs_NDJF_d_nitrate | $mMN.m^{-3}$ | Average winter (Nov-Feb) nitrate concentration deep layer |
| 68 | Obs_MJJA_d_nitrate | $mMN.m^{-3}$ | Average summer (May-Aug) nitrate concentration deep layer |
| 69 | Obs_NDJF_s_ammonia | $mMN.m^{-3}$ | Average winter (Nov-Feb) ammonia concentration shallow layer |
| 70 | Obs_MJJA_s_ammonia | $mMN.m^{-3}$ | Average summer (May-Aug) ammonia concentration shallow layer |
| 71 | Obs_NDJF_d_ammonia | $mMN.m^{-3}$ | Average winter (Nov-Feb) ammonia concentration deep layer |

| | | | |
|---|---|---|---|
| 72 | Obs_MJJA_d_ammonia | mMN.m$^{-3}$ | Average summer (May-Aug) ammonia concentration deep layer |
| 73 | Obs_carn_io_ratio | Dimensionless | Inshore offshore ratio of annual mean carnivorous zooplankton depth averaged concentration |
| 74 | Obs_omni_io_ratio | Dimensionless | Inshore offshore ratio of annual mean omnivorous zooplankton depth averaged concentration |
| 75 | Obs_phyt_io_ratio | Dimensionless | Inshore offshore ratio of annual mean phytoplankton surface layer concentration |
| 76 | Obs_nit_io_ratio | Dimensionless | Inshore offshore ratio of annual mean nitrate surface layer concentration |
| 77 | Obs_amm_io_ratio | Dimensionless | Inshore offshore ratio of annual mean ammonia surface layer concentration |
| 78 | Obs_pfish_io_ratio | Dimensionless | Inshore offshore ratio of annual mean planktivorous fish density ( m$^{-2}$) |
| 79 | Obs_dfish_io_ratio | Dimensionless | Inshore offshore ratio of annual mean demersal fish density ( m$^{-2}$) |
| 80 | Obs_birddisc | mMN.m$^{-2}$.y$^{-1}$ | Annual (discarded) bycatch of birds |
| 81 | Obs_sealdisc | mMN.m$^{-2}$.y$^{-1}$ | Annual (discarded) bycatch of pinnipeds |
| 82 | Obs_cetadisc | mMN.m$^{-2}$.y$^{-1}$ | Annual (discarded) bycatch of cetaceans |
| 83 | Obs_kelp_beachcast | Dimensionless | Proportion of macrophyte annual nitrogen uptake exported as beach-cast |
| 84 | Obs_Ctland_livewt | mMN.m$^{-2}$.y$^{-1}$ | Cetacean landed (live weight) by whale hunters |

**Table 27.** Column details in the database of observed monthly-based indices of nutrient and plankton concentrations in the model domain during the period corresponding to the physical and chemical driving data ("*monthly_observed*.csv*"). Details of the variables referred to in column 2 are given in Table 28.

| Column number | Column name | Description | User editable |
|---|---|---|---|
| 1 | Month | Values 1-12 denoting months January – December | No |
| 2 | Variable | Name used in the model code to identify each variable | No |
| 3 | median | Median of observed values in the model domain over the period corresponding to the model driving data | Yes |
| 4 | lower_centile | Lower centile value of observed values in the model domain over the period corresponding to the model driving data | Yes |
| 5 | upper_centile | Upper centile value of observed values in the model domain over the period corresponding to the model driving data | Yes |
| 6 | Units | Units of the observed data | No |
| 7 | low_cent_value | Lower centile level (either 5% or 17%) | Yes |

| | | | |
|---|---|---|---|
| 8 | upp_cent_value | Upper centile level (either 83% or 95%) | Yes |
| 9 | Comments | Free text to describe the provenance of the observed data | Yes |

**Table 28.** Details of the variables in the database (Table 27) of observed monthly-based indices of of nutrient and plankton concentrations in the model domain during the period corresponding to the physical and chemical driving data ("*monthly_observed***.csv*").

| Variable name | Units | Description |
|---|---|---|
| surface_nitrate | $mMNm^{-3}$ | Nitrate concentrations in the combined volume of the inshore zone and the upper layer of the offshore zone |
| deep_nitrate | $mMNm^{-3}$ | Nitrate concentrations in the lower layer of the offshore zone |
| surface_ammonia | $mMNm^{-3}$ | Ammonia concentrations in the combined volume of the inshore zone and the upper layer of the offshore zone |
| deep_ammonia | $mMNm^{-3}$ | Ammonia concentrations in the lower layer of the offshore zone |
| surface_chlorophyll | $mgm^{-3}$ | Chlorophyll concentrations in the combined volume of the inshore zone and the upper layer of the offshore zone |
| omniv_zooplankton | $mMNm^{-3}$ | Omnivorous zooplankton concentrations in the combined volume of the inshore and offshore zones |
| carniv_zooplankton | $mMNm^{-3}$ | Carnivorous zooplankton concentrations in the combined volume of the inshore and offshore zones |
| larvae_susp_dep_benthos | $mMNm^{-3}$ | Larvae of suspension/deposit feeding benthos - concentrations in the combined volume of the inshore and offshore zones |
| larvae_carniv_scav_benthos | $mMNm^{-3}$ | Larvae of carnivorous/scavenge feeding benthos - concentrations in the combined volume of the inshore and offshore zones |

**Table 29.** Table of independently known regional harvest ratios for each guild for the whole model domain (aggregated over the inshore and offshore zones) in the file "*regional_harvest_r*.csv*". Illustrated by the data file for the 2003-2013 North Sea model. This file is required only for calculating an initial rough estimate of values for the effort-harvest ratio scaling coefficients, given known gear activity rates, using the function e2e_calculate_hrscale().

| Guild | Regional harvest ratio ($d^{-1}$) | Comments |
|---|---|---|
| Planktivorous_fish | 2.6387E-04 | 1970-1999 harvest ratio from Heath 2012 upscaled to account for discards and rescaled to 03_13 from ICES ecoreview |
| Demersal_fish | 3.2340E-04 | 1970-1999 harvest ratio from Heath 2012 upscaled to account for discards and rescaled to 03_13 from ICES ecoreview |
| Migratory_fish | 1.6101E-04 | 1970-1999 harvest ratio from Heath 2012 upscaled to account for discards and rescaled |

| | | |
|---|---|---|
| | | to 03_13 from ICES ecoreview |
| Benthos_susp-dep | 1.0637E-04 | 1970-1999 harvest ratio from Heath 2012 upscaled to account for discards and rescaled to 03_13 from ICES ecoreview |
| Benthos_carn-scav | 4.0802E-04 | 1970-1999 harvest ratio from Heath 2012 upscaled to account for discards and rescaled to 03_13 from ICES ecoreview |
| Zooplankton_carn | 4.9460E-04 | Guess at harvest ratio for squid |
| Birds | 1.6492E-06 | Rough estimate for harvest ratio from synthesis of bycatch data |
| Pinnipeds | 2.6053E-05 | Rough estimate for harvest ratio from synthesis of bycatch data |
| Cetaceans | 1.2055E-04 | Rough estimate for harvest ratio from synthesis of bycatch data and strandings data |
| Macrophytes | 0.0000E+00 | No kelp harvesting in the North Sea |

**Table 30.** Details of the file specifying target inshore and offshore harvest ratios of each guild (*zonal_harvest_r*.csv*). The file is required only by the simulated annealing function e2e_optimize_act(… , selection="HR", …) to find the combination of gear activity scaling values producing the best fit of the harvest ratios generated the fleet model to prior estimate inshore and offshore values, given a known relative spatial distribution of each gear and known effort-harvest ratio scaling values. The numeric values in the table (indicated here by xxxx) could be generated by compiling a model object using the e2e_read() function with inputs being gear activity densities (Table 16) and distributions (Table 20), and harvest ratio scaling parameters (Table 14) commensurate with the regional harvest ratios in Table 29. The 'Comments' column is free text and a possible example is shown here.

| **Guild** | **Inshore harvest ratio ($d^{-1}$)** | **Offshore harvest ratio ($d^{-1}$)** | **Use 1=yes,0=no** | **Comments** |
|---|---|---|---|---|
| Planktivorous_fish | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Demersal_fish | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Migratory_fish | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Benthos_susp-dep | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Benthos_carn-scav | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Zooplankton_carn | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |

| | | | | |
|---|---|---|---|---|
| Birds | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Pinnipeds | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Cetaceans | xxxx | xxxx | 1 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |
| Macrophytes | xxxx | xxxx | 0 | Harvest ratios extracted from the model object for a run with fleet model parameters calibrated against known regional_HRs |

## Anciliary parameter files – control files for simulated annualing, sensitivity analysis and credible interval estimation

**Table 31.** Details of the control file **"***optimize_ecology.csv*" which is located in the "c*ontrol*" sub-directory of the "*Param*" folder for each model version. This file should not be renamed. However, the values in column 1 (examples shown here) can be edited during a simulated annealing run to fit the ecology model parameters and have an immediate effect on the real-time plot of the fitting progress and on the search band-width for each group of parameters.

| Value | Description - these can all be edited DURING a run and have immediate effect |
|---|---|
| 0 | Axis_minimum_for_realtime_plot |
| 0.6 | Axis_maximum_for_realtime_plot |
| 0.02 | CV_ie_SD/mean_for_preference_parameters |
| 0.01 | CV_ie_SD/mean_for_maximum_uptake_rates_may_need_to_be_up_to_10x_smaller_than_other_classes |
| 0.01 | CV_ie_SD/mean_for_half_saturation_coefficients_may_need_to_be_up_to_10x_smaller_than_other_classes |
| 0.04 | CV_ie_SD/mean_for_microbial_rates_may_need_to_be_upto_10x_larger_than_other_classes |
| 0.02 | CV_ie_SD/mean_for_density_dependent_mortality_parameters |
| 0.02 | CV_ie_SD/mean_for_other_parameters |

**Table 32.** Details of the control file **"***optimize_fishing.csv*" which is located in the "*control*" sub-directory of the "*Param*" folder for each model version. This file should not be renamed. However, the values in column 1 (examples shown here) can be edited during a simulated annealing run to fit either the the fishing activity rates or the harvest ratio scaling values and have an immediate effect on the real-time plot of the fitting progress and on the search band-width for the parameters.

| Value | Description - these can all be edited DURING a run and have immediate effect |
|---|---|
| 0 | Axis_minimum_for_realtime_plot |

| | |
|---|---|
| 0.3 | Axis_maximum_for_realtime_plot |
| 0.05 | CV_ie_SD/mean_for_fishing_fleet_parameters |

**Table 33.** Details of the control file **"***sensitivity.csv*" which is located in the "*control*" sub-directory of the *"Param*" folder for each model version. This file should not be renamed. However, the values in column 1 (examples shown here) can be edited during a sensitivity analysis run to control the axis range of the real-time plot which monitors the progress of the analysis.

| **Value** | **Description - these can all be edited DURING a run and have immediate effect** |
|---|---|
| 0 | Axis_minimum_for_realtime_plot |
| 0.6 | Axis_maximum_for_realtime_plot |

**Table 34.** Details of the control file **"***monte_carlo.csv*" which is located in the "*control*" sub-directory of the "*Param*" folder for each model version. This file should not be renamed. However, the axis range values in column 1 (examples shown here) can be edited during a credible interval simulation run run to control the real-time plot which monitors the progress of the analysis. The CV values for each group of variables should not be edited during a run but can be reset to some other values ahead of a run.

| Value | **Description – axis ranges can be edited DURING a run and have immediate effect – do not edit the CVs during a run** |
|---|---|
| 0 | Axis_minimum_for_realtime_plot |
| 0.6 | Axis_maximum_for_realtime_plot |
| 0.1 | CV_ie_SD/mean_for_preference_parameters |
| 0.1 | CV_ie_SD/mean_for_maximum_uptake_rates |
| 0.1 | CV_ie_SD/mean_for_half_saturation_coefficients |
| 0.1 | CV_ie_SD/mean_for_microbial_rates |
| 0.1 | CV_ie_SD/mean_for_density_dependent_mortality_parameters |
| 0.1 | CV_ie_SD/mean_for_other_parameters |

## READING THE MODEL INPUT FILES

The function:

```
e2e_ls(models.path = NULL)
```

provides a list of the models and their variants available in the designated folder.

Arguments

| | |
|---|---|
| models.path | Relative path from the current working directory to a folder containing a library of model configurations (typically "Folder/Models"). Setting models.path="" is valid. Default models.path=NULL, meaning read a North Sea model setup from the package folder extdata/Models. |

The function:

```
e2e_read(model.name, model.variant, models.path=NULL, results.path=NULL, results.subdir="", model.ident="base", quiet=TRUE, silent=FALSE)
```

creates an R-list object which contains all of the input data gathered from the "'*.csv*" files which define the model setup, parameters and driving data (Table 35).

Arguments

| | |
|---|---|
| model.name | Name of model to read |
| model.variant | Read the designated model variant (no default) |
| models.path | Relative path from the current working directory to a folder containing a library of model configurations (typically "Folder/Models"). Setting models.path="" is valid. Default models.path=NULL, meaning read a North Sea model setup from the package folder extdata/Models. |
| results.path | Relative path from the current working directory to a folder for writing and reading model output files (e.g. "E2E_results"). Setting results.path="" is valid. Model-specific sub-folders will be assigned and if necessary auto-created according to the model name and variant. Default results.path=NULL, meaning write/read to/from a temporary directory. |
| results.subdir | Subdirectory of "working_directory/results.path/model_name/model_variant" to be created if required. (Default="", meaning no subdirectory will be created). |
| model.ident | Identifier text appended to output file names (e.g. OFFSHORE_model_annualresults-TEXT.csv instead of just OFFSHORE_model_annualresults.csv). (Default="base").Default = "base". |
| quiet | Logical. If FALSE then see on-screen information on indvidual parameter files as they are read (default=TRUE). |

silent Logical. If FALSE then see on-screen information on model and results paths (default=FALSE). If set TRUE then this over-rides any quiet=FALSE setting and forces quiet=TRUE.

Example

```
model <- e2e_read("North_Sea", "1970-1999")
```

**Table 35**. Structure and contents of the R-list object created by the e2e_read() function

| Primary-level object name | Secondary-level object name | Tertiary level object name | Data type | Description |
|---|---|---|---|---|
| $setup | | | List (7 elements) | List object containing details of the paths to the model configuration data, and results identifiers |
| | $read.only | | Logical | Internal setting – set to "read.only" if the model is loaded from the internally provided folders in the package - to prevent functions writing back to the installation. |
| | $model.name | | Character string | Name of the model to be run, located in the the $model.path folder |
| | $model.variant | | Character string | Name of the model variant, located in the $model.name folder |
| | $model.ident | | Character string | Identifier to be appended to all output **.csv* file-names |
| | $model.subdir | | Character string | Sub-directory of of $resultsdir to be created if necessary, to hold outputs files from the modle run |
| | $model.path | | Character string | Full path to the folder containinhg the model definition directories |
| | $resultsdir | | Character string | Full path to the results folder for model output |
| $data | | | List (8 elements) | List object comprising the compiled input data to the ecology model |
| | $fixed.parameters | | List (51 elements) | Fixed parameter values gathered from the "*fixed_parameter*.csv*" files |

| | | | |
|---|---|---|---|
| $fitted.parameters | | List (171 elements) | Fixed parameter values gathered from the "*fitted_parameter*.csv*" files |
| $physical.parameters | | List (63 elements) | Physical parameters defning the model configuration (layer thicknesses, areas, etc.) |
| $physics.drivers | | Dataframe | Monthly values of physics driving data defining the repeating annual cycle of divers to be applied to the model |
| $chemistry.drivers | | Dataframe | Monthly values of boundary chemical driving data defining the repeating annual cycle of divers to be applied to the model |
| $biological.events | | Dataframe | Parameters defining the timing of biological events in the model |
| $fleet.model | | List (19 elements) | List object comprising the compiled input data to the fishing fleet model |
| | $gear_labels | Factor with 12 levels | Names of the up to 12 fishing gear defined in the model |
| | $gear_codes | Factor with 12 levels | Short names (2 or 3 letter codes) for each fishing gear |
| | $gear_activity | Numeric vector | Activity rates of each fishing gear |
| | $gear_group_rel_power | Dataframe | Catching power for each fishing gear with respect to each harvestable guild in the ecology model |
| | $gear_group_discard | Dataframe | Externally defined discard rate for each fishing gear with respect to each harvestable guild in the ecology model |
| | $gear_group_gutting | Dataframe | Processing-at-sea rate for each fishing gear with respect to each harvestable guild in the ecology model |
| | $gear_ploughing_rate | Numeric vector | Seabed abrasion rate for each fishing gear |
| | $gear_habitat_activity | Dataframe | Proportional distribution of the activity of each fishing gear across the up to 8 seabed habitats in the model |
| | $HRscale_vector | Named numeric vector | Scaling values linking effort applied to each harvestable guild (integrated across all gears) to the harvest ratio (mortality rate). Ordering of values as in the input *.csv* file (see Table 14). |

| | | | | |
|---|---|---|---|---|
| | | $HRscale_vector_multiplier | Named numeric vector | Multipliers to be applied to harvest ratio values before being piped into the ecology model – useful for setting up fishing scenarios |
| | | $offal_prop_live_weight | Numeric value | Proportion of live weight which is discarded as offal during processing at sea |
| | | $gear_mult | Numeric vector | Multipliers to be applied to gear activity rates before being integrated and converted into harvest ratios – useful for setting up fishing scenarios |
| | | $quota_nonquota_parms_vector | Numeric vector | Parameters of the empirically based relationships linking undersize and non-quota species fraction of demersal fish catch to demersal biomass |
| | | $DFsize_SWITCH | Numeric value | Switch defining how the ecology model represents demersal fish size selectivity |
| | | $DFdiscard_SWITCH | Numeric value | Switch defining how the ecology model represents discarding of demersal fish |
| | | $plough_thickness | Numeric value | Penetration depth of fishing gears into seabed sediments |
| | | $plough_depth_vector | Numeric vector | Proportion of each seabed sediment layer thickness penetrated by fishing gears. |
| | $initial.state | | List (403 elements) | Initial values for the state variable in the model (typically originating from a prior long-run to stationary state of the model), plus zero values for all of the fluxes and derived variables output by the model |

## Writing your own code to create model scenarios

Typical use of the model might involve

- comparing a baseline run with a scenario run involving some changes in driving data (e.g. different temperature conditions or different activity rates of selected gears),

- conducting an analysis of the sensitivity to systematic changes in driving data (e.g. incrememts in harvest ratio over some range of values).

Users have two options for configuring such experiments

- manually edit the *.csv* input files as required and rerun the model,
- use coding to alter the required elements of the R list object created by the e2e_read() function, assigning a unique identifier to the outputs from each run.

Below are two examples of code to configure and run scenario cases of the the 2003-2013 North Sea model provided with the package. The first example runs 2003-2013 North Sea model as a baseline, and then adds an increment to the temperatures in all spatial zones and reruns the model. The second example iterates through seven levels of demersal fish harvest ratio ranging from 0 to 3-times the value in the 2003-2013 model (in steps of 0.5-times). Note that the changes in harvest ratio are not accompanied by any changes in fishing gear activity.

Example 1

```
# Example of code to run a baseline case of the North Sea model with 2003-2013 conditions, and then edit the
# model list object to create a scenario run with the temperature in all zones increased by 2 deg-C
#-------------------------------------------------------
# Read the embedded North Sea 2003-2013 model and assign an identifier for the results
baseTemp_model<-e2e_read("North_Sea", "2003-2013",model.ident="baseTemp")
# Run the model for 10 years and save the results to a named list object
baseTemp_results<-e2e_run(baseTemp_model,nyears=10)
# Visualise the output from the run (should show a repeating annual cycle with no trend)
e2e_plot_ts(baseTemp_model,baseTemp_results,selection=""ECO")
#-------------------------------------------------------
T_rise<-2    # temperature increase to add to all temperatures in the model drivers
# copy the baseline model list object to a new model list
baseTemp_plusTC_model<-baseTemp_model
# add temperature increase to upper layer offshore temperatures
baseTemp_plusTC_model$data$physics.drivers$so_temp <- baseTemp_model$data$physics.drivers$so_temp+T_rise
# add temperature increase to inshore temperatures
baseTemp_plusTC_model$data$physics.drivers$si_temp <- baseTemp_model$data$physics.drivers$si_temp+T_rise
# add temperature increase to lower layer offshore temperatures
baseTemp_plusTC_model$data$physics.drivers$d_temp  <- baseTemp_model$data$physics.drivers$d_temp+T_rise
```

```
# Assign a unique identifier for the .csv outputs
baseTemp_plusTC_model$setup$model.ident <- "baseTemp_plusTC"
# Run the model for 10 years and save the results to a named list object
baseTemp_plusTC_results<-e2e_run(baseTemp_plusTC_model,nyears=10)
# Visualise the output from the run (should show trends in outputs due to change in T)
e2e_plot_ts(baseTemp_plusTC_model,baseTemp_plusTC_results,selection=”ECO”)
#-------------------------------------------------------
```

Example 2

```
# Example of code to loop through a set of seven levels of demersal fish harvest ratio ranging from 0 to 3-times
# the baseline value for the 2003-2013 North Sea model. The .csv outputs for each level are saved to unique
# filenames but the results list-object is discarded. The baseline case is the third level (HScale=1). Each level
# is run for 40 years.
#-------------------------------------------------------
model<-e2e_read("North_Sea", "2003-2013")                # Read the embedded North Sea 2003-2013 model
for(i in 1:7) {                                          # Start loop through seven model scenarios
  HScale <- (i-1)*0.5                                    # HScale becomes 0 to 3 in steps of 0.5
     # Assign a unique identifier for each set of .csv outputs (here saved in a temporary folder)
  model$setup$model.ident <- paste("Dem_HR_scale_",HScale,sep="")
     # Set the demersal fish harvest ratio multipler to HScale
  model$data$fleet.model$HRscale_vector_multiplier[2] <- HScale
          # Run the model, save the .csv results, overwrite any previous list-object
  results<-e2e_run(model,nyears=40)
  print(paste("Harvest Ratio scaling = ",HScale,sep=""))     # Print a screen message to monitor progress
  print("-----------------------------------")               # Print a screen message to moinitor progress
  e2e_plot_ts(model,results,selection=”ECO”)                # Visualise the output from each run

}                                                          # End loop through scenarios
#-------------------------------------------------------
```

# OUTPUTS FROM A BASIC SINGLE RUN OF THE MODEL

## Structure of the output data

The function

```
e2e_run(model, nyears)
```

performs a single run of the model with the current R-list object defining the model setup.

Arguments

| | |
|---|---|
| model | current model configuration (list-object created by e2e_read()) |
| nyears | number of years to run the model, default = 5 |

Example

```
model <- e2e_read("North_Sea", "1970-1999")
results <- e2e_run(model,nyears=20)
```

The outputs from running the basic model are a set of comma-separated-variable (.csv) files, and an R list object ("results" in the example above) which contains 7 primary data structures (Table 36). The contents of the *.csv* outputs are replicated in the R list.

Output *.csv* files are directed to a "*results*" folder either in the user home workspace by default, or to a workspace defined in the arguments of the e2e_read() function (Figure 3). The *.csv* files each have a generic file name plus an alpha-numeric identifier (model.ident) assigned by the user as an argument of the e2e_read() function (default = "base"). An abbreviated view of the contents of the results object can be obtained by the R-function str() (e.g. str(results)). To view the names of primary level objects in the results list, use the function names() (e.g. names(results)). Tables 37-46 provide details of the R-list object, and of each individual data element of the object and corresponding *.csv* file where applicable.

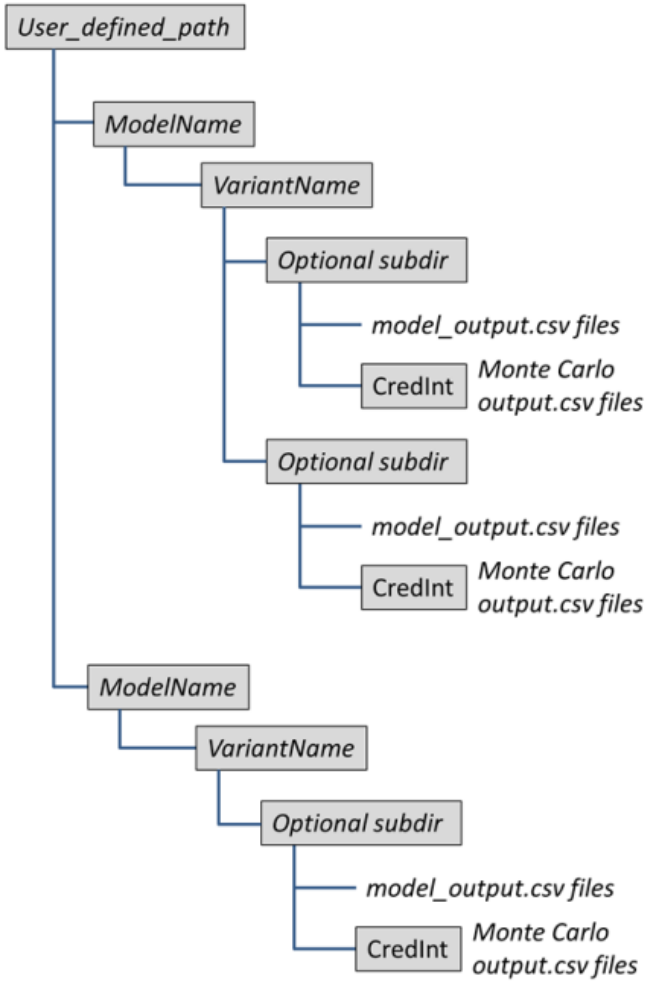


**Figure 3. Folder structure for model results.** Italicised folder names are free for user specification. The folder structure will be automatically created in the user defined folder by the running model unless otherwise specified in the model setup. "*ModelName"* and "*VarianName*" will be auto-created to replicate the structure in the model definition folders unless already existing. The "*CredInt*" subfolder wil be auto-created on the first instance of the Mont Carlo function in the package.

**Table 36**. High-level details of the 7 data objects contained in the R-list created by running the model.

| Object name | Data-type | Description |
|---|---|---|
| $build | List | Objects defining all the input conditions for the model run |
| $output | Dataframe | Primary output from the ecology model. |
| $aggregates | Dataframe | Aggregates of primary outputs from the model |
| $fleet.output | List | Datasets output from the fleet model. |
| $total.annual.catch | List | Annually integrated catch data for each model guild, for each successive year of the model run. |
| $annual.catch.by.gear | List | Annually integrated catch data for each successive year of the model run, disaggregated by fishing gears |
| $final.year.outputs | List | Data products derived from the final year only of the model run. |

**Table 37**. Details of the contents of each of the 7 data objects saved within the R-list created by running the model, and the corresponding *.csv* file names where applicable.

| Primary-level object name | Secondary-level object name | Tertiary-level object name | R data type | .csv file name where applicable | Brief description |
|---|---|---|---|---|---|
| $build | | | List | | List of objects defining all the input conditions for the model run |
| | $model.parameters | | Named numeric vector | | Vector of parameter values, compile dfrom al the input data, which is piped into the ecology model |
| | $run | | List | | List of objects defining the duration and timing of events in the run |
| | | $nyears | Numeric value | | Number of simulation years for the model run |
| | | $ndays | Numeric value | | Number of simulation days for the model run |
| | | $drndays | Numeric value | | Number of values in the sequence of driving data |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | supplied for the modle run |
| | | $times | Numeric vector | | Times in days at which output is expected from the model. Vector length = $ndays |
| | | $drtimes | Numeric vector | | Times in days at which driving data are defined for the model run. Vector length = $drndays |
| | | $sprectimes | Numeric vector | | Times in days at which spawning and recruitment events occur |
| | | $daynum | Numeric vector | | Sequence of days defining an annual cycle (0 – 360 in intervals of 1) |
| | $drivers | | List of 51 | | Set of R-functions whish return the values of model drivers at any given day number e.g $driversslight() returns the sea surface light intensity on a given day. |
| | $forcings | | List of 53 | | Values of all the drivers generated by $drivers at times defined by $run$drtimes which are piped into the ecoloy model |
| $output | | | Dataframe | | Primary output from the ecology model. First column is the time (days from the beginning of the run) of each output event, and the remaining columns are the values of the state variables (mMN) and a range of cumulative fluxes at the sequence of daily intervals (rows). |
| $aggregates | | | List of 130 | | Aggregates of primary outputs.<br>List of 124 numeric vectors of length equal to the number of rows in “output”, plus six numeric values (vectotrs length 1) of aggregated volumetric data. The aggregates of the |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | primary outputs are *e.g.* the combined mass of all material in the model, or the combined mass of a property in the whole model domain, obtained by summing across state variables or summing the values in the inshore and offshore zones. |
| $fleet.output | | | List | | List of datasets output from the fleet model. |
| | $fleet_vector | | Numeric vector | | Parameters generated by the fleet model which become embedded in the ecology model parameter set (model.parameters). |
| | $offshore_gear_group_prop_effort | | Dataframe | | Final year proportional distribution of offshore effort density across gears for each guild (rows = gears, columns = guilds, column values sum to 1). Used to disaggregate total catch output from the model into catches by gears. |
| | $inshore_gear_group_prop_effort | | Dataframe | | As above for the inshore zone. |
| | $offshore_gear_to_region_discard_rate_ratio | | Dataframe | | Final year ratios of gear-discard rate in the offshore zone, to the regional effort weighted all-gear discard rate of each guild (rows = gears, columns = guilds). Used to disaggregate total catch output from the model into catches by gears. |
| | $inshore_gear_to_region_discard_rate_ratio | | Dataframe | | As above for the inshore zone. |
| | $offshore_gear_group_props | | Dataframe | | Combines and flattens the data provided in the dataframes offshore_gear_group_prop_effort and offshore_gear_to_region_discard_rate_ratio, and replicates for each year of the model run. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Rows = years of the run; columns : [1] = year, [2:13] = proportional distribution of planktivorous fish effort across trhe 12 gears, [14:25] = proportional distribution of demersal fish `effort across trhe 12 gears, etc to column 121; [122:133] = ratios of planktivorous fish discard rate for each gear, [134:145] = ratios of demersal fish discard rate for each gear, etc to comumn 241. Used to disaggregate total catch output from the model into catches by gears. |
| | $inshore_gear_group_props | | Dataframe | | As above for the inshore zone. |
| $total.annual.catch | | | List | | List of annually integrated catch datasets for each successive year of the model run. |
| | $offshore_annual_group_land_disc | | Dataframe | model_offshore_annual_landings_discards-* | Annual landings and discards (mMN.$y^{-1}$) of each harvestable guild in the offshore zone, for each year of the model run |
| | $inshore_annual_group_land_disc | | Dataframe | model_inshore_annual_landings_discards-* | As above for the inshore zone |
| $annual.catch.by.gear | | | List | | List of annually catch datasets for each successive year of the model run, disaggregated by fishing gears |
| | $offshore_annual_group_gear_land_disc | | Dataframe | | Annual integrals of landings and discards (mMN.$y^{-1}$) of each harvestable guild in the offshore zone, disaggregated by gear (columns), for each year of the model run (rows). |
| | $inshore_annual_group_gear_land_disc | | Dataframe | | As above for the inshore zone. |
| $final.year.outputs | | | List | | List of data products derived from the final year only of the model run. |
| | $inshore_catchmat | | Array | INSHORE_catchcomposition_by_gear-* | Catch mass (mMN.$y^{-1}$) in the |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | inshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears). |
| | $inshore_discmat | | Array | INSHORE_discardcomposition_by_gear-* | Landed live mass (mMN.$y^{-1}$) from the inshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears). |
| | $inshore_landmat | | Array | INSHORE_landingcomposition_by_gear-* | Discarded live mass (mMN.$y^{-1}$) in the inshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears) |
| | $offshore_catchmat | | Array | OFFSHORE_catchcomposition_by_gear-* | Catch mass (mMN.$y^{-1}$) in the offshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears). |
| | $offshore_landmat | | Array | OFFSHORE_landingcomposition_by_gear-* | Landed live mass (mMN.$y^{-1}$) from the offshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears). |
| | $offshore_discmat | | Array | OFFSHORE_discardcomposition_by_gear-* | Discarded live mass (mMN.$y^{-1}$) in the offshore zone distributed across guilds and fishing gears (rows = guilds, columns = gears). |
| | $monthly.averages | | Dataframe | model_monthlyresults-* | Monthly averages of water column nutrients,chlorophyll, and zooplankton classes including meroplankton concentratiions (mMN.$m^{-3}$, except chlorophyll mg.$m^{-3}$) averaged over the whole model domain. Rows: months, columns: variable averages. Chlorophyll estimated assuming a fixed Redfield molar carbon:nitrogen ratio (106:16) and carbon:chlorophyll weight ratio of 20. |

| | | | | | |
|---|---|---|---|---|---|
| | $mass_results_inshore | | Dataframe | INSHORE_model_anav_biomass-* | Final year annual mean mass (mMN) of each state variable in the inshore zone, plus the area-proportions and thicknesses of water column and sediment layers to enable mass data to be converted to area-densities ($mMN.m^{-2}$) or layer concentrations ($mMN.m^{-3}$) |
| | $maxmass_results_inshore | | Dataframe | INSHORE_model_maximum_biomass-* | Final year annual maximum mass (mMN) of each state variable in the inshore zone, plus the area-proportions and thicknesses of water column and sediment layers to enable mass data to be converted to area-densities ($mMN.m^{-2}$) or layer concentrations ($mMN.m^{-3}$) |
| | $minmass_results_inshore | | Dataframe | INSHORE_model_minimum_biomass-* | Final year annual minimum mass (mMN) of each state variable in the inshore zone, plus the area-proportions and thicknesses of water column and sediment layers to enable mass data to be converted to area-densities ($mMN.m^{-2}$) or layer concentrations ($mMN.m^{-3}$) |
| | $annual_flux_results_inshore | | Dataframe | INSHORE_model_annualresults-* | A range of final year annual fluxes ($mMN.y^{-1}$) – boundary influxes and efluxes (including live and gutted landed weights) for the inshore zone; gross and net production rates; feeding and excretion fluxes; egg production and recruitment; plus the area-proportions and thicknesses of water column and sediment layers to enable mass fluxes to be converted to area-density fluxes ($mMN.m^{-2}.y^{-1}$) or layer-concentration fluxes |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | (mMN.$m^{-3}$.$y^{-1}$). |
| | $mass_results_offshore | | Dataframe | OFFSHORE_model_anav_biomass-* | As above for the offshore zone |
| | $maxmass_results_offshore | | Dataframe | OFFSHORE_model_maximum_biomass-* | As above for the offshore zone |
| | $minmass_results_offshore | | Dataframe | OFFSHORE_model_minimum_biomass-* | As above for the offshore zone |
| | $annual_flux_results_offshore | | Dataframe | OFFSHORE_model_annualresults-* | As above for the offshore zone |
| | $mass_results_wholedomain | | Dataframe | WHOLEDOMAIN_model_anav_biomass-* | As above for the whole model domain (inshore and offshore combined) |
| | $maxmass_results_wholedomain | | Dataframe | WHOLEDOMAIN _model_maximum_biomass-* | As above for the whole model domain (inshore and offshore combined) |
| | $minmass_results_wholedomain | | Dataframe | WHOLEDOMAIN _model_minimum_biomass-* | As above for the whole model domain (inshore and offshore combined) |
| | $annual_flux_results_wholedomain | | Dataframe | WHOLEDOMAIN _model_annualresults-* | As above for the whole model domain (inshore and offshore combined) |
| | $flow_matrix_all_fluxes | | Dataframe | flow_matrix_all_fluxes-* | Final year matrix of annual integrated flows through the whole model domain network of state variable between sources (rows) and destinations (columns), including model boundary flows and spawning and recruitments fluxes between adult and egg/larvae stages. |
| | $flow_matrix_excl_spawn_recruit | | Dataframe | flow_matrix_excl_spawn_recuit-* | As above but exluding the fluxes due to spawning and recruitment. |
| | $NetworkIndexResults | | Dataframe | Network_indices_output-* | Table of results from applying the flow matrix data above to the functions provided in the NetIndices R package |
| | $annual.target.data | | Dataframe | | Input data on the 'real life' observed data on annual metrics (annual target data) copied directly for the input *.csv* file (Tables 25, 26). These data are included here so that they are |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | easily available for plotting and comparison with model outputs. |
| | $monthly.target.data | | Dataframe | | Input data on the 'real life' observed data on monthly averages of nutrient and plankton state variables (monthly target data) copied directly for the input *.csv* file (Tables 27, 28). These data are included here so that they are easily available for plotting and comparison with model outputs |
| | $annual_obj | | Numeric value | | Single value corresponding to the likelihood of the observed annual target data given the model structure, driving data and parameters. |
| | $partial_chi | | Dataframe | model_likelihood_results-* | Table of the partial likelihoods corresponding to each element of the observed annual target data. |
| | $opt_results | | Dataframe | model_target_annualresults_plus_chi-* | Table combining the input observed annual target data (*$annual.target.data*) with the corresponding annual model ouputs, and the "chi-squared" value for each observation (data column labelled "Chi"). The likelihood of each observed value (see *$partial_chi*) is given by exp-(Chi)) |

**Table 38. Key data (area and volumetric parameters) saved in the vector "$build$model.parameters" of the R-list generated by the model, that will be required by users for post-processing of results**. These parameters are needed to convert state variable mass and fluxes into area-densities and layer concentrations. The notation ..$parameter.name denotes the prefix results.object.name$build$model.parameters

| Variable name (prefixed by ..$build$model.parameters | Description | Units |
|---|---|---|

| | | |
|---|---|---|
| ..$shallowprop | Area-proportion of the inshore zone | Dimensionless |
| ..$thik_so | Thickness of the offshore zone upper water column layer | m |
| ..$thik_d | Thickness of the offshore zone lower water column layer | m |
| ..$thik_si | Thickness of the inshore zone water column layer | m |
| ..$area_s0 | Area-proportion of the inshore rock habitat | Dimensionless |
| ..$area_s1 | Area-proportion of the inshore zone sediment habitat 1 | Dimensionless |
| ..$area_s2 | Area-proportion of the inshore zone sediment habitat 2 | Dimensionless |
| ..$area_s3 | Area-proportion of the inshore zone sediment habitat 3 | Dimensionless |
| ..$area_d0 | Area-proportion of the offshore rock habitat | Dimensionless |
| ..$area_d1 | Area-proportion of the offshore zone sediment habitat 1 | Dimensionless |
| ..$area_d2 | Area-proportion of the offshore zone sediment habitat 2 | Dimensionless |
| ..$area_d3 | Area-proportion of the offshore zone sediment habitat 3 | Dimensionless |
| ..$thik_x_s1 | Thickness of the inshore zone sediment habitat 1 | m |
| ..$thik_x_s2 | Thickness of the inshore zone sediment habitat 2 | m |
| ..$think_x_s3 | Thickness of the inshore zone sediment habitat 3 | m |
| ..$thik_x_d1 | Thickness of the offshore zone sediment habitat 1 | m |
| ..$thik_x_d2 | Thickness of the offshore zone sediment habitat 2 | m |
| ..$think_x_d3 | Thickness of the offshore zone sediment habitat 3 | m |
| ..$porosity_s1 | Porosity (fluid volume-proportion) of the inshore zone sediment habitat 1 | Dimensionless |
| ..$porosity _s2 | Porosity (fluid volume-proportion) of the inshore zone sediment habitat 2 | Dimensionless |
| ..$porosity_s3 | Porosity (fluid volume-proportion) of the inshore zone sediment habitat 3 | Dimensionless |
| ..$porosity_d1 | Porosity (fluid volume-proportion) of the offshore zone sediment habitat 1 | Dimensionless |
| ..$porosity_d2 | Porosity (fluid volume-proportion) of the offshore zone sediment habitat 2 | Dimensionless |
| ..$porosity_d3 | Porosity (fluid volume-proportion) of the offshore zone sediment habitat 3 | Dimensionless |

## Details of the raw data outputs from the model

**Table 39. Details of the data columns in the dataframe "$output" generated by the model.** Rows in the dataframe are the sequential outputs at daily intervals. State variable mass columns (2:78) are the masses of nitrogen or carbon associate with the state variables in the model; cumulative flux columns (79:404) are the accumulated flows of mass over time between the given compartments. The rate of flow over any given interval is given by the difference in cumulative flux between appropriate rows in the dataframe. The notional sea surface area of the whole model domain is $1m^2$; the configuration parameters defining vertical layer thicknesses and horizontal area-proportions in the inshore and offshore zone and in the seabed habitats are given in the "$build$model.parameters" object (see Table 38). These parameters are required to convert state variable mass and fluxes output from the model into area densities ($m^{-2}$) and layer concentrations ($m^{-3}$).

| Column number | Column name | Data type | Description | Units |
|---|---|---|---|---|
| 1 | Time | Cumulative time | Time from start of run (0 to 360 x number of years) | Days |
| 2 | detritus_so | State variable mass | Offshore upper layer suspended detritus and bacteria | mMN |
| 3 | detritus_d | State variable mass | Offshore lower layer suspended detritus and bacteria | mMN |
| 4 | x_detritus_s1 | State variable mass | Inshore sediment class 1 labile detritus and bacteria | mMN |
| 5 | x_detritus_s2 | State variable mass | Inshore sediment class 2 labile detritus and bacteria | mMN |
| 6 | x_detritus_s3 | State variable mass | Inshore sediment class 3 labile detritus and bacteria | mMN |
| 7 | x_detritus_d1 | State variable mass | Offshore sediment class 1 labile detritus and bacteria | mMN |
| 8 | x_detritus_d2 | State variable mass | Offshore sediment class 2 labile detritus and bacteria | mMN |
| 9 | x_detritus_d3 | State variable mass | Offshore sediment class 3 labile detritus and bacteria | mMN |
| 10 | xR_detritus_s1 | State variable mass | Inshore sediment class 1 refractory detritus | mMN |
| 11 | xR_detritus_s2 | State variable mass | Inshore sediment class 2 refractory detritus | mMN |
| 12 | xR_detritus_s3 | State variable mass | Inshore sediment class 3 refractory detritus | mMN |
| 13 | xR_detritus_d1 | State variable mass | Offshore sediment class 1 refractory detritus | mMN |
| 14 | xR_detritus_d2 | State variable mass | Offshore sediment class 2 refractory detritus | mMN |
| 15 | xR_detritus_d3 | State variable mass | Offshore sediment class 3 refractory detritus | mMN |

| | | | | |
|---|---|---|---|---|
| 16 | discard_o | State variable mass | Offshore discarded material from fisheries | mMN |
| 17 | corpse_s1 | State variable mass | Inshore sediment class 1 seabed corpses | mMN |
| 18 | corpse_s2 | State variable mass | Inshore sediment class 2 seabed corpses | mMN |
| 19 | corpse_s3 | State variable mass | Inshore sediment class 3 seabed corpses | mMN |
| 20 | corpse_d1 | State variable mass | Offshore sediment class 1 seabed corpses | mMN |
| 21 | corpse_d2 | State variable mass | Offshore sediment class 2 seabed corpses | mMN |
| 22 | corpse_d3 | State variable mass | Offshore sediment class 3 seabed corpses | mMN |
| 23 | ammonia_so | State variable mass | Offshore upper layer ammonia | mMN |
| 24 | ammonia_d | State variable mass | Offshore lower layer ammonia | mMN |
| 25 | x_ammonia_s1 | State variable mass | Inshore sediment class 1 porewater ammonia | mMN |
| 26 | x_ammonia_s2 | State variable mass | Inshore sediment class 2 porewater ammonia | mMN |
| 27 | x_ammonia_s3 | State variable mass | Inshore sediment class 3 porewater ammonia | mMN |
| 28 | x_ammonia_d1 | State variable mass | Offshore sediment class 1 porewater ammonia | mMN |
| 29 | x_ammonia_d2 | State variable mass | Offshore sediment class 2 porewater ammonia | mMN |
| 30 | x_ammonia_d3 | State variable mass | Offshore sediment class 3 porewater ammonia | mMN |
| 31 | nitrate_so | State variable mass | Offshore upper layer nitrate | mMN |
| 32 | nitrate_d | State variable mass | Offshore lower layer nitrate | mMN |
| 33 | x_nitrate_s1 | State variable mass | Inshore sediment class 1 porewater nitrate | mMN |
| 34 | x_nitrate_s2 | State variable mass | Inshore sediment class 2 porewater nitrate | mMN |
| 35 | x_nitrate_s3 | State variable mass | Inshore sediment class 3 porewater nitrate | mMN |
| 36 | x_nitrate_d1 | State variable mass | Offshore sediment class 1 porewater nitrate | mMN |
| 37 | x_nitrate_d2 | State variable mass | Offshore sediment class 2 porewater nitrate | mMN |
| 38 | x_nitrate_d3 | State variable mass | Offshore sediment class 3 porewater nitrate | mMN |
| 39 | phyt_so | State variable mass | Offshore upper layer phytoplankton | mMN |
| 40 | phyt_d | State variable mass | Offshore lower layer phytoplankton | mMN |
| 41 | omni_o | State variable mass | Offshore omnivorous zooplankton | mMN |
| 42 | carn_o | State variable mass | Offshore carnivorous zooplankton | mMN |
| 43 | benthslar_o | State variable mass | Offshore larvae of susp/dep feeding benthos | mMN |
| 44 | benths_o | State variable mass | Offshore susp/dep feeding benthos | mMN |
| 45 | benthclar_o | State variable mass | Offshore larvae of carn/scav feeding benthos | mMN |

| | | | | |
|---|---|---|---|---|
| 46 | benthc_o | State variable mass | Offshore carn/scav feeding benthos | mMN |
| 47 | fishp_o | State variable mass | Offshore planktivorous fish | mMN |
| 48 | fishplar_o | State variable mass | Offshore larvae of planktivorous fish | mMN |
| 49 | fishd_o | State variable mass | Offshore demersal fish | mMN |
| 50 | fishdlar_o | State variable mass | Offshore larvae of demersal fish | mMN |
| 51 | fishm_o | State variable mass | Offshore migratory fish | mMN |
| 52 | bird_o | State variable mass | Offshore birds | mMN |
| 53 | detritus_si | State variable mass | Inshore suspended detritus and bacteria | mMN |
| 54 | ammonia_si | State variable mass | Inshore ammonia | mMN |
| 55 | nitrate_si | State variable mass | Inshore nitrate | mMN |
| 56 | phyt_si | State variable mass | Inshore phytoplankton | mMN |
| 57 | benthslar_i | State variable mass | Inshore larvae of susp/dep feeding benthos | mMN |
| 58 | benthclar_i | State variable mass | Inshore larvae of carn/scav feeding benthos | mMN |
| 59 | benths_i | State variable mass | Inshore susp/dep feeding benthos | mMN |
| 60 | benthc_i | State variable mass | Inshore carn/scav feeding benthos | mMN |
| 61 | discard_i | State variable mass | Inshore disarded material from fisheries | mMN |
| 62 | omni_i | State variable mass | Inshore omnivorous zooplankton | mMN |
| 63 | carn_i | State variable mass | Inshore carnivorous zooplankton | mMN |
| 64 | fishplar_i | State variable mass | Inshore larvae of planktivorous fish | mMN |
| 65 | fishdlar_i | State variable mass | Inshore larvae of demersal fish | mMN |
| 66 | fishp_i | State variable mass | Inshore planktivorous fish | mMN |
| 67 | fishm_i | State variable mass | Inshore migratory fish | mMN |
| 68 | fishd_i | State variable mass | Inshore demersal fish | mMN |
| 69 | bird_i | State variable mass | Inshore birds | mMN |
| 70 | seal_o | State variable mass | Offshore pinnipeds | mMN |
| 71 | seal_i | State variable mass | Inshore pinnipeds | mMN |
| 72 | ceta_o | State variable mass | Offshore cetaceans | mMN |
| 73 | ceta_i | State variable mass | Inshore cetaceans | mMN |
| 74 | corpse_s0 | State variable mass | Inshore rock seabed corpses | mMN |
| 75 | corpse_d0 | State variable mass | Offshore rock seabed corpses | mMN |

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| 76 | kelpC | State variable mass | Inshore macrophyte carbon | mMC |
| 77 | kelpN | State variable mass | Inshore macrphyte nitrogen | mMN |
| 78 | kelpdebris | State variable mass | Inshore macrophyte debris | mMN |
| 79 | netpprod_o | Cumulative flux | Offshore phytoplankton net production | mMN |
| 80 | netpprod_i | Cumulative flux | Inshore phytoplankton net production | mMN |
| 81 | PNP_o | Cumulative flux | Offshore net nitrate draw-down (PNP) | mMN |
| 82 | PNP_i | Cumulative flux | Inshore net nitrate draw-down (PNP) | mMN |
| 83 | phytgrossprod_o | Cumulative flux | Offshore phytoplankton gross production | mMN |
| 84 | phytgrossprod_i | Cumulative flux | Inshore phytoplankton gross production | mMN |
| 85 | kelpCprod_i | Cumulative flux | Inshore macrophyte carbon production | mMC |
| 86 | kelpCexud_i | Cumulative flux | Inshore macrophyte carbon exudation | mMC |
| 87 | kelpNprod_i | Cumulative flux | Inshore macrophyte nitrogen production | mMN |
| 88 | omnigrossprod_o | Cumulative flux | Offshore omnivorous zooplankton gross production | mMN |
| 89 | omnigrossprod_i | Cumulative flux | Inshore omnivorous zooplankton gross production | mMN |
| 90 | carngrossprod_o | Cumulative flux | Offshore carnivorous zooplankton gross production | mMN |
| 91 | carngrossprod_i | Cumulative flux | Inshore carnivorous zooplankton gross production | mMN |
| 92 | pfishlargrossprod_o | Cumulative flux | Offshore larvae of planktivorous fish gross production | mMN |
| 93 | pfishlargrossprod_i | Cumulative flux | Inshore larvae of planktivorous fish gross production | mMN |
| 94 | dfishlargrossprod_o | Cumulative flux | Offshore larvae of demersal fish gross production | mMN |
| 95 | dfishlargrossprod_i | Cumulative flux | Inshore larvae of demersal fish gross production | mMN |
| 96 | pfishgrossprod_o | Cumulative flux | Offshore planktivorous fish gross production | mMN |
| 97 | pfishgrossprod_i | Cumulative flux | Inshore planktivorous fish gross production | mMN |
| 98 | mfishgrossprod_o | Cumulative flux | Offshore migratory fish gross production | mMN |
| 99 | mfishgrossprod_i | Cumulative flux | Inshore migratory fish gross production | mMN |
| 100 | dfishgrossprod_o | Cumulative flux | Offshore demersal fish gross production | mMN |
| 101 | dfishgrossprod_i | Cumulative flux | Inshore demersal fish gross production | mMN |
| 102 | benthslargrossprod_o | Cumulative flux | Offshore larvae of susp/dep feeding benthos gross production | mMN |
| 103 | benthslargrossprod_i | Cumulative flux | Inshore larvae of susp/dep feeding benthos gross production | mMN |
| 104 | benthclargrossprod_o | Cumulative flux | Offshore larvae of carn/scav feeding benthos gross production | mMN |
| 105 | benthclargrossprod_i | Cumulative flux | Inshore larvae of carn/scav feeding benthos gross production | mMN |

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| 106 | benthsgrossprod_o | Cumulative flux | Offshore susp/dep feeding benthos gross production | mMN |
| 107 | benthsgrossprod_i | Cumulative flux | Inshore susp/dep feeding benthos gross production | mMN |
| 108 | benthcgrossprod_o | Cumulative flux | Offshore fsuspdep feeding benthos gross production | mMN |
| 109 | benthcgrossprod_i | Cumulative flux | Inshore susp/dep feeding benthos gross production | mMN |
| 110 | birdgrossprod_o | Cumulative flux | Offshore birds gross production | mMN |
| 111 | birdgrossprod_i | Cumulative flux | Inshore birds gross production | mMN |
| 112 | sealgrossprod_o | Cumulative flux | Offshore pinnipeds gross production | mMN |
| 113 | sealgrossprod_i | Cumulative flux | Inshore pinnipeds gross production | mMN |
| 114 | cetagrossprod_o | Cumulative flux | Offshore cetaceans gross production | mMN |
| 115 | cetagrossprod_i | Cumulative flux | Inshore cetaceans gross production | mMN |
| 116 | wcdenitrif_o | Cumulative flux | Offshore water column denitrification | mMN |
| 117 | wcdenitrif_i | Cumulative flux | Inshore water column denitrification | mMN |
| 118 | seddenitrif_o | Cumulative flux | Offshore sediment denitrification | mMN |
| 119 | seddenitrif_i | Cumulative flux | Inshore sediment denitrification | mMN |
| 120 | fluxsedamm_wcamm | Whole domain cumulative flux | Sediment to water column ammonia | mMN |
| 121 | fluxwcdet_wcamm | Whole domain cumulative flux | Suspended detritus to water column ammonia | mMN |
| 122 | fluxomni_wcamm | Whole domain cumulative flux | Omnivorous zooplankton ammonia excretion | mMN |
| 123 | fluxcarn_wcamm | Whole domain cumulative flux | Carnivorous zooplankton ammonia excretion | mMN |
| 124 | fluxpfishlar_wcamm | Whole domain cumulative flux | Larvae of planktivorous fish ammonia excretion | mMN |
| 125 | fluxdfishlar_wcamm | Whole domain cumulative flux | Larvae of demersal fish ammonia excretion | mMN |
| 126 | fluxpfish_wcamm | Whole domain cumulative flux | Planktivorous fish ammonia excretion | mMN |
| 127 | fluxmfish_wcamm | Whole domain cumulative flux | Migratory fish ammonia excretion | mMN |
| 128 | fluxdfish_wcamm | Whole domain cumulative flux | Demersal fish ammonia excretion | mMN |
| 129 | fluxbenthslar_wcamm | Whole domain cumulative flux | Larvae of susp/dep feeding benthos ammonia excretion | mMN |
| 130 | fluxbenthclar_wcamm | Whole domain cumulative flux | Larvae of carn/scav feeding benthos ammonia excretion | mMN |
| 131 | fluxbenths_wcamm | Whole domain cumulative flux | Susp/dep feeding benthos ammonia excretion | mMN |
| 132 | fluxbenthc_wcamm | Whole domain cumulative flux | Carn/scav feeding benthos ammonia excretion | mMN |
| 133 | fluxbird_wcamm | Whole domain cumulative flux | Birds ammonia excretion | mMN |
| 134 | fluxseal_wcamm | Whole domain cumulative flux | Pinnipeds ammonia excretion | mMN |
| 135 | fluxceta_wcamm | Whole domain cumulative flux | Cetaceans ammonia excretion | mMN |

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| 136 | fluxxdet_sedamm | Whole domain cumulative flux | Sediment labile detritus to porewater ammonia | mMN |
| 137 | fluxxRdet_sedamm | Whole domain cumulative flux | Sediment refractory detritus to porewater ammonia | mMN |
| 138 | fluxwcamm_wcnit | Whole domain cumulative flux | Water column ammonia to water column nitrate | mMN |
| 139 | fluxsednit_wcnit | Whole domain cumulative flux | Sediment porewater nitrate to water column nitrate | mMN |
| 140 | fluxsedamm_sednit | Whole domain cumulative flux | Sediment porewater ammonia to porewater nitrate | mMN |
| 141 | fluxxdet_wcdet | Whole domain cumulative flux | Sediment labile detritus to water column detritus | mMN |
| 142 | fluxkelpdebris_wcdet | Whole domain cumulative flux | Macrophyte debris to water column detritus | mMN |
| 143 | fluxcorp_wcdet | Whole domain cumulative flux | Seabed corpses to water column detritus | mMN |
| 144 | fluxphyt_wcdet | Whole domain cumulative flux | Phytoplankton to water column detritus | mMN |
| 145 | fluxomni_wcdet | Whole domain cumulative flux | Omnivorous zooplankton to water column detritus | mMN |
| 146 | fluxcarn_wcdet | Whole domain cumulative flux | Carnivorous zooplankton to water column detritus | mMN |
| 147 | fluxpfishlar_wcdet | Whole domain cumulative flux | Larvae of planktivorous fish to water column detritus | mMN |
| 148 | fluxdfishlar_wcdet | Whole domain cumulative flux | Larvae of demersal fish to water column detritus | mMN |
| 149 | fluxpfish_wcdet | Whole domain cumulative flux | Planktivorous fish to water column detritus | mMN |
| 150 | fluxmfish_wcdet | Whole domain cumulative flux | Migratory fish to water column detritus | mMN |
| 151 | fluxdfish_wcdet | Whole domain cumulative flux | Demersal fish to water column detritus | mMN |
| 152 | fluxbenthslar_wcdet | Whole domain cumulative flux | Larvae of susp/dep feeding benthos to water column detritus | mMN |
| 153 | fluxbenthclar_wcdet | Whole domain cumulative flux | Larvae of carn/scav feeding benthos to water column detritus | mMN |
| 154 | fluxbenths_wcdet | Whole domain cumulative flux | Susp/dep feeding benthos to water column detritus | mMN |
| 155 | fluxbenthc_wcdet | Whole domain cumulative flux | Carn/scav feeding benthos to water column detritus | mMN |
| 156 | fluxbird_wcdet | Whole domain cumulative flux | Birds to water column detritus | mMN |
| 157 | fluxseal_wcdet | Whole domain cumulative flux | Pinnipeds to water column detritus | mMN |
| 158 | fluxceta_wcdet | Whole domain cumulative flux | Cetaceans to water column detritus | mMN |
| 159 | fluxwcdet_xdet | Whole domain cumulative flux | Water column detritus to sediment labile detritus | mMN |
| 160 | fluxcorp_xdet | Whole domain cumulative flux | Corpses to sediment labile detritus | mMN |
| 161 | fluxbenths_xdet | Whole domain cumulative flux | Sups/dep feeding benthos to sediment labile detritus | mMN |
| 162 | fluxbenthc_xdet | Whole domain cumulative flux | Carn/scav feeding benthos to sediment labile detritus | mMN |
| 163 | fluxxdet_xRdet | Whole domain cumulative flux | Sediment labile detritus to refractory detritus | mMN |
| 164 | fluxkelpdebris_xRdet | Whole domain cumulative flux | Macrophyte debris to refractory detritus | mMN |
| 165 | fluxcorp_xRdet | Whole domain cumulative flux | Corpses to refractory detritus | mMN |

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| 166 | fluxkelp_kelpdebris | Whole domain cumulative flux | Macrophytes to macrophyte debris | mMN |
| 167 | fluxdisc_corp | Whole domain cumulative flux | Fishery discarded material to seabed corpse | mMN |
| 168 | fluxpfish_corp | Whole domain cumulative flux | Planktivorous fish to seabed corpse | mMN |
| 169 | fluxmfish_corp | Whole domain cumulative flux | Migratory fish to seabed corpse | mMN |
| 170 | fluxdfish_corp | Whole domain cumulative flux | Demersal fish to seabed corpse | mMN |
| 171 | fluxbenths_corp | Whole domain cumulative flux | Susp/dep feeding benthos to seabed corpse | mMN |
| 172 | fluxbenthc_corp | Whole domain cumulative flux | Carn/scav feeding benthos to seabed corpse | mMN |
| 173 | fluxbird_corp | Whole domain cumulative flux | Birds to seabed corpse | mMN |
| 174 | fluxseal_corp | Whole domain cumulative flux | Pinnipeds to seabed corpse | mMN |
| 175 | fluxceta_corp | Whole domain cumulative flux | Cetaceans to seabed corpses | mMN |
| 176 | fluxwcamm_kelp | Whole domain cumulative flux | Uptake of water column ammonia by macrophytes | mMN |
| 177 | fluxwcnit_kelp | Whole domain cumulative flux | Uptake of water column nitrate by macrophytes | mMN |
| 178 | fluxwcamm_phyt_o | Cumulative flux | Offshore uptake of water column ammonia by phytoplankton | mMN |
| 179 | fluxwcamm_phyt_i | Cumulative flux | Inshore uptake of water column ammonia by phytoplankton | mMN |
| 180 | fluxwcnit_phyt_o | Cumulative flux | Offshore uptake of water column nitrate by phytoplankton | mMN |
| 181 | fluxwcnit_phyt_i | Cumulative flux | Inshore uptake of water column nitrate by phytoplankton | mMN |
| 182 | fluxwcdet_omni | Whole domain cumulative flux | Consumption of suspended detritus by omnivorous zooplankton | mMN |
| 183 | fluxphyt_omni | Whole domain cumulative flux | Consumption of phytoplankton by omnivorous zooplankton | mMN |
| 184 | fluxbenthslar_omni | Whole domain cumulative flux | Consumption of larvae of susp/dep benthos by omnivorous zooplankton | mMN |
| 185 | fluxbenthclar_omni | Whole domain cumulative flux | Consumption of larvae of carn/scav benthos by omnivorous zooplankton | mMN |
| 186 | fluxomni_carn | Whole domain cumulative flux | Consumption of omnivorous zooplankton by carnivorous zooplankton | mMN |
| 187 | fluxpfishlar_carn | Whole domain cumulative flux | Consumption of larvae of planktivorous fish by carnivorous zooplankton | mMN |
| 188 | fluxdfishlar_carn | Whole domain cumulative flux | Consumption of larvae of demersal fish by carnivorous zooplankton | mMN |
| 189 | fluxbenthslar_carn | Whole domain cumulative flux | Consumption of larvae of susp/dep benthos by carnivorous zooplankton | mMN |
| 190 | fluxbenthclar_carn | Whole domain cumulative flux | Consumption of larvae of carn/scav benthos by carnivorous zooplankton | mMN |
| 191 | fluxomni_pfishlar | Whole domain cumulative flux | Consumption of omnivorous zooplankton by larvae of planktivorous fish | mMN |
| 192 | fluxbenthslar_pfishlar | Whole domain cumulative flux | Consumption of larvae of susp/dep feeding benthos by larvae of planktivorous fish | mMN |
| 193 | fluxbenthclar_pfishlar | Whole domain cumulative flux | Consumption of larvae of carn/scav feeding benthos by larvae of planktivorous fish | mMN |
| 194 | fluxomni_dfishlar | Whole domain cumulative flux | Consumption of omnivorous zooplankton by larvae of demersal fish | mMN |
| 195 | fluxbenthslar_dfishlar | Whole domain cumulative flux | Consumption of larvae of susp/dep feeding benthos by larvae of demersal fish | mMN |

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| 196 | fluxbenthclar_dfishlar | Whole domain cumulative flux | Consumption of larvae of carn/scav feeding benthos by larvae of demersal fish | mMN |
| 197 | fluxomni_pfish | Whole domain cumulative flux | Consumption of omnivorous zooplankton by planktivorous fish | mMN |
| 198 | fluxcarn_pfish | Whole domain cumulative flux | Consumption of carnivorous zooplankton by planktivorous fish | mMN |
| 199 | fluxpfishlar_pfish | Whole domain cumulative flux | Consumption of larvae of planktivorous fish by planktivorous fish | mMN |
| 200 | fluxdfishlar_pfish | Whole domain cumulative flux | Consumption of larvae of demersal fish by planktivorous fish | mMN |
| 201 | fluxbenthslar_pfish | Whole domain cumulative flux | Consumption of larvae of susp/dep feeding benthos by planktivorous fish | mMN |
| 202 | fluxbenthclar_pfish | Whole domain cumulative flux | Consumption of larvae of carn/scav feeding benthos by planktivorous fish | mMN |
| 203 | fluxomni_mfish | Whole domain cumulative flux | Consumption of omnivorous zooplankton by migratory fish | mMN |
| 204 | fluxcarn_mfish | Whole domain cumulative flux | Consumption of carnivorous zooplankton by migratory fish | mMN |
| 205 | fluxpfishlar_mfish | Whole domain cumulative flux | Consumption of larvae of planktivorous fish by migratory fish | mMN |
| 206 | fluxdfishlar_mfish | Whole domain cumulative flux | Consumption of larvae of demersal fish by migratory fish | mMN |
| 207 | fluxbenthslar_mfish | Whole domain cumulative flux | Consumption of larvae of susp/dep feeding benthos by migratory fish | mMN |
| 208 | fluxbenthclar_mfish | Whole domain cumulative flux | Consumption of larvae of carn/scav feeding benthos by migratory fish | mMN |
| 209 | fluxcorp_dfish | Whole domain cumulative flux | Consumption of seabed corpses by demersal fish | mMN |
| 210 | fluxdisc_dfish | Whole domain cumulative flux | Consumption of fishery discards by demersal fish | mMN |
| 211 | fluxcarn_dfish | Whole domain cumulative flux | Consumption of carnivorous zooplankton by demersal fish | mMN |
| 212 | fluxpfishlar_dfish | Whole domain cumulative flux | Consumption of larvae of planktivorous fish by demersal fish | mMN |
| 213 | fluxdfishlar_dfish | Whole domain cumulative flux | Consumption of larvae of demersal fish by demersal fish | mMN |
| 214 | fluxpfish_dfish | Whole domain cumulative flux | Consumption of planktivorous fish by demersal fish | mMN |
| 215 | fluxmfish_dfish | Whole domain cumulative flux | Consumption of migratory fish by demersal fish | mMN |
| 216 | fluxdfish_dfish | Whole domain cumulative flux | Consumption of demersal fish by demersal fish | mMN |
| 217 | fluxbenths_dfish | Whole domain cumulative flux | Consumption of susp/dep feeding benthos by demersal fish | mMN |
| 218 | fluxbenthc_dfish | Whole domain cumulative flux | Consumption of carn/scav feeding benthos by demersal fish | mMN |
| 219 | fluxwcdet_benthslar | Whole domain cumulative flux | Consumption of water column detritus by larvae of susp/dep feeding benthos | mMN |
| 220 | fluxphyt_benthslar | Whole domain cumulative flux | Consumption of phytoplankton by larvae of susp/dep feeding benthos | mMN |
| 221 | fluxwcdet_benthclar | Whole domain cumulative flux | Consumption of water column detritus by larvae of carn/scav feeding benthos | mMN |
| 222 | fluxphyt_benthclar | Whole domain cumulative flux | Consumption of phytoplankton by larvae of carn/scav feeding benthos | mMN |
| 223 | fluxwcdet_benths | Whole domain cumulative flux | Consumption of water column detritus by susp/dep feeding benthos | mMN |
| 224 | fluxxdet_benths | Whole domain cumulative flux | Consumption of sediment labile detritus by susp/dep feeding benthos | mMN |
| 225 | fluxxRdet_benths | Whole domain cumulative flux | Consumption of sediment refractory detritus by susp/dep feeding benthos | mMN |

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| 226 | fluxphyt_benths | Whole domain cumulative flux | Consumption of phytoplankton by susp/dep feeding benthos | mMN |
| 227 | fluxkelp_benthc | Whole domain cumulative flux | Consumption of macrophytes by carn/scav feeding benthos | mMN |
| 228 | fluxkelpdebris_benthc | Whole domain cumulative flux | Consumption of macrophyte debris by carn/scav feeding benthos | mMN |
| 229 | fluxcorp_benthc | Whole domain cumulative flux | Consumption of seabed corpses by carn/scav feeding benthos | mMN |
| 230 | fluxbenths_benthc | Whole domain cumulative flux | Consumption of susp/dep feeding benthos by carn/scav feeding benthos | mMN |
| 231 | fluxcorp_bird | Whole domain cumulative flux | Consumption of seabed corpses by birds | mMN |
| 232 | fluxdisc_bird | Whole domain cumulative flux | Consumption of fishery discards by birds | mMN |
| 233 | fluxcarn_bird | Whole domain cumulative flux | Consumption of carnivorous zooplankton by birds | mMN |
| 234 | fluxpfish_bird | Whole domain cumulative flux | Consumption of planktivorous fish by birds | mMN |
| 235 | fluxmfish_bird | Whole domain cumulative flux | Consumption of migratory fish by birds | mMN |
| 236 | fluxdfish_bird | Whole domain cumulative flux | Consumption of demersal fish by birds | mMN |
| 237 | fluxbenths_bird | Whole domain cumulative flux | Consumption of susp/dep feeding benthos by birds | mMN |
| 238 | fluxbenthc_bird | Whole domain cumulative flux | Consumption of carn/scav feeding benthos by birds | mMN |
| 239 | fluxcorp_seal | Whole domain cumulative flux | Consumption of seabed corpses by pinnipeds | mMN |
| 240 | fluxdisc_seal | Whole domain cumulative flux | Consumption of fishery discards by pinnipeds | mMN |
| 241 | fluxcarn_seal | Whole domain cumulative flux | Consumption of carnivorous zooplankton by pinnipeds | mMN |
| 242 | fluxpfish_seal | Whole domain cumulative flux | Consumption of planktivorous fish by pinnipeds | mMN |
| 243 | fluxmfish_seal | Whole domain cumulative flux | Consumption of migratory fish by pinnipeds | mMN |
| 244 | fluxdfish_seal | Whole domain cumulative flux | Consumption of demersal fish by pinnipeds | mMN |
| 245 | fluxbenths_seal | Whole domain cumulative flux | Consumption of susp/dep feeding benthos by pinnipeds | mMN |
| 246 | fluxbenthc_seal | Whole domain cumulative flux | Consumption of carn/scav feeding benthos by pinnipeds | mMN |
| 247 | fluxbird_seal | Whole domain cumulative flux | Consumption of birds by pinnipeds | mMN |
| 248 | fluxdisc_ceta | Whole domain cumulative flux | Consumption of fishery discards by cetaceans | mMN |
| 249 | fluxomni_ceta | Whole domain cumulative flux | Consumption of omnnivorous zooplankton by cetaceans | mMN |
| 250 | fluxcarn_ceta | Whole domain cumulative flux | Consumption of carnnivorous zooplankton by cetaceans | mMN |
| 251 | fluxpfish_ceta | Whole domain cumulative flux | Consumption of planktivorous fish by cetaceans | mMN |
| 252 | fluxmfish_ceta | Whole domain cumulative flux | Consumption of migratory fish by cetaceans | mMN |
| 253 | fluxdfish_ceta | Whole domain cumulative flux | Consumption of demersal fish by cetaceans | mMN |
| 254 | fluxbenths_ceta | Whole domain cumulative flux | Consumption of susp/dep feeding benthos by cetaceans | mMN |
| 255 | fluxbenthc_ceta | Whole domain cumulative flux | Consumption of carn/scav feeding benthos by cetaceans | mMN |

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| 256 | fluxbird_ceta | Whole domain cumulative flux | Consumption of birds by cetaceans | mMN |
| 257 | fluxseal_ceta | Whole domain cumulative flux | Consumption of pinnipeds by cetaceans | mMN |
| 258 | Bs_spawn | Whole domain cumulative flux | Egg production by susp/dep feeding benthos | mMN |
| 259 | Bs_recruit | Whole domain cumulative flux | Recruitment of susp/dep feeding benthos | mMN |
| 260 | Bc_spawn | Whole domain cumulative flux | Egg production by carn/scav feeding benthos | mMN |
| 261 | Bc_recruit | Whole domain cumulative flux | Recruitment of carn/scav feeding benthos | mMN |
| 262 | Pfish_spawn | Whole domain cumulative flux | Egg production by planktivorous fish | mMN |
| 263 | Pfish_recruit | Whole domain cumulative flux | Recruitment of planktivorous fish | mMN |
| 264 | Dfish_spawn | Whole domain cumulative flux | Egg production by demersal fish | mMN |
| 265 | Dfish_recruit | Whole domain cumulative flux | Recruitment of demersal fish | mMN |
| 266 | fluxwcnit_Ngas | Whole domain cumulative flux | Water column nitrate to nitrogen gas | mMN |
| 267 | fluxsednit_Ngas | Whole domain cumulative flux | Sediment porewater nitrate to nitrogen gas | mMN |
| 268 | fluxkelpdebris_beachexport | Whole domain cumulative flux | Beach-cast of macrophyte debris | mMN |
| 269 | fluxAMMoutflow_o | Cumulative flux | Offshore boundary export of water column ammonia | mMN |
| 270 | fluxNITоutflow_o | Cumulative flux | Offshore boundary export of water column nitrate | mMN |
| 271 | fluxAMMoutflow_i | Cumulative flux | Inshore boundary export of water column ammonia | mMN |
| 272 | fluxNITоutflow_i | Cumulative flux | Inshore boundary export of water column nitrate | mMN |
| 273 | fluxPHYToutflow_o | Cumulative flux | Offshore boundary export of phytoplankton | mMN |
| 274 | fluxDEToutflow_o | Cumulative flux | Offshore boundary export of water column detritus | mMN |
| 275 | fluxPHYToutflow_i | Cumulative flux | Inshore boundary export of phytoplankton | mMN |
| 276 | fluxDEToutflow_i | Cumulative flux | Inshore boundary export of water column detritus | mMN |
| 277 | mfish_emigration | Cumulative flux | Offshore migratory fish emigration from the domain | mMN |
| 278 | fluxsedboundary_o | Cumulative flux | Offshore net burial in seabed sediments | mMN |
| 279 | fluxsedboundary_i | Cumulative flux | Inshore net burial in seabed sediments | mMN |
| 280 | fluxAMMinflow_o | Cumulative flux | Offshore boundary import of water column ammonia | mMN |
| 281 | fluxNITinflow_o | Cumulative flux | Offshore boundary import of water column nitrate | mMN |
| 282 | fluxAMMinflow_i | Cumulative flux | Inshore boundary import of water column ammonia | mMN |
| 283 | fluxNITinflow_i | Cumulative flux | Inshore boundary import of water column nitrate | mMN |
| 284 | fluxPHYTinflow_o | Cumulative flux | Offshore boundary import of phytoplankton | mMN |
| 285 | fluxDETinflow_o | Cumulative flux | Offshore boundary import of water column detritus | mMN |

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| 286 | fluxPHYTinflow_i | Cumulative flux | Inshore boundary import of phytoplankton | mMN |
| 287 | fluxDETinflow_i | Cumulative flux | Inshore boundary import of water column detritus | mMN |
| 288 | mfish_imigration | Cumulative flux | Offshore migratory fish immigration to the domain | mMN |
| 289 | atmosAMMinput_o | Cumulative flux | Offshore atmospheric deposition of ammonia | mMN |
| 290 | atmosNITinput_o | Cumulative flux | Offshore atmospheric deposition of nitrate | mMN |
| 291 | atmosAMMinput_i | Cumulative flux | Inshore atmospheric deposition of ammonia | mMN |
| 292 | atmosNITinput_i | Cumulative flux | Inshore atmospheric deposition of nitrate | mMN |
| 293 | rivAMMinflow | Cumulative flux | Inshore river inflow of ammonia | mMN |
| 294 | rivNITinflow | Cumulative flux | Inshore river inflow of nitrate | mMN |
| 295 | rivPARTinflow | Cumulative flux | Inshore river inflow of detritus | mMN |
| 296 | DINflux_i_o | Cumulative flux | Inshore to offshore flux of total dissolved inorganic nitrogen | mMN |
| 297 | DINflux_o_i | Cumulative flux | Offshore to inshore flux of total dissolved inorganic nitrogen | mMN |
| 298 | PARTflux_i_o | Cumulative flux | Inshore to offshore passive flux of total particulate nitrogen | mMN |
| 299 | PARTflux_o_i | Cumulative flux | Offshore to inshore passive flux of total particulate nitrogen | mMN |
| 300 | activemigpelfish_i_o | Cumulative flux | Inshore to offshore active migration of planktivoroius fish | mMN |
| 301 | activemigmigfish_i_o | Cumulative flux | Inshore to offshore active migration of migratory fish | mMN |
| 302 | activemigdemfish_i_o | Cumulative flux | Inshore to offshore active migration of demersal fish | mMN |
| 303 | activemigbird_i_o | Cumulative flux | Inshore to offshore active migration of birds | mMN |
| 304 | activemigseal_i_o | Cumulative flux | Inshore to offshore active migration of pinnipeds | mMN |
| 305 | activemigceta_i_o | Cumulative flux | Inshore to offshore active migration of cetaceans | mMN |
| 306 | activemigpelfish_o_i | Cumulative flux | Offshore to inshore active migration of planktivoroius fish | mMN |
| 307 | activemigmigfish_o_i | Cumulative flux | Offshore to inshore active migration of migratory fish | mMN |
| 308 | activemigdemfish_o_i | Cumulative flux | Offshore to inshore active migration of demersal fish | mMN |
| 309 | activemigbird_o_i | Cumulative flux | Offshore to inshore active migration of birds | mMN |
| 310 | activemigseal_o_i | Cumulative flux | Offshore to inshore active migration of pinnipeds | mMN |
| 311 | activemigceta_o_i | Cumulative flux | Offshore to inshore active migration of cetaceans | mMN |
| 312 | vertnitflux | Whole domain cumulative flux | Vertical mixing and advection of nitrate | mMN |
| 313 | horiznitflux | Whole domain cumulative flux | Upper layers horizontal mixing and advection of nitrate | mMN |
| 314 | landp_o | Cumulative flux | Offshore landings of planktivorous fish (live weight) | mMN |
| 315 | landd_quota_o | Cumulative flux | Offshore landings of quota-limited demersal fish (live weight) | mMN |

| | | | | |
|---|---|---|---|---|
| 316 | landd_nonquota_o | Cumulative flux | Offshore landings of non-quota demersal fish (live weight) | mMN |
| 317 | landm_o | Cumulative flux | Offshore landings of migratory fish (live weight) | mMN |
| 318 | landsb_o | Cumulative flux | Offshore landings of susp/dep feeding benthos (live weight) | mMN |
| 319 | landcb_o | Cumulative flux | Offshore landings of carn/scav feeding benthos (live weight) | mMN |
| 320 | landcz_o | Cumulative flux | Offshore landings of carnivorous zooplankton (live weight) | mMN |
| 321 | landbd_o | Cumulative flux | Offshore landings of birds (live weight) | mMN |
| 322 | landsl_o | Cumulative flux | Offshore landings of pinnipeds (live weight) | mMN |
| 323 | landct_o | Cumulative flux | Offshore landings of cetaceans (live weight) | mMN |
| 324 | discpel_o | Cumulative flux | Offshore discards of planktivorous fish (live weight) | mMN |
| 325 | discdem_quota_o | Cumulative flux | Offshore discards of quota-limited demersal fish (live weight) | mMN |
| 326 | discdem_nonquota_o | Cumulative flux | Offshore discards of non-quota demersal fish (live weight) | mMN |
| 327 | discmig_o | Cumulative flux | Offshore discards of migratory fish (live weight) | mMN |
| 328 | discsb_o | Cumulative flux | Offshore discards of susp/dep feeding benthos (live weight) | mMN |
| 329 | disccb_o | Cumulative flux | Offshore discards of carn/scav feeding benthos (live weight) | mMN |
| 330 | disccz_o | Cumulative flux | Offshore discards of carnivorous zooplankton (live weight) | mMN |
| 331 | discbd_o | Cumulative flux | Offshore discards of birds (live weight) | mMN |
| 332 | discsl_o | Cumulative flux | Offshore discards of pinnipeds (live weight) | mMN |
| 333 | discct_o | Cumulative flux | Offshore discards of cetaceans (live weight) | mMN |
| 334 | landp_i | Cumulative flux | Inshore landings of planktivorous fish (live weight) | mMN |
| 335 | landd_quota_i | Cumulative flux | Inshore landings of quota-limited demersal fish (live weight) | mMN |
| 336 | landd_nonquota_i | Cumulative flux | Inshore landings of non-quota demersal fish (live weight) | mMN |
| 337 | landm_i | Cumulative flux | Inshore landings of migratory fish (live weight) | mMN |
| 338 | landsb_i | Cumulative flux | Inshore landings of susp/dep feeding benthos (live weight) | mMN |
| 339 | landcb_i | Cumulative flux | Inshore landings of carn/scav feeding benthos (live weight) | mMN |
| 340 | landcz_i | Cumulative flux | Inshore landings of carnivorous zooplankton (live weight) | mMN |
| 341 | landbd_i | Cumulative flux | Inshore landings of birds (live weight) | mMN |
| 342 | landsl_i | Cumulative flux | Inshore landings of pinnipeds (live weight) | mMN |
| 343 | landct_i | Cumulative flux | Inshore landings of cetaceans (live weight) | mMN |
| 344 | landkp_i | Cumulative flux | Inshore landings of macrophytes (live weight) | mMN |
| 345 | discpel_i | Cumulative flux | Inshore discards of planktivorous fish (live weight) | mMN |

| | | | | |
|---|---|---|---|---|
| 346 | discdem_quota_i | Cumulative flux | Inshore discards of quota-limited demersal fish (live weight) | mMN |
| 347 | discdem_nonquota_i | Cumulative flux | Inshore discards of non-quota demersal fish (live weight) | mMN |
| 348 | discmig_i | Cumulative flux | Inshore discards of migratory fish (live weight) | mMN |
| 349 | discsb_i | Cumulative flux | Inshore discards of susp/dep feeding benthos (live weight) | mMN |
| 350 | disccb_i | Cumulative flux | Inshore discards of carn/scav feeding benthos (live weight) | mMN |
| 351 | disccz_i | Cumulative flux | Inshore discards of carnivorous zooplankton (live weight) | mMN |
| 352 | discbd_i | Cumulative flux | Inshore discards of birds (live weight) | mMN |
| 353 | discsl_i | Cumulative flux | Inshore discards of pinnipeds (live weight) | mMN |
| 354 | discct_i | Cumulative flux | Inshore discards of cetaceans (live weight) | mMN |
| 355 | disckp_i | Cumulative flux | Inshore discards of macrophytes (live weight) | mMN |
| 356 | offalpel_o | Cumulative flux | Offshore offal from processing of planktivorous fish catch | mMN |
| 357 | offaldem_quota_o | Cumulative flux | Offshore offal from processing of quota-limited demersal fish catch | mMN |
| 358 | offaldem_nonquota_o | Cumulative flux | Offshore offal from processing of non-quota demersal fish catch | mMN |
| 359 | offalmig_o | Cumulative flux | Offshore offal from processing of migratory fish catch | mMN |
| 360 | offalsb_o | Cumulative flux | Offshore offal from processing of fsusp/dep feeding benthos catch | mMN |
| 361 | offalcb_o | Cumulative flux | Offshore offal from processing of carn/scav feeding benthos catch | mMN |
| 362 | offalcz_o | Cumulative flux | Offshore offal from processing of carnivorous zooplankton catch | mMN |
| 363 | offalbd_o | Cumulative flux | Offshore offal from processing of bird catch | mMN |
| 364 | offalsl_o | Cumulative flux | Offshore offal from processing of pinniped catch | mMN |
| 365 | offalct_o | Cumulative flux | Offshore offal from processing of cetacean catch | mMN |
| 366 | offalpel_i | Cumulative flux | Inshore offal from processing of planktivorous fish catch | mMN |
| 367 | offaldem_quota_i | Cumulative flux | Inshore offal from processing of quota-limited demersal fish catch | mMN |
| 368 | offaldem_nonquota_i | Cumulative flux | Inshore offal from processing of non-quota demersal fish catch | mMN |
| 369 | offalmig_i | Cumulative flux | Inshore offal from processing of migratory fish catch | mMN |
| 370 | offalsb_i | Cumulative flux | Inshore offal from processing of susp/dep feeding benthos catch | mMN |
| 371 | offalcb_i | Cumulative flux | Inshore offal from processing of carn/scav feeding benthos catch | mMN |
| 372 | offalcz_i | Cumulative flux | Inshore offal from processing of carnivorous zooplankton catch | mMN |
| 373 | offalbd_i | Cumulative flux | Inshore offal from processing of bird catch | mMN |
| 374 | offalsl_i | Cumulative flux | Inshore offal from processing of pinniped catch | mMN |
| 375 | offalct_i | Cumulative flux | Inshore offal from processing of cetacean catch | mMN |

| | | | | |
|---|---|---|---|---|
| 376 | offalkp_i | Cumulative flux | Inshore offal from processing of macrophyte catch | mMN |
| 377 | omninetprod_o | Cumulative flux | Offshore omnivorous zooplanton net production | mMN |
| 378 | omninetprod_i | Cumulative flux | Inshore omnivorous zooplanton net production | mMN |
| 379 | carnnetprod_o | Cumulative flux | Offshore carnivorous zooplanton net production | mMN |
| 380 | carnnetprod_i | Cumulative flux | Inshore carnivorous zooplanton net production | mMN |
| 381 | pfishlarnetprod_o | Cumulative flux | Offshore larvae of planktivorous fish net production | mMN |
| 382 | pfishlarnetprod_i | Cumulative flux | Inshore larvae of planktivorous fish net production | mMN |
| 383 | dfishlarnetprod_o | Cumulative flux | Offshore larvae of demersal fish net production | mMN |
| 384 | dfishlarnetprod_i | Cumulative flux | Inshore larvae of demersal fish net production | mMN |
| 385 | pfishnetprod_o | Cumulative flux | Offshore planktivorous fish net production | mMN |
| 386 | pfishnetprod_i | Cumulative flux | Inshore planktivorous fish net production | mMN |
| 387 | mfishnetprod_o | Cumulative flux | Offshore migratory fish net production | mMN |
| 388 | mfishnetprod_i | Cumulative flux | Inshore migratory fish net production | mMN |
| 389 | dfishnetprod_o | Cumulative flux | Offshore demersal fish net production | mMN |
| 390 | dfishnetprod_i | Cumulative flux | Inshore demersal fish net production | mMN |
| 391 | benthslarnetprod_o | Cumulative flux | Offshore larvae of susp/dep feeding benthos net production | mMN |
| 392 | benthslarnetprod_i | Cumulative flux | Inshore larvae of susp/dep feeding benthos net production | mMN |
| 393 | benthclarnetprod_o | Cumulative flux | Offshore larvae of carn/scav feeding benthos net production | mMN |
| 394 | benthclarnetprod_i | Cumulative flux | Inshore larvae of carn/scav feeding benthos net production | mMN |
| 395 | benthsnetprod_o | Cumulative flux | Offshore susp/dep feeding benthos net production | mMN |
| 396 | benthsnetprod_i | Cumulative flux | Inshore susp/dep feeding benthos net production | mMN |
| 397 | benthcnetprod_o | Cumulative flux | Offshore carn/scav feeding benthos net production | mMN |
| 398 | benthcnetprod_i | Cumulative flux | Inshore carn/scav feeding benthos net production | mMN |
| 399 | birdnetprod_o | Cumulative flux | Offshore birds net production | mMN |
| 400 | birdnetprod_i | Cumulative flux | Inshore birds net production | mMN |
| 401 | sealnetprod_o | Cumulative flux | Offshore pinnipeds net production | mMN |
| 402 | sealnetprod_i | Cumulative flux | Inshore pinnipeds net production | mMN |
| 403 | cetanetprod_o | Cumulative flux | Offshore cetaceans net production | mMN |
| 404 | cetanetprod_i | Cumulative flux | Inshore cetaceans net production | mMN |

**Table 40. Details of the data columns in the list object "$aggregates" generated by the model.** The list comprises 124 numeric vectors representing the sequential outputs at daily intervals. Hence the length of these vectors is exactly the same number of rows in the dataframe "$outputs". Objects 1:34 in the list are the masses of nitrogen or carbon associated with the state variables in the model aggregated to the whole model domain; objects 35 to 124 are cumulative fluxes accumulated over time between the given compartments aggregated to the whole model domain. The rate of flow over any given interval is given by the difference in cumulative flux between appropriate rows in the dataframe. The final 6 objects in the list are single numeric values (vectors length 1) of the volumetric data for the layers and zones aggregared over the whole model domain. The notional sea surface area of the whole model domain is $1m^2$; the configuration parameters defining vertical layer thicknesses and horizontal area-proportions in the inshore and offshore zone and in the seabed habitats are given in the "$build$model.parameters" object (see Table 38). The aggregates of these parameters are required to convert aggregated state variable mass and fluxes output from the model into area densities ($m^{-2}$) and concentrations ($m^{-3}$).

| Column number | Column name | Data type | Description | Units |
|---|---|---|---|---|
| 1 | totalN | Derived mass | Whole domain mass of all forms of organic and inorganic nitrogen | mMN |
| 2 | totalN_o | Derived mass | Offshore mass of all forms of organic and inorganic nitrogen | mMN |
| 3 | totalN_i | Derived mass | Inshore mass of all forms of organic and inorganic nitrogen | mMN |
| 4 | x_detritus | Derived mass | Whole domain sediment labile and refratory detritus | mMN |
| 5 | x_detritus_o | Derived mass | Offshore sediment labile and refractory detritus | mMN |
| 6 | x_detritus_i | Derived mass | Inshore sediment labile and refractory detritus | mMN |
| 7 | corpse | Derived mass | Whole domain seabed corpses | mMN |
| 8 | corpse_o | Derived mass | Offshore seabed corpses | mMN |
| 9 | corpse_i | Derived mass | Inshore seabed corpses | mMN |
| 10 | x_ammonia | Derived mass | Whole domain sediment porweater ammonia | mMN |
| 11 | x_ammonia_o | Derived mass | Offshore sediment porweater ammonia | mMN |
| 12 | x_ammonia_i | Derived mass | Inshore sediment porweater ammonia | mMN |
| 13 | x_nitrate | Derived mass | Whole domain sediment porweater nitrate | mMN |
| 14 | x_nitrate_o | Derived mass | Offshore sediment porweater nitrate | mMN |
| 15 | x_nitrate_i | Derived mass | Inshore sediment porweater nitrate | mMN |
| 16 | s_detritus | Derived mass | Whole domain upper layers water column detritus | mMN |
| 17 | s_ammonia | Derived mass | Whole domain upper layers water column ammonia | mMN |
| 18 | s_nitrate | Derived mass | Whole domain upper layers water column nitrate | mMN |
| 19 | s_phyt | Derived mass | Whole domain upper layers phytoplankton | mMN |

| | | | | |
|---|---|---|---|---|
| 20 | benthslar | Derived mass | Whole domain larvae of susp/dep feeding benthos | mMN |
| 21 | benthclar | Derived mass | Whole domain larvae of carn/scav feeding benthos | mMN |
| 22 | benths | Derived mass | Whole domain susp/dep feeding benthos | mMN |
| 23 | benthc | Derived mass | Whole domain carn/scav feeding benthos | mMN |
| 24 | discard | Derived mass | Whole domain discarded material from fisheries | mMN |
| 25 | omni | Derived mass | Whole domain omnivorous zooplankton | mMN |
| 26 | carn | Derived mass | Whole domain carnivorous zooplankton | mMN |
| 27 | fishp | Derived mass | Whole domain planktivorous fish | mMN |
| 28 | fishd | Derived mass | Whole domain demersal fish | mMN |
| 29 | fishm | Derived mass | Whole domain migratory fish | mMN |
| 30 | bird | Derived mass | Whole domain birds | mMN |
| 31 | seal | Derived mass | Whole domain pinnipeds | mMN |
| 32 | ceta | Derived mass | Whole domain cetaceans | mMN |
| 33 | fishplar | Derived mass | Whole domain larvae of planktivorous fish | mMN |
| 34 | fishdlar | Derived mass | Whole domain larvae of demersal fish | mMN |
| 35 | PNP | Derived cumulative flux | Whole domain nitrate draw-down (PNP) | mMN |
| 36 | netpprod | Derived cumulative flux | Whole domain phytoplankton net production | mMN |
| 37 | fluxwcamm_phyt | Derived cumulative flux | Whole domain uptake of ammonia by phytoplankton | mMN |
| 38 | fluxwcnit_phyt | Derived cumulative flux | Whole domain uptake of nitrate by phytoplankton | mMN |
| 39 | phytgrossprod | Derived cumulative flux | Whole domain phytoplankton gross production | mMN |
| 40 | omnigrossprod | Derived cumulative flux | Whole domain omnivorous zooplankton gross production | mMN |
| 41 | carngrossprod | Derived cumulative flux | Whole domain carnivorous zooplankton gross production | mMN |
| 42 | pfishlargrossprod | Derived cumulative flux | Whole domain larvae of planktivorous fish gross production | mMN |
| 43 | dfishlargrossprod | Derived cumulative flux | Whole domain larvae of demersal fish gross production | mMN |
| 44 | pfishgrossprod | Derived cumulative flux | Whole domain planktivorous fish gross production | mMN |
| 45 | mfishgrossprod | Derived cumulative flux | Whole domain migratory fish gross production | mMN |
| 46 | dfishgrossprod | Derived cumulative flux | Whole domain demersal fish gross production | mMN |
| 47 | benthslargrossprod | Derived cumulative flux | Whole domain larvae of susp/dep feeding benthos gross production | mMN |
| 48 | benthclargrossprod | Derived cumulative flux | Whole domain larvae of carn/scav feeding benthos gross production | mMN |
| 49 | benthsgrossprod | Derived cumulative flux | Whole domain susp/dep feeding benthos gross production | mMN |

| | | | | |
|---|---|---|---|---|
| 50 | benthcgrossprod | Derived cumulative flux | Whole domain carn/scav feeding benthos gross production | mMN |
| 51 | birdgrossprod | Derived cumulative flux | Whole domain birds gross production | mMN |
| 52 | sealgrossprod | Derived cumulative flux | Whole domain pinnipeds gross production | mMN |
| 53 | cetagrossprod | Derived cumulative flux | Whole domain cetaceans gross production | mMN |
| 54 | omninetprod | Derived cumulative flux | Whole domain omnivorous zooplankton net production | mMN |
| 55 | carnnetprod | Derived cumulative flux | Whole domain carnivorous zooplankton net production | mMN |
| 56 | pfishlarnetprod | Derived cumulative flux | Whole domain larvae of planktivorous fish net production | mMN |
| 57 | dfishlarnetprod | Derived cumulative flux | Whole domain larvae of demersal fish net production | mMN |
| 58 | pfishnetprod | Derived cumulative flux | Whole domain planktivorous fish net production | mMN |
| 59 | mfishnetprod | Derived cumulative flux | Whole domain migratory fish net production | mMN |
| 60 | dfishnetprod | Derived cumulative flux | Whole domain demersal fish net production | mMN |
| 61 | benthslarnetprod | Derived cumulative flux | Whole domain larvae of susp/dep feeding benthos net production | mMN |
| 62 | benthclarnetprod | Derived cumulative flux | Whole domain larvae of carn/scav feeding benthos net production | mMN |
| 63 | benthsnetprod | Derived cumulative flux | Whole domain susp/dep feeding benthos net production | mMN |
| 64 | benthcnetprod | Derived cumulative flux | Whole domain carn/scav feeding benthos net production | mMN |
| 65 | birdnetprod | Derived cumulative flux | Whole domain birds net production | mMN |
| 66 | sealnetprod | Derived cumulative flux | Whole domain pinnipeds net production | mMN |
| 67 | cetanetprod | Derived cumulative flux | Whole domain cetaceans net production | mMN |
| 68 | wcdenitrif | Derived cumulative flux | Whole domain water column denitrification | mMN |
| 69 | seddenitrif | Derived cumulative flux | Whole domain sediment denitrification | mMN |
| 70 | fluxsedboundary | Derived cumulative flux | Whole domain net burial in seabed sediments | mMN |
| 71 | DIN_NET_flux_o_i | Derived cumulative flux | Offshore to inshore net flux of dissolved inorganic nitrogen | mMN |
| 72 | PART_NET_flux_o_i | Derived cumulative flux | Offshore to inshore net passive flux of particulate nitrogen | mMN |
| 73 | NET_activemigpelfish_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of planktivorous fish | mMN |
| 74 | NET_activemigmigfish_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of migratory fish | mMN |
| 75 | NET_activemigdemfish_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of demersal fish | mMN |
| 76 | NET_activemigbird_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of birds | mMN |
| 77 | NET_activemigseal_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of pinnipeds | mMN |
| 78 | NET_activemigceta_o_i | Derived cumulative flux | Offshore to inshore net active migrationflux of cetaceans | mMN |
| 79 | NET_mfish_ext_o | Derived cumulative flux | Offshore boundary net migration flux of migratory fish | mMN |

| | | | | |
|---|---|---|---|---|
| 80 | fluxDINinflow | Derived cumulative flux | Whole domain import of dissolved inorganic nitrogen | mMN |
| 81 | fluxDINoutflow | Derived cumulative flux | Whole domain export of dissolved inorganic nitrogen | mMN |
| 82 | fluxPARTinflow | Derived cumulative flux | Whole domain import of particulate organic nitrogen | mMN |
| 83 | fluxPARToutflow | Derived cumulative flux | Whole domain export of particulate organic nitrogen | mMN |
| 84 | atmosDINinput | Derived cumulative flux | Whole domain atmospheric deposition of dissolved inorganic nitrogen | mMN |
| 85 | rivDINinflow | Derived cumulative flux | Whole domain river inflow of dissolved inorganic nitrogen | mMN |
| 86 | landp | Derived cumulative flux | Whole domain landings of planktivorous fish (live weight) | mMN |
| 87 | landd | Derived cumulative flux | Whole domain landings of all demersal fish (live weight) | mMN |
| 88 | landd_o | Derived cumulative flux | Offshore landings of all demersal fish (live weight) | mMN |
| 89 | landd_i | Derived cumulative flux | Inshore landings of all demersal fish (live weight) | mMN |
| 90 | landd_quota | Derived cumulative flux | Whole domain landings of quota-limited demersal fish (live weight) | mMN |
| 91 | landd_nonquota | Derived cumulative flux | Whole domain landings of non-quota demersal fish (live weight) | mMN |
| 92 | landm | Derived cumulative flux | Whole domain landings of migratory fish (live weight) | mMN |
| 93 | landsb | Derived cumulative flux | Whole domain landings of susp/dep feeding benthos (live weight) | mMN |
| 94 | landcb | Derived cumulative flux | Whole domain landings of carn/scav feeding benthos (live weight) | mMN |
| 95 | landcz | Derived cumulative flux | Whole domain landings of carnivorous zooplankton (live weight) | mMN |
| 96 | landbd | Derived cumulative flux | Whole domain landings of birds (live weight) | mMN |
| 97 | landsl | Derived cumulative flux | Whole domain landings of pinnipeds (live weight) | mMN |
| 98 | landct | Derived cumulative flux | Whole domain landings of cetaceans (live weight) | mMN |
| 99 | discpel | Derived cumulative flux | Whole domain discards of planktivorous fish (live weight) | mMN |
| 100 | discdem | Derived cumulative flux | Whole domain discards of all demersal fish (live weight) | mMN |
| 101 | discdem_o | Derived cumulative flux | Offshore discards of all demersal fish (live weight) | mMN |
| 102 | discdem_i | Derived cumulative flux | Inshore discards of all demersal fish (live weight) | mMN |
| 103 | discdem_quota | Derived cumulative flux | Whole domain discards of quota-limited demersal fish (live weight) | mMN |
| 104 | discdem_nonquota | Derived cumulative flux | Whole domain discards of non-quota demersal fish (live weight) | mMN |
| 105 | discmig | Derived cumulative flux | Whole domain discards of migratory fish (live weight) | mMN |
| 106 | discsb | Derived cumulative flux | Whole domain discards of susp/dep feeding benthos (live weight) | mMN |
| 107 | disccb | Derived cumulative flux | Whole domain discards of carn/scav feeding benthos (live weight) | mMN |
| 108 | disccz | Derived cumulative flux | Whole domain discards of carnivorous zooplankton (live weight) | mMN |
| 109 | discbd | Derived cumulative flux | Whole domain discards of birds (live weight) | mMN |

| | | | | |
|---|---|---|---|---|
| 110 | discsl | Derived cumulative flux | Whole domain discards of pinnipeds (live weight) | mMN |
| 111 | discct | Derived cumulative flux | Whole domain discards of cetaceans (live weight) | mMN |
| 112 | offalpel | Derived cumulative flux | Whole domain offal from processing of planktivorous fish catch | mMN |
| 113 | offaldem | Derived cumulative flux | Whole domain offal from processing of all demersal fish catch | mMN |
| 114 | offaldem_o | Derived cumulative flux | Offshore offal from processing of all demersal fish catch | mMN |
| 115 | offaldem_i | Derived cumulative flux | Inshore offal from processing of all demersal fish catch | mMN |
| 116 | offaldem_quota | Derived cumulative flux | Whole domain offal from processing of quota-limited demersal fish catch | mMN |
| 117 | offaldem_nonquota | Derived cumulative flux | Whole domain offal from processing of non-quota demersal fish catch | mMN |
| 118 | offalmig | Derived cumulative flux | Whole domain offal from processing of migratory fish catch | mMN |
| 119 | offalsb | Derived cumulative flux | Whole domain offal from processing of susp/dep feeding benthos catch | mMN |
| 120 | offalcb | Derived cumulative flux | Whole domain offal from processing of carn/scav feeding benthos catch | mMN |
| 121 | offalcz | Derived cumulative flux | Whole domain offal from processing of carnivorous zooplankton catch | mMN |
| 122 | offalbd | Derived cumulative flux | Whole domain offal from processing of bird catch | mMN |
| 123 | offalsl | Derived cumulative flux | Whole domain offal from processing of pinniped catch | mMN |
| 124 | offalct | Derived cumulative flux | Whole domain offal from processing of cetacean catch | mMN |

**Table 41. Details of the data columns in the dataframes "$offshore_annual_group_land_disc" and "$inshore_annual_group_land_disc" which are saved in the object "$total.annual.catch" of the list generated by the model.** The data are integrals of the daily landings and discards of each guild over successive years of the model run. Rows in the dataframe represent the sequential data from each year. Units of landings and discards: $mMN.y^{-1}$.

| Column number | Column name | Description |
|---|---|---|
| 1 | year | Year-number in the model run |
| 2 | PFland | Planktivorous fish landings |
| 3 | DFQland | Quota-limited demersal fish landings |
| 4 | DFNQland | Non-quota demersal fish landings |
| 5 | MFland | Migratory fish landings |
| 6 | SBland | Susp/dep feeding benthos landings |
| 7 | CBland | Carn/scav feeding benthos landings |
| 8 | CZland | Carnivorous zooplankton landings |
| 9 | BDland | Birds landings |
| 10 | SLland | Pinnipeds landings |
| 11 | CTland | Cetaceans landings |
| 12 | KPland | Macrophytes landings |
| 13 | PFdisc | Planktivorous fish discards |
| 14 | DFQdisc | Quota-limited demersal fish discards |
| 15 | DFNQdisc | Non-quota demersal fish discards |
| 16 | MFdisc | Migratory fish discards |
| 17 | SBdisc | Susp/dep feeding benthos discards |
| 18 | CBdisc | Carn/scav feeding benthos discards |
| 19 | CZdisc | Carnivorous zooplankton discards |
| 20 | BDdisc | Birds discards |
| 21 | SLdisc | Pinnipeds discards |
| 22 | CTdisc | Cetaceans discards |
| 23 | KPdisc | Macrophytes discards |

**Table 42. Details of the data columns in the dataframes "$offshore_annual_group_gear_land_disc" and "$inshore_annual_group_gear_land_disc" which are saved in the object "$total.annual.catch" of the list generated by the model.** The data are dis-aggregations of the annual landings and discards of each guild contained in "$total.annuaal.catch" of the list generated by the model into the fractions attributable to each fishing gear. Rows in the dataframe represent the sequential data for each year of the model run. Units of landings and discards: $mMN.y^{-1}$.

| Column number | Column name | Description |
|---|---|---|
| 1 | year | Year-number in the model run |
| 2 | PF_1_L | Planktivorous fish, gear id 1, landings |
| 3 | PF_2_L | Planktivorous fish, gear id 2, landings |
| 4 | PF_3_L | Planktivorous fish, gear id 3, landings |
| 5 | PF_4_L | Planktivorous fish, gear id 4, landings |
| 6 | PF_5_L | Planktivorous fish, gear id 5, landings |
| 7 | PF_6_L | Planktivorous fish, gear id 6, landings |
| 8 | PF_7_L | Planktivorous fish, gear id 7, landings |
| 9 | PF_8_L | Planktivorous fish, gear id 8, landings |
| 10 | PF_9_L | Planktivorous fish, gear id 9, landings |
| 11 | PF_10_L | Planktivorous fish, gear id 10, landings |
| 12 | PF_11_L | Planktivorous fish, gear id 11, landings |
| 13 | PF_12_L | Planktivorous fish, gear id 12, landings |
| 14 | DFQ_1_L | Quota-limited demersal fish, gear id 1, landings |
| 15 | DFQ_2_L | Quota-limited demersal fish, gear id 2, landings |
| 16 | DFQ_3_L | Quota-limited demersal fish, gear id 3, landings |
| 17 | DFQ_4_L | Quota-limited demersal fish, gear id 4, landings |
| 18 | DFQ_5_L | Quota-limited demersal fish, gear id 5, landings |
| 19 | DFQ_6_L | Quota-limited demersal fish, gear id 6, landings |
| 20 | DFQ_7_L | Quota-limited demersal fish, gear id 7, landings |
| 21 | DFQ_8_L | Quota-limited demersal fish, gear id 8, landings |
| 22 | DFQ_9_L | Quota-limited demersal fish, gear id 9, landings |
| 23 | DFQ_10_L | Quota-limited demersal fish, gear id 10, landings |

| | | |
|---|---|---|
| 24 | DFQ_11_L | Quota-limited demersal fish, gear id 11, landings |
| 25 | DFQ_12_L | Quota-limited demersal fish, gear id 12, landings |
| 26 | DFNQ_1_L | Non-quota demersal fish, gear id 1, landings |
| 27 | DFNQ_2_L | Non-quota demersal fish, gear id 2, landings |
| 28 | DFNQ_3_L | Non-quota demersal fish, gear id 3, landings |
| 29 | DFNQ_4_L | Non-quota demersal fish, gear id 4, landings |
| 30 | DFNQ_5_L | Non-quota demersal fish, gear id 5, landings |
| 31 | DFNQ_6_L | Non-quota demersal fish, gear id 6, landings |
| 32 | DFNQ_7_L | Non-quota demersal fish, gear id 7, landings |
| 33 | DFNQ_8_L | Non-quota demersal fish, gear id 8, landings |
| 34 | DFNQ_9_L | Non-quota demersal fish, gear id 9, landings |
| 35 | DFNQ_10_L | Non-quota demersal fish, gear id 10, landings |
| 36 | DFNQ_11_L | Non-quota demersal fish, gear id 11, landings |
| 37 | DFNQ_12_L | Non-quota demersal fish, gear id 12, landings |
| 38 | MF_1_L | Migratory fish, gear id 1, landings |
| 39 | MF_2_L | Migratory fish, gear id 2, landings |
| 40 | MF_3_L | Migratory fish, gear id 3, landings |
| 41 | MF_4_L | Migratory fish, gear id 4, landings |
| 42 | MF_5_L | Migratory fish, gear id 5, landings |
| 43 | MF_6_L | Migratory fish, gear id 6, landings |
| 44 | MF_7_L | Migratory fish, gear id 7, landings |
| 45 | MF_8_L | Migratory fish, gear id 8, landings |
| 46 | MF_9_L | Migratory fish, gear id 9, landings |
| 47 | MF_10_L | Migratory fish, gear id 10, landings |
| 48 | MF_11_L | Migratory fish, gear id 11, landings |
| 49 | MF_12_L | Migratory fish, gear id 12, landings |
| 50 | SB_1_L | Susp/dep feeding benthos, gear id 1, landings |
| 51 | SB_2_L | Susp/dep feeding benthos, gear id 2, landings |
| 52 | SB_3_L | Susp /dep feeding benthos, gear id 3, landings |

| | | |
|---|---|---|
| 53 | SB_4_L | Susp /dep feeding benthos, gear id 4, landings |
| 54 | SB_5_L | Susp /dep feeding benthos, gear id 5, landings |
| 55 | SB_6_L | Susp /dep feeding benthos, gear id 6, landings |
| 56 | SB_7_L | Susp /dep feeding benthos, gear id 7, landings |
| 57 | SB_8_L | Susp /dep feeding benthos, gear id 8, landings |
| 58 | SB_9_L | Susp /dep feeding benthos, gear id 9, landings |
| 59 | SB_10_L | Susp /dep feeding benthos, gear id 10, landings |
| 60 | SB_11_L | Susp /dep feeding benthos, gear id 11, landings |
| 61 | SB_12_L | Susp /dep feeding benthos, gear id 12, landings |
| 62 | CB_1_L | Carn/scav feeding benthos, gear id 1, landings |
| 63 | CB_2_L | Carn/scav feeding benthos, gear id 2, landings |
| 64 | CB_3_L | Carn/scav feeding benthos, gear id 3, landings |
| 65 | CB_4_L | Carn/scav feeding benthos, gear id 4, landings |
| 66 | CB_5_L | Carn/scav feeding benthos, gear id 5, landings |
| 67 | CB_6_L | Carn/scav feeding benthos, gear id 6, landings |
| 68 | CB_7_L | Carn/scav feeding benthos, gear id 7, landings |
| 69 | CB_8_L | Carn/scav feeding benthos, gear id 8, landings |
| 70 | CB_9_L | Carn/scav feeding benthos, gear id 9, landings |
| 71 | CB_10_L | Carn/scav feeding benthos, gear id 10, landings |
| 72 | CB_11_L | Carn/scav feeding benthos, gear id 11, landings |
| 73 | CB_12_L | Carn/scav feeding benthos, gear id 12, landings |
| 74 | CZ_1_L | Carnivorous zooplankton, gear id 1, landings |
| 75 | CZ_2_L | Carnivorous zooplankton, gear id 2, landings |
| 76 | CZ_3_L | Carnivorous zooplankton, gear id 3, landings |
| 77 | CZ_4_L | Carnivorous zooplankton, gear id 4, landings |
| 78 | CZ_5_L | Carnivorous zooplankton, gear id 5, landings |
| 79 | CZ_6_L | Carnivorous zooplankton, gear id 6, landings |
| 80 | CZ_7_L | Carnivorous zooplankton, gear id 7, landings |
| 81 | CZ_8_L | Carnivorous zooplankton, gear id 8, landings |

| | | |
|---|---|---|
| 82 | CZ_9_L | Carnivorous zooplankton, gear id 9, landings |
| 83 | CZ_10_L | Carnivorous zooplankton, gear id 10, landings |
| 84 | CZ_11_L | Carnivorous zooplankton, gear id 11, landings |
| 85 | CZ_12_L | Carnivorous zooplankton, gear id 12, landings |
| 86 | BD_1_L | Birds, gear id 1, landings |
| 87 | BD_2_L | Birds, gear id 2, landings |
| 88 | BD_3_L | Birds, gear id 3, landings |
| 89 | BD_4_L | Birds, gear id 4, landings |
| 90 | BD_5_L | Birds, gear id 5, landings |
| 91 | BD_6_L | Birds, gear id 6, landings |
| 92 | BD_7_L | Birds, gear id 7, landings |
| 93 | BD_8_L | Birds, gear id 8, landings |
| 94 | BD_9_L | Birds, gear id 9, landings |
| 95 | BD_10_L | Birds, gear id 10, landings |
| 96 | BD_11_L | Birds, gear id 11, landings |
| 97 | BD_12_L | Birds, gear id 12, landings |
| 98 | SL_1_L | Pinnipeds, gear id 1, landings |
| 99 | SL_2_L | Pinnipeds, gear id 2, landings |
| 100 | SL_3_L | Pinnipeds, gear id 3, landings |
| 101 | SL_4_L | Pinnipeds, gear id 4, landings |
| 102 | SL_5_L | Pinnipeds, gear id 5, landings |
| 103 | SL_6_L | Pinnipeds, gear id 6, landings |
| 104 | SL_7_L | Pinnipeds, gear id 7, landings |
| 105 | SL_8_L | Pinnipeds, gear id 8, landings |
| 106 | SL_9_L | Pinnipeds, gear id 9, landings |
| 107 | SL_10_L | Pinnipeds, gear id 10, landings |
| 108 | SL_11_L | Pinnipeds, gear id 11, landings |
| 109 | SL_12_L | Pinnipeds, gear id 12, landings |
| 110 | CT_1_L | Cetaceans, gear id 1, landings |

| | | |
|---|---|---|
| 111 | CT_2_L | Cetaceans, gear id 2, landings |
| 112 | CT_3_L | Cetaceans, gear id 3, landings |
| 113 | CT_4_L | Cetaceans, gear id 4, landings |
| 114 | CT_5_L | Cetaceans, gear id 5, landings |
| 115 | CT_6_L | Cetaceans, gear id 6, landings |
| 116 | CT_7_L | Cetaceans, gear id 7, landings |
| 117 | CT_8_L | Cetaceans, gear id 8, landings |
| 118 | CT_9_L | Cetaceans, gear id 9, landings |
| 119 | CT_10_L | Cetaceans, gear id 10, landings |
| 120 | CT_11_L | Cetaceans, gear id 11, landings |
| 121 | CT_12_L | Cetaceans, gear id 12, landings |
| 122 | KP_1_L | Macrophytes, gear id 1, landings |
| 123 | KP_2_L | Macrophytes, gear id 2, landings |
| 124 | KP_3_L | Macrophytes, gear id 3, landings |
| 125 | KP_4_L | Macrophytes, gear id 4, landings |
| 126 | KP_5_L | Macrophytes, gear id 5, landings |
| 127 | KP_6_L | Macrophytes, gear id 6, landings |
| 128 | KP_7_L | Macrophytes, gear id 7, landings |
| 129 | KP_8_L | Macrophytes, gear id 8, landings |
| 130 | KP_9_L | Macrophytes, gear id 9, landings |
| 131 | KP_10_L | Macrophytes, gear id 10, landings |
| 132 | KP_11_L | Macrophytes, gear id 11, landings |
| 133 | KP_12_L | Macrophytes, gear id 12, landings |
| 134 | PF_1_D | Planktivorous fish, gear id 1, discards |
| 135 | PF_2_D | Planktivorous fish, gear id 2, discards |
| 136 | PF_3_D | Planktivorous fish, gear id 3, discards |
| 137 | PF_4_D | Planktivorous fish, gear id 4, discards |
| 138 | PF_5_D | Planktivorous fish, gear id 5, discards |
| 139 | PF_6_D | Planktivorous fish, gear id 6, discards |

| | | |
|---|---|---|
| 140 | PF_7_D | Planktivorous fish, gear id 7, discards |
| 141 | PF_8_D | Planktivorous fish, gear id 8, discards |
| 142 | PF_9_D | Planktivorous fish, gear id 9, discards |
| 143 | PF_10_D | Planktivorous fish, gear id 10, discards |
| 144 | PF_11_D | Planktivorous fish, gear id 11, discards |
| 145 | PF_12_D | Planktivorous fish, gear id 12, discards |
| 146 | DFQ_1_D | Quota-limited demersal fish, gear id 1, discards |
| 147 | DFQ_2_D | Quota-limited demersal fish, gear id 2, discards |
| 148 | DFQ_3_D | Quota-limited demersal fish, gear id 3, discards |
| 149 | DFQ_4_D | Quota-limited demersal fish, gear id 4, discards |
| 150 | DFQ_5_D | Quota-limited demersal fish, gear id 5, discards |
| 151 | DFQ_6_D | Quota-limited demersal fish, gear id 6, discards |
| 152 | DFQ_7_D | Quota-limited demersal fish, gear id 7, discards |
| 153 | DFQ_8_D | Quota-limited demersal fish, gear id 8, discards |
| 154 | DFQ_9_D | Quota-limited demersal fish, gear id 9, discards |
| 155 | DFQ_10_D | Quota-limited demersal fish, gear id 10, discards |
| 156 | DFQ_11_D | Quota-limited demersal fish, gear id 11, discards |
| 157 | DFQ_12_D | Quota-limited demersal fish, gear id 12, discards |
| 158 | DFNQ_1_D | Non-quota demersal fish, gear id 1, discards |
| 159 | DFNQ_2_D | Non-quota demersal fish, gear id 2, discards |
| 160 | DFNQ_3_D | Non-quota demersal fish, gear id 3, discards |
| 161 | DFNQ_4_D | Non-quota demersal fish, gear id 4, discards |
| 162 | DFNQ_5_D | Non-quota demersal fish, gear id 5, discards |
| 163 | DFNQ_6_D | Non-quota demersal fish, gear id 6, discards |
| 164 | DFNQ_7_D | Non-quota demersal fish, gear id 7, discards |
| 165 | DFNQ_8_D | Non-quota demersal fish, gear id 8, discards |
| 166 | DFNQ_9_D | Non-quota demersal fish, gear id 9, discards |
| 167 | DFNQ_10_D | Non-quota demersal fish, gear id 10, discards |
| 168 | DFNQ_11_D | Non-quota demersal fish, gear id 11, discards |

| | | |
|---|---|---|
| 169 | DFNQ_12_D | Non-quota demersal fish, gear id 12, discards |
| 170 | MF_1_D | Migratory fish, gear id 1, discards |
| 171 | MF_2_D | Migratory fish, gear id 2, discards |
| 172 | MF_3_D | Migratory fish, gear id 3, discards |
| 173 | MF_4_D | Migratory fish, gear id 4, discards |
| 174 | MF_5_D | Migratory fish, gear id 5, discards |
| 175 | MF_6_D | Migratory fish, gear id 6, discards |
| 176 | MF_7_D | Migratory fish, gear id 7, discards |
| 177 | MF_8_D | Migratory fish, gear id 8, discards |
| 178 | MF_9_D | Migratory fish, gear id 9, discards |
| 179 | MF_10_D | Migratory fish, gear id 10, discards |
| 180 | MF_11_D | Migratory fish, gear id 11, discards |
| 181 | MF_12_D | Migratory fish, gear id 12, discards |
| 182 | SB_1_D | Susp/dep feeding benthos, gear id 1, discards |
| 183 | SB_2_D | Susp/dep feeding benthos, gear id 2, discards |
| 184 | SB_3_D | Susp/dep feeding benthos, gear id 3, discards |
| 185 | SB_4_D | Susp/dep feeding benthos, gear id 4, discards |
| 186 | SB_5_D | Susp/dep feeding benthos, gear id 5, discards |
| 187 | SB_6_D | Susp/dep feeding benthos, gear id 6, discards |
| 188 | SB_7_D | Susp/dep feeding benthos, gear id 7, discards |
| 189 | SB_8_D | Susp/dep feeding benthos, gear id 8, discards |
| 190 | SB_9_D | Susp/dep feeding benthos, gear id 9, discards |
| 191 | SB_10_D | Susp/dep feeding benthos, gear id 10, discards |
| 192 | SB_11_D | Susp/dep feeding benthos, gear id 11, discards |
| 193 | SB_12_D | Susp/dep feeding benthos, gear id 12, discards |
| 194 | CB_1_D | Carn/scav feeding benthos, gear id 1, discards |
| 195 | CB_2_D | Carn/scav feeding benthos, gear id 2, discards |
| 196 | CB_3_D | Carn/scav feeding benthos, gear id 3, discards |
| 197 | CB_4_D | Carn/scav feeding benthos, gear id 4, discards |

| | | |
|---|---|---|
| 198 | CB_5_D | Carn/scav feeding benthos, gear id 5, discards |
| 199 | CB_6_D | Carn/scav feeding benthos, gear id 6, discards |
| 200 | CB_7_D | Carn/scav feeding benthos, gear id 7, discards |
| 201 | CB_8_D | Carn/scav feeding benthos, gear id 8, discards |
| 202 | CB_9_D | Carn/scav feeding benthos, gear id 9, discards |
| 203 | CB_10_D | Carn/scav feeding benthos, gear id 10, discards |
| 204 | CB_11_D | Carn/scav feeding benthos, gear id 11, discards |
| 205 | CB_12_D | Carn/scav feeding benthos, gear id 12, discards |
| 206 | CZ_1_D | Carnivorous zooplankton, gear id 1, discards |
| 207 | CZ_2_D | Carnivorous zooplankton, gear id 2, discards |
| 208 | CZ_3_D | Carnivorous zooplankton, gear id 3, discards |
| 209 | CZ_4_D | Carnivorous zooplankton, gear id 4, discards |
| 210 | CZ_5_D | Carnivorous zooplankton, gear id 5, discards |
| 211 | CZ_6_D | Carnivorous zooplankton, gear id 6, discards |
| 212 | CZ_7_D | Carnivorous zooplankton, gear id 7, discards |
| 213 | CZ_8_D | Carnivorous zooplankton, gear id 8, discards |
| 214 | CZ_9_D | Carnivorous zooplankton, gear id 9, discards |
| 215 | CZ_10_D | Carnivorous zooplankton, gear id 10, discards |
| 216 | CZ_11_D | Carnivorous zooplankton, gear id 11, discards |
| 217 | CZ_12_D | Carnivorous zooplankton, gear id 12, discards |
| 218 | BD_1_D | Birds, gear id 1, discards |
| 219 | BD_2_D | Birds, gear id 2, discards |
| 220 | BD_3_D | Birds, gear id 3, discards |
| 221 | BD_4_D | Birds, gear id 4, discards |
| 222 | BD_5_D | Birds, gear id 5, discards |
| 223 | BD_6_D | Birds, gear id 6, discards |
| 224 | BD_7_D | Birds, gear id 7, discards |
| 225 | BD_8_D | Birds, gear id 8, discards |
| 226 | BD_9_D | Birds, gear id 9, discards |

| | | |
|---|---|---|
| 227 | BD_10_D | Birds, gear id 10, discards |
| 228 | BD_11_D | Birds, gear id 11, discards |
| 229 | BD_12_D | Birds, gear id 12, discards |
| 230 | SL_1_D | Pinnipeds, gear id 1, discards |
| 231 | SL_2_D | Pinnipeds, gear id 2, discards |
| 232 | SL_3_D | Pinnipeds, gear id 3, discards |
| 233 | SL_4_D | Pinnipeds, gear id 4, discards |
| 234 | SL_5_D | Pinnipeds, gear id 5, discards |
| 235 | SL_6_D | Pinnipeds, gear id 6, discards |
| 236 | SL_7_D | Pinnipeds, gear id 7, discards |
| 237 | SL_8_D | Pinnipeds, gear id 8, discards |
| 238 | SL_9_D | Pinnipeds, gear id 9, discards |
| 239 | SL_10_D | Pinnipeds, gear id 10, discards |
| 240 | SL_11_D | Pinnipeds, gear id 11, discards |
| 241 | SL_12_D | Pinnipeds, gear id 12, discards |
| 242 | CT_1_D | Cetaceans, gear id 1, discards |
| 243 | CT_2_D | Cetaceans, gear id 2, discards |
| 244 | CT_3_D | Cetaceans, gear id 3, discards |
| 245 | CT_4_D | Cetaceans, gear id 4, discards |
| 246 | CT_5_D | Cetaceans, gear id 5, discards |
| 247 | CT_6_D | Cetaceans, gear id 6, discards |
| 248 | CT_7_D | Cetaceans, gear id 7, discards |
| 249 | CT_8_D | Cetaceans, gear id 8, discards |
| 250 | CT_9_D | Cetaceans, gear id 9, discards |
| 251 | CT_10_D | Cetaceans, gear id 10, discards |
| 252 | CT_11_D | Cetaceans, gear id 11, discards |
| 253 | CT_12_D | Cetaceans, gear id 12, discards |
| 254 | KP_1_D | Macrophytes, gear id 1, discards |
| 255 | KP_2_D | Macrophytes, gear id 2, discards |

| | | |
|---|---|---|
| 256 | KP_3_D | Macrophytes, gear id 3, discards |
| 257 | KP_4_D | Macrophytes, gear id 4, discards |
| 258 | KP_5_D | Macrophytes, gear id 5, discards |
| 259 | KP_6_D | Macrophytes, gear id 6, discards |
| 260 | KP_7_D | Macrophytes, gear id 7, discards |
| 261 | KP_8_D | Macrophytes, gear id 8, discards |
| 262 | KP_9_D | Macrophytes, gear id 9, discards |
| 263 | KP_10_D | Macrophytes, gear id 10, discards |
| 264 | KP_11_D | Macrophytes, gear id 11, discards |
| 265 | KP_12_D | Macrophytes, gear id 12, discards |

## Details of $final.year.outputs data saved in the results list object and output to *.csv* files

On completion of the differential equation solving phase of the model run, the code generates a set of standard outputs based on the last annual cycle of the run. If the model has been run to a stationary state then the final year represents a repeating annual cycle of output given the repeating annual cycle of model driving data.

The final year standard outputs are embedded in the R-list object generated by the model run (see Table 36, 37), and replicated in a set of *.csv* output files directed to the users' working directory. A variety of plotting functions are provided with the package which can be used to display these single run data. However, it is expected that users will wish to write their own code to create other tables and graphics which, for example compare results from a scenario run of the model with a basline run. To facilitate user access to the standard final year outputs, either from the R-list object or the *.csv* files, each of the data structures is documented in Tables 43-47.

**Table 43. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run - the data fields within the dataframe "$monthly.averages".** The same data are also output as a standard *.csv* file. Rows (12 in total) are the averages of the set of variable (columns) over each successive 30 day interval of model output during the final year (corresponding to months). The variables are designed to correspond to the observational month data in the file */Target_data/ monthly_target_data_*.csv*

| Column number | Column name | Data description |
|---|---|---|
| 1 | surfnitratemMm3 | Nitrate concentration (mMN.m$^{-3}$) aggregated across the inshore zone and the offshore upper layer |
| 2 | deepnitratemMm3 | Nitrate concentration (mMN.m$^{-3}$) in the offshore lower layer |
| 3 | surfammoniamMm3 | Ammonia concentration (mMN.m$^{-3}$) aggregated across the inshore zone and the offshore upper layer |
| 4 | deepammoniamMm3 | Ammonia concentration (mMN.m$^{-3}$) in the offshore lower layer |
| 5 | surfchlmgm3 | Chlorophyll concentration (mg.m$^{-3}$) aggregated across the inshore zone and the offshore upper layer. Chlorophyll derived assuming Redfield carbon:nitrogen molar ratio and a carbon:chlorophyll weight ratio of 20 |
| 6 | omnizoomMNm3 | Omnivorous zooplanktoin concentration (mMN.m$^{-3}$) aggregated across the inshore and offshore zones |
| 7 | carnzoomMNm3 | Carnivorous zooplanktoin concentration (mMN.m$^{-3}$) aggregated across the inshore and offshore zones |
| 8 | benthslarmMNm3 | Larvae of susp/dep feeding benthos concentration (mMN.m$^{-3}$) aggregated across the inshore and offshore zones |
| 9 | benthclarmMNm3 | Larvae of carn/scav feeding benthos concentration (mMN.m$^{-3}$) aggregated across the inshore and offshore zones |

**Table 44. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run - the data fields within the dataframes "$mass_results_inshore", "$maxmass_results_inshore" and "$minmass_results_inshore", and the corresponding dataframes for the offshore zone and the whole model domain.** The same data are also output as standard .csv files. Columns are (1) the data value, (2) units (text field), and (3) a description of the data (text field). Certain outputs are not available for the inshore and offshore zones so the data value for these rows is given as NA which R interprets as a missing value. Lower layer outputs are not available for the inshore zone. Kelp and kelp detritus values are not available for the offshore zone. Units for the state variables correspond to the mass in the whole model domain which is notionally 1 $m^2$. Area and volumetric parameters are appended at the bottom of the .csv table to enable the mass values to be converted to area densities or layer concentrations, but not in the dataframes within "$final.year.outputs" since these parameters are available in $build$model.parameters, as detailed in Table 38.

| Row number | Units | Description |
|---|---|---|
| 1 | mMN in the whole model domain (1 $m^2$) | Surface layer detritus (and bacteria) |
| 2 | mMN in the whole model domain (1 $m^2$) | Deep layer detritus (and bacteria) |
| 3 | mMN in the whole model domain (1 $m^2$) | Sediment labile plus refractory detritus (and bacteria) |
| 4 | mMN in the whole model domain (1 $m^2$) | Sediment refractory detritus |
| 5 | mMN in the whole model domain (1 $m^2$) | Fishery discards |
| 6 | mMN in the whole model domain (1 $m^2$) | Corpses |
| 7 | mMN in the whole model domain (1 $m^2$) | Kelp debris |
| 8 | mMN in the whole model domain (1 $m^2$) | Surface layer ammonia |
| 9 | mMN in the whole model domain (1 $m^2$) | Deep layer ammonia |
| 10 | mMN in the whole model domain (1 $m^2$) | Sediment porewater ammonia |
| 11 | mMN in the whole model domain (1 $m^2$) | Surface layer nitrate |
| 12 | mMN in the whole model domain (1 $m^2$) | Deep layer nitrate |
| 13 | mMN in the whole model domain (1 $m^2$) | Sediment porewater nitrate |
| 14 | mMN in the whole model domain (1 $m^2$) | Kelp nitrogen |
| 15 | mMN in the whole model domain (1 $m^2$) | Surface layer phytoplankton |
| 16 | mMN in the whole model domain (1 $m^2$) | Deep layer phytoplankton |
| 17 | mMN in the whole model domain (1 $m^2$) | Omnivorous zooplankton |
| 18 | mMN in the whole model domain (1 $m^2$) | Carnivorous zooplankton |
| 19 | mMN in the whole model domain (1 $m^2$) | Benthos susp/dep feeders larvae |

| | | |
|---|---|---|
| 20 | mMN in the whole model domain (1 $m^2$) | Benthos susp/dep feeders |
| 21 | mMN in the whole model domain (1 $m^2$) | Benthos carn/scav feeders larvae |
| 22 | mMN in the whole model domain (1 $m^2$) | Benthos carn/scav feeders |
| 23 | mMN in the whole model domain (1 $m^2$) | Planktivorous fish larvae |
| 24 | mMN in the whole model domain (1 $m^2$) | Planktivorous fish |
| 25 | mMN in the whole model domain (1 $m^2$) | Migratory fish |
| 26 | mMN in the whole model domain (1 $m^2$) | Demersal fish larvae |
| 27 | mMN in the whole model domain (1 $m^2$) | Demersal fish |
| 28 | mMN in the whole model domain (1 $m^2$) | Bird |
| 29 | mMN in the whole model domain (1 $m^2$) | Seals |
| 30 | mMN in the whole model domain (1 $m^2$) | Cetaceans |
| 31 | mMN in the whole model domain (1 $m^2$) | Total nitrogen mass |
| 32 | Dimensionless | Area proportion of inshore zone **(only in the *.csv* output file)** |
| 33 | M | Thickness of inshore surface layer **(only in the *.csv* output file)** |
| 34 | M | Thickness of offshore surface layer **(only in the *.csv* output file)** |
| 35 | M | Thickness of offshore deep layer **(only in the *.csv* output file)** |
| 36 | Dimensionless | Area proportion inshore rock **(only in the *.csv* output file)** |
| 37 | Dimensionless | Area proportion inshore sediment s1 **(only in the *.csv* output file)** |
| 38 | Dimensionless | Area proportion inshore sediment s2 **(only in the *.csv* output file)** |
| 39 | Dimensionless | Area proportion inshore sediment s3 **(only in the *.csv* output file)** |
| 40 | Dimensionless | Area proportion offshore rock **(only in the *.csv* output file)** |
| 41 | Dimensionless | Area proportion offshore sediment d1 **(only in the *.csv* output file)** |
| 42 | Dimensionless | Area proportion offshore sediment d2 **(only in the *.csv* output file)** |
| 43 | Dimensionless | Area proportion offshore sediment d3 **(only in the *.csv* output file)** |
| 44 | M | Thickness of inshore sediment layer s1 **(only in the *.csv* output file)** |
| 45 | M | Thickness of inshore sediment layer s2 **(only in the *.csv* output file)** |
| 46 | M | Thickness of inshore sediment layer s3 **(only in the *.csv* output file)** |
| 47 | M | Thickness of offshore sediment layer d1 **(only in the *.csv* output file)** |
| 48 | M | Thickness of offshore sediment layer d2 **(only in the *.csv* output file)** |
| 49 | M | Thickness of offshore sediment layer d3 **(only in the *.csv* output file)** |

| | | |
|---|---|---|
| 50 | Dimensionless | Porosity of inshore sediment layer s1 **(only in the *.csv* output file)** |
| 51 | Dimensionless | Porosity of inshore sediment layer s2 **(only in the *.csv* output file)** |
| 51 | Dimensionless | Porosity of inshore sediment layer s3 **(only in the *.csv* output file)** |
| 53 | Dimensionless | Porosity of offshore sediment layer d1 **(only in the *.csv* output file)** |
| 54 | Dimensionless | Porosity of offshore sediment layer d2 **(only in the *.csv* output file)** |
| 55 | Dimensionless | Porosity of offshore sediment layer d3 **(only in the *.csv* output file)** |

**Table 45. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run - the data fields within the dataframe "$annual_flux_results_inshore", and the corresponding dataframes for the offshore zone and the whole model domain.** The same data are also output as standard *.csv* files. Columns are (1) the data value, (2) units (text field), and (3) a description of the data (text field). Certain outputs are not available for the inshore and offshore zones so the data value for these rows is given as NA which R interprets as a missing value. Lower layer outputs are not available for the inshore zone. Kelp and kelp detritus values are not available for the offshore zone. Units for the fluxes correspond to the mass flux per unikt time in the whole model domain which is notionally 1 $m^2$. Area and volumetric parameters are appended at the bottom of the .csv table to enable the mass values to be converted to area densities or layer concentrations, but not in the dataframes within "$final.year.outputs" since these parameters are available in $build$model.parameters, as detailed in Table 38.

| Row number | Units | Description |
|---|---|---|
| 1 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | DIN inflow (nitrate + ammonia inflow from the external ocean) |
| 2 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | DIN outflow (nitrate + ammonia outflow from the model to the ocean) |
| 3 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Particulate inflow (detritus & bacteria + phytoplankton inflow from the ocean) |
| 4 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Particulate outflow (detritus & bacteria + phytoplankton outflow from the model to the ocean) |
| 5 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Atmosphere DIN input (deposition of nitrate and ammonia on the sea surface) |
| 6 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | River DIN inflow (inflow of nitrate and ammonia from rivers) |
| 7 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | River particulate inflow (inflow of suspended detritus from rivers) |
| 8 | mMN in the whole model domain (1 $m^2$) during | Summer DIN inflow (nitrate + ammonia inflow from the external ocean) |

| | | |
|---|---|---|
| | summer months only (April-September) | |
| 9 | mMN in the whole model domain (1 $m^2$) during summer months only (April-September) | Summer DIN outflow (nitrate + ammonia outflow from the model to the ocean) |
| 10 | mMN in the whole model domain (1 $m^2$) during summer months only (April-September) | Summer particulate inflow (detritus & bacteria + phytoplankton inflow from the ocean) |
| 11 | mMN in the whole model domain (1 $m^2$) during summer months only (April-September) | Summer particulate outflow (detritus & bacteria + phytoplankton outflow from the model to the ocean) |
| 12 | mMN in the whole model domain (1 $m^2$) during summer months only (April-September) | Summer river DIN inflow (inflow of nitrate and ammonia from rivers) |
| 13 | mMN in the whole model domain (1 $m^2$) during summer months only (April-September) | Summer atmosphere DIN input (deposition of nitrate and ammonia on the sea surface) |
| 14 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Vertical nitrate flux |
| 15 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Surface horizontal nitrate flux |
| 16 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Net import/export flux in the sediment |
| 17 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Beachcast export of kelp debris |
| 18 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | DIN Net flux offshore to inshore |
| 19 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Particulate net flux offshore to inshore |
| 20 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Plank.fish net active migration offshore to inshore |
| 21 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Mig.fish net active migration offshore to inshore |
| 22 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Dem.fish net active migration offshore to inshore |
| 23 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Bird net active migration offshore to inshore |
| 24 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Seal net active migration offshore to inshore |
| 25 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Cetacean net active migration offshore to inshore |
| 26 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Mig.fish net migration external offshore |
| 27 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Mig.fish annual immigration |
| 28 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Mig.fish annual emigration |
| 29 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Phytoplankton net primary production |
| 30 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Phytoplankton new production (nitrate drawdown) |
| 31 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Phytoplankton new production (traditional) |
| 32 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Phytoplankton new production (Heath&Beare) |
| 33 | mMN.$y^{-1}$ in the whole model domain (1 $m^2$) | Phytoplankton nitrate uptake |

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| 34 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Phytoplankton ammonia uptake |
| 35 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Phytoplankton fratio (H&B/NetPP) |
| 36 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Phytoplankton fratio (traditional) |
| 37 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp nitrate uptake |
| 38 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp ammonia uptake |
| 39 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp gross production |
| 40 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Phytoplankton gross production |
| 41 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Omniv.zooplankton gross production |
| 42 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton gross production |
| 43 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Planktiv.fish larvae gross production |
| 44 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish larvae gross production |
| 45 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Planktiv.fish gross production |
| 46 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish gross production |
| 47 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish gross production |
| 48 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos susp/dep larvae gross production |
| 49 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos carn/scav larvae gross production |
| 50 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos susp/dep gross production |
| 51 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos carn/scav gross production |
| 52 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird gross production |
| 53 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal gross production |
| 54 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean gross production |
| 55 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Omniv.zooplankton net production |
| 56 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton net production |
| 57 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Planktiv.fish larvae net production |
| 58 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish larvae net production |
| 59 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Planktiv.fish net production |
| 60 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish net production |
| 61 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish net production |
| 62 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos susp/dep larvae net production |
| 63 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos carn/scav larvae net production |

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| 64 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos susp/dep net production |
| 65 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthos carn/scav net production |
| 66 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird net production |
| 67 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal net production |
| 68 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean net production |
| 69 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Water column detritus production |
| 70 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment detritus production |
| 71 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Corpse production |
| 72 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux of detritus from water to sediment |
| 73 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux of discards to corpses |
| 74 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Pelagic fauna ammonia production |
| 75 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthic fauna ammonia production |
| 76 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Water column detritus mineralisation |
| 77 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment detritus mineralisation |
| 78 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Water column nitrification |
| 79 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment nitrification |
| 80 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Water column denitrification |
| 81 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment denitrification |
| 82 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment to water ammonia flux |
| 83 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Sediment to water nitrate flux |
| 84 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux detritus to omniv.zooplankton |
| 85 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux phytoplankton to omniv.zooplankton |
| 86 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to omniv.zooplankton |
| 87 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to omniv.zooplankton |
| 88 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux omniv.zooplankton to carniv.zooplankton |
| 89 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish.larvae to carniv.zooplankton |
| 90 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish.larvae to carniv.zooplankton |
| 91 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to carniv.zooplankton |
| 92 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to carniv.zooplankton |
| 93 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux omniv.zooplankton to plank.fish.larvae |

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| 94 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to plank.fish.larvae |
| 95 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to plank.fish.larvae |
| 96 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux omniv.zooplankton to dem.fish.larvae |
| 97 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to dem.fish.larvae |
| 98 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to dem.fish.larvae |
| 99 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux omniv.zooplankton to plank.fish |
| 100 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to plank.fish |
| 101 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish.larvae to plank.fish |
| 102 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish.larvae to plank.fish |
| 103 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to plank.fish |
| 104 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to plank.fish |
| 105 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux omniv.zooplankton to mig.fish |
| 106 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to mig.fish |
| 107 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish.larvae to mig.fish |
| 108 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish.larvae to mig.fish |
| 109 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d.larvae to mig.fish |
| 110 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s.larvae to mig.fish |
| 111 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux corpses to dem.fish |
| 112 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux discards to dem.fish |
| 113 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to dem.fish |
| 114 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish.larvae to dem.fish |
| 115 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish.larvae to dem.fish |
| 116 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish to dem.fish |
| 117 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux mig.fish to dem.fish |
| 118 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish to dem.fish |
| 119 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d to dem.fish |
| 120 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s to dem.fish |
| 121 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux detritus to Benthoss/d.larvae |
| 122 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux phytoplankton to Benthoss/d.larvae |
| 123 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux detritus to benthosc/s.larvae |

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| 124 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux phytoplankton to benthosc/s.larvae |
| 125 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux detritus to Benthoss/d |
| 126 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux sediment.detritus to Benthoss/d |
| 127 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux phytoplankton to Benthoss/d |
| 128 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux kelp.debris to benthosc/s |
| 129 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux corpses to benthosc/s |
| 130 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux kelp to benthosc/s |
| 131 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d to benthosc/sc |
| 132 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux corpses to birds |
| 133 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux discards to birds |
| 134 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to birds |
| 135 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish to birds |
| 136 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux mig.fish to birds |
| 137 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish to birds |
| 138 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d to birds |
| 139 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s to birds |
| 140 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux corpses to seals |
| 141 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux discards to seals |
| 142 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to seals |
| 143 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish to seals |
| 144 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux mig.fish to seals |
| 145 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish to seals |
| 146 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d to seals |
| 147 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s to seals |
| 148 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux birds to seals |
| 149 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux discards to cetaceans |
| 150 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux ominiv.zooplankton to cetaceans |
| 151 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux carniv.zooplankton to cetaceans |
| 152 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux plank.fish to cetaceans |
| 153 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux mig.fish to cetaceans |

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| 154 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux dem.fish to cetaceans |
| 155 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux Benthoss/d to cetaceans |
| 156 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux benthosc/s to cetaceans |
| 157 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux birds to cetaceans |
| 158 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Flux seals to cetaceans |
| 159 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Net production of all secondary and higher trophic levels |
| 160 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Export from secondary producers |
| 161 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish annual spawning |
| 162 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish annual recruitment |
| 163 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish annual spawning |
| 164 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish annual recruitment |
| 165 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d annual spawning |
| 166 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d annual recruitment |
| 167 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/s annual spawning |
| 168 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/sc annual recruitment |
| 169 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish landings live weight |
| 170 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish landings live weight |
| 171 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish landings live weight |
| 172 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish quota limited landings live weight |
| 173 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish non.quota landings live weight |
| 174 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d landings live weight |
| 175 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/s landings live weight |
| 176 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton landings live weight |
| 177 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird landings live weight |
| 178 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal landings live weight |
| 179 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean landings live weight |
| 180 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp landings live weight |
| 181 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish discards |
| 182 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish discards |
| 183 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish discards |

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| 184 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish quota limited discards |
| 185 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish non.quota discards |
| 186 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d discards |
| 187 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/s discards |
| 188 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton discards |
| 189 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird discards |
| 190 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal discards |
| 191 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean discards |
| 192 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp discards |
| 193 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish offal |
| 194 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish offal |
| 195 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish offal |
| 196 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish quota limited offal |
| 197 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish non.quota offal |
| 198 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d offal |
| 199 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/s offal |
| 200 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton offal |
| 201 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird offal |
| 202 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal offal |
| 203 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean offal |
| 204 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp offal |
| 205 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Plank.fish landings processed weight |
| 206 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Mig.fish landings processed weight |
| 207 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish landings processed weight |
| 208 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish quota limited landings processed weight |
| 209 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Dem.fish non.quota landings processed weight |
| 210 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthoss/d landings processed weight |
| 211 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Benthosc/s landings processed weight |
| 212 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Carniv.zooplankton landings processed weight |
| 213 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Bird landings processed weight |

| | | |
|---|---|---|
| 214 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Seal landings processed weight |
| 215 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Cetacean landings processed weight |
| 216 | mMN.y$^{-1}$ in the whole model domain (1 m$^2$) | Kelp landings processed weight |
| 217 | Dimensionless | Area proportion of inshore zone **(only in the *.csv* output file)** |
| 218 | m | Thickness of inshore surface layer **(only in the *.csv* output file)** |
| 219 | m | Thickness of offshore surface layer **(only in the *.csv* output file)** |
| 220 | m | Thickness of offshore deep layer **(only in the *.csv* output file)** |
| 221 | Dimensionless | Area proportion inshore rock **(only in the *.csv* output file)** |
| 222 | Dimensionless | Area proportion inshore sediment s1 **(only in the *.csv* output file)** |
| 223 | Dimensionless | Area proportion inshore sediment s2 **(only in the *.csv* output file)** |
| 224 | Dimensionless | Area proportion inshore sediment s3 **(only in the *.csv* output file)** |
| 225 | Dimensionless | Area proportion offshore rock **(only in the *.csv* output file)** |
| 226 | Dimensionless | Area proportion offshore sediment d1 **(only in the *.csv* output file)** |
| 227 | Dimensionless | Area proportion offshore sediment d2 **(only in the *.csv* output file)** |
| 228 | Dimensionless | Area proportion offshore sediment d3 **(only in the *.csv* output file)** |
| 229 | m | Thickness of inshore sediment layer s1 **(only in the *.csv* output file)** |
| 230 | m | Thickness of inshore sediment layer s2 **(only in the *.csv* output file)** |
| 231 | m | Thickness of inshore sediment layer s3 **(only in the *.csv* output file)** |
| 232 | m | Thickness of offshore sediment layer d1 **(only in the *.csv* output file)** |
| 233 | m | Thickness of offshore sediment layer d2 **(only in the *.csv* output file)** |
| 234 | m | Thickness of offshore sediment layer d3 **(only in the *.csv* output file)** |
| 235 | Dimensionless | Porosity of inshore sediment layer s1 **(only in the *.csv* output file)** |
| 236 | Dimensionless | Porosity of inshore sediment layer s2 **(only in the *.csv* output file)** |
| 237 | Dimensionless | Porosity of inshore sediment layer s3 **(only in the *.csv* output file)** |
| 238 | Dimensionless | Porosity of offshore sediment layer d1 **(only in the *.csv* output file)** |
| 239 | Dimensionless | Porosity of offshore sediment layer d2 **(only in the *.csv* output file)** |
| 240 | Dimensionless | Porosity of offshore sediment layer d3 **(only in the *.csv* output file)** |

**Table 46. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run – row and column details for the dataframe forming the matrix "$flow_matrix_all_fluxes".** These data are for the whole model domain, and the same structure is also output as a standard *.csv* file. The data are in the format expected by the NetIndices package for the derivation of network indices (see Table 47). The rows of the matrix are all the sources of flows in the network - state variables and import sources to the model. The columns are all the destinations for flows in the network - state variables, import sources and export destinations for the model. The matrix contains additional columns (exports to fishery landings and exports to macrophyte beachcast) which are not represented in the rows.

| Row/column number | Row/column name | Details |
|---|---|---|
| 1 | Wcammonia | Water column ammonia |
| 2 | Sedammonia | Sediment porewater ammonia |
| 3 | Wcnitrate | Water column nitrate |
| 4 | Sednitrate | Sediment porewater nitrate |
| 5 | Wcdetritus | Water column detritus and bacteria |
| 6 | Seddetritus | Sediment labile detritus and bacteria |
| 7 | seddetritusR | Sediment refractory detritus |
| 8 | Kelpdebris | Macrophyte debris |
| 9 | Corpses | Corpses |
| 10 | Discards | Fishery discards |
| 11 | Kelp | Macrophytes |
| 12 | Phyt | Phytoplankton |
| 13 | Omnivzoo | Omnivorous zooplankton |
| 14 | Carnzoo | Carnivorous zooplankton |
| 15 | Pfishlar | Larvae of planktivorous fish |
| 16 | Dfishlar | Larvae of demersal fish |
| 17 | Pfish | Planktivorous fish |
| 18 | Mfish | Migratory fish |
| 19 | Dfish | Demersal fish |
| 20 | Benthslar | Larvae of susp/dep feeding benthos |
| 21 | Benthclar | Larvae of carn/scav feeding benthos |

| | | |
|---|---|---|
| 22 | Benths | Susp/dep feeding benthos |
| 23 | Benthc | Carn/scav feeding benthos |
| 24 | Bird | Birds |
| 25 | Seal | Pinnipeds |
| 26 | Ceta | Cetaceans |
| 27 | Ocean | External ocean outside the model domain |
| 28 | Rivers | Rivers flowing into the model domain |
| 29 | Atmosphere | Atmosphere above the model domain |
| 30 | Seabed | Seabed sediments beneath the active modelled layer in the model |
| (31) | Landings | Fishery landings (processed weight) (column-data only) |
| (32) | Beachcast | Macrophyte beachcast (column-data ony) |

**Table 47. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run –** details of the $NetworkIndexReults object containing results generated by the NetIndices R package from the flow matrix data assembled for the final year of a model run. The same data are also output as a standard *.csv* file. The column 'Function in NetIndices' shows the specific function within the NetIndices package which is used to generate each output variable. For details of these functions see the documentation for the R NetIndices package (Kones et al., 2009, Soetaert & Kones, 2014).

| Row number | Row name | Function in NetIndices | Explanation |
|---|---|---|---|
| 1 | wcammonia_trophiclevel | TrophInd | Annual mean tropic level of ammonia (always = 1) |
| 2 | sedammonia_trophiclevel | TrophInd | Annual mean tropic level of sediment ammonia (always = 1) |
| 3 | wcnitrate_trophiclevel | TrophInd | Annual mean tropic level of nitrate (always = 1) |
| 4 | sednitrate_trophiclevel | TrophInd | Annual mean tropic level of sediment nitrate (always = 1) |
| 5 | wcdetritus_trophiclevel | TrophInd | Annual mean tropic level of detritus and bacteria (always = 1) |
| 6 | seddetritus_trophiclevel | TrophInd | Annual mean tropic level of sediment labile detritus and bacteria (always = 1) |
| 7 | seddetritusR_trophiclevel | TrophInd | Annual mean tropic level of refractory detritus (always = 1) |
| 8 | kelpdebris_trophiclevel | TrophInd | Annual mean tropic level of macrophyte debris (always = 1) |
| 9 | corpses_trophiclevel | TrophInd | Annual mean tropic level of corpses (always = 1) |
| 10 | discards_trophiclevel | TrophInd | Annual mean tropic level of fishery discards (always = 1) |

| | | | |
|---|---|---|---|
| 11 | kelp_trophiclevel | TrophInd | Annual mean tropic level of macrophytes (always = 2) |
| 12 | phyt_trophiclevel | TrophInd | Annual mean tropic level of phytoplankton (always = 2) |
| 13 | omnivzoo_trophiclevel | TrophInd | Annual mean tropic level of omnivorous zooplankton |
| 14 | carnzoo_trophiclevel | TrophInd | Annual mean tropic level of carnivorous zooplankton |
| 15 | pfishlar_trophiclevel | TrophInd | Annual mean tropic level of larvae of planktivorous fish |
| 16 | dfishlar_trophiclevel | TrophInd | Annual mean tropic level of larvae of demersal fish |
| 17 | pfish_trophiclevel | TrophInd | Annual mean tropic level of planktivorous fish |
| 18 | mfish_trophiclevel | TrophInd | Annual mean tropic level of migratory fish |
| 19 | dfish_trophiclevel | TrophInd | Annual mean tropic level of demersal fish |
| 20 | benthslar_trophiclevel | TrophInd | Annual mean tropic level of larvae of susp/dep feeding benthos |
| 21 | benthclar_trophiclevel | TrophInd | Annual mean tropic level of larvae of carn/scav feeding benthos |
| 22 | benths_trophiclevel | TrophInd | Annual mean tropic level of susp/dep feeding benthos |
| 23 | benthc_trophiclevel | TrophInd | Annual mean tropic level of carn/scav feeding benthos |
| 24 | bird_trophiclevel | TrophInd | Annual mean tropic level of birds |
| 25 | seal_trophiclevel | TrophInd | Annual mean tropic level of pinnipeds |
| 26 | ceta_trophiclevel | TrophInd | Annual mean tropic level of cetaceans |
| 27 | wcammonia_omnivoryindex | TrophInd | Omnivory index for ammonia (always = 0) |
| 28 | sedammonia_omnivoryindex | TrophInd | Omnivory index for sediment ammonia (always = 0) |
| 29 | wcnitrate_omnivoryindex | TrophInd | Omnivory index for nitrate (always = 0) |
| 30 | sednitrate_omnivoryindex | TrophInd | Omnivory index for sediment nitrate (always = 0) |
| 31 | wcdetritus_omnivoryindex | TrophInd | Omnivory index for detritus and bacteria (always = 0) |
| 32 | seddetritus_omnivoryindex | TrophInd | Omnivory index for sediment labile detritus and bacteria (always = 0) |
| 33 | seddetritusR_omnivoryindex | TrophInd | Omnivory index for sediment refractory detritus (always = 0) |
| 34 | kelpdebris_omnivoryindex | TrophInd | Omnivory index for macrophyte debris (always = 0) |
| 35 | corpses_omnivoryindex | TrophInd | Omnivory index for corpses (always = 0) |
| 36 | discards_omnivoryindex | TrophInd | Omnivory index for fishery discards (always = 0) |
| 37 | kelp_omnivoryindex | TrophInd | Omnivory index for macrophytes |
| 38 | phyt_omnivoryindex | TrophInd | Omnivory index for phytoplankton |
| 39 | omnivzoo_omnivoryindex | TrophInd | Omnivory index for omnivorous zooplankton |

| | | | |
|---|---|---|---|
| 40 | carnzoo_omnivoryindex | TrophInd | Omnivory index for carnivorous zooplankton |
| 41 | pfishlar_omnivoryindex | TrophInd | Omnivory index for larvae of planktivorous fish |
| 42 | dfishlar_omnivoryindex | TrophInd | Omnivory index for larvae of demersal fish |
| 43 | pfish_omnivoryindex | TrophInd | Omnivory index for planktivorous fish |
| 44 | mfish_omnivoryindex | TrophInd | Omnivory index for migratory fish |
| 45 | dfish_omnivoryindex | TrophInd | Omnivory index for demersal fish |
| 46 | benthslar_omnivoryindex | TrophInd | Omnivory index for larvae of susp/dep feeding benthos |
| 47 | benthclar_omnivoryindex | TrophInd | Omnivory index for larvae of carn/scav feeding bnenthos |
| 48 | benths_omnivoryindex | TrophInd | Omnivory index for susp/dep feeding benthos |
| 49 | benthc_omnivoryindex | TrophInd | Omnivory index for carn/scav feeding bnenthos |
| 50 | bird_omnivoryindex | TrophInd | Omnivory index for birds |
| 51 | seal_omnivoryindex | TrophInd | Omnivory index for pinnipeds |
| 52 | ceta_omnivoryindex | TrophInd | Omnivory index for cetaceans |
| 53 | Ascendency_total | AscInd | Total ascendency of the network |
| 54 | Ascendency_internal | AscInd | Ascendency excluding external inflows and outflows |
| 55 | Ascendency_import | AscInd | Ascendency - import flows |
| 56 | Ascendency_external | AscInd | Ascendency - export flows including dissipation |
| 57 | Ascendency_dissipation | AscInd | Ascendency – usable and unusable flows |
| 58 | Overhead_total | AscInd | Total overhead of the network |
| 59 | Overhead_internal | AscInd | Overhead excluding external inflows and outflows |
| 60 | Overhead_import | AscInd | Overhead - import flows |
| 61 | Overhead_external | AscInd | Overhead - export flows including dissipation |
| 62 | Overhead_dissipation | AscInd | Overhead – usable and unusable flows |
| 63 | Capacity_total | AscInd | Total capacity of the network |
| 64 | Capacity_internal | AscInd | Capacity excluding external inflows and outflows |
| 65 | Capacity_import | AscInd | Capacity - import flows |
| 66 | Capacity_external | AscInd | Capacity - export flows including dissipation |
| 67 | Capacity_dissipation | AscInd | Capacity – usable and unusable flows |
| 68 | ACratio_total | AscInd | Ratio of total ascendency to total capacity |

| | | | |
|---|---|---|---|
| 69 | ACratio_internal | AscInd | Ascendency/capacity - excluding external inflows and outflows |
| 70 | ACratio_import | AscInd | Ascendency/capacity - import flows |
| 71 | ACratio_external | AscInd | Ascendency/capacity - export flows including dissipation |
| 72 | ACratio_dissipation | AscInd | Ascendency/capacity – usable and unusable flows |
| 73 | Total_system_cycled_thoughflow_TSTC | PathInd | Total system cycled thoughflow (TSTC) |
| 74 | Non_cycled_throughflow_TSTS | PathInd | Non cycled throughflow (TSTS) |
| 75 | Finns_cycling_index_FCI | PathInd | Finns cycling index (FCI) |
| 76 | Revised_Finns_cycling_index_FCIb | PathInd | Revised Finns cycling index (FCIb) |
| 77 | Average_path_length | PathInd | Average path length |
| 78 | Number_of_compartments_N | GenInd | Number of compartments (N) |
| 79 | Total_system_throughput_T | GenInd | Total system throughput (T) |
| 80 | Total_system_throughflow_TST | GenInd | Total system throughflow (TST) |
| 81 | Number_of_internal_links_Lint | GenInd | Number of internal links (Lint) |
| 82 | Total_number_of_links_Ltot | GenInd | Total number of links (Ltot) |
| 83 | Link_density_LD | GenInd | Link density (LD) |
| 84 | Connectance_C | GenInd | Connectance © |
| 85 | Average_link_weight_Tijbar | GenInd | Average link weight (Tijbar) |
| 86 | Average_compartment_thoughflow_TSTbar | GenInd | Average compartment thoughflow (TSTbar) |
| 87 | Compartmentalization_Cbar | GenInd | Compartmentalization (Cbar) |
| 88 | Network_aggradation_NAG | EnvInd | Network aggradation (NAG) |
| 89 | Homogenization_index_HP | EnvInd | Homogenization index (HP) |
| 90 | Synergism_BC | EnvInd | Synergism (BC) |
| 91 | Dominance_of_indirect_effects_ID | EnvInd | Dominance of indirect effects (ID) |
| 92 | Mean_of_non_dimension_flowmatrix_MN | EnvInd | Mean of non-dimensional flowmatrix (MN) |
| 93 | Mean_of_direct_flowmatrix_MG | EnvInd | Mean of direct flowmatrix (MG) |
| 94 | CV_of_non_dimension_flowmatrix_MN | EnvInd | CV of non-dimensional flowmatrix (MN) |
| 95 | CV_of_direct_flowmatrix_MG | EnvInd | CV of direct flowmatrix (MG) |
| 96 | Effective_connectance_CZ | EffInd | Effective connectance (CZ) |
| 97 | Effective_flows_FZ | EffInd | Effective flows (FZ) |

| | | | |
|---|---|---|---|
| 98 | Effective_nodes_NZ | EffInd | Effective nodes (NZ) |
| 99 | Effective_roles_RZ | EffInd | Effective roles (RZ) |

**Table 48. Details of data-object within the "$final.year.outputs" object of the main results list generated by the model run –** details of the **$opt_results** object containing the model outputs corresponding to the set of observational indices to which the model parameters are optimized by the simulated annealing schemes in the package. The dataframe merges some of the columns of the target data set (Tables 25, 26) with the model outputs. The row details are as Table 26. This table provides the Column details of the datafarme.

| Column number | Column name | Description |
|---|---|---|
| 1 | Annual_measure | Numeric value of the oibservational measure specified by the description in column "Name". Missing values denoted by NA (from Table 25). |
| 2 | SD_of_measure | Standard deviation of the observational measure. Missing values denoted by NA (from Table 25). |
| 3 | Model_data | Model output value corresponding to the observational measure |
| 4 | Use1_0 | Switch setting to determine whether the measure is included in likelihood calculations (1 = yes, 0 = no) (from Table 25). |
| 5 | Chi | "Error tem" between the observed and modelled values of a term (i) in the observational target data set $\chi^2_{\theta i^*} = \sum_{i=1}^{i=I}\left(\frac{\left(observed_i - simulated_{\theta^*,i}\right)^2}{2\sigma_i^2}\right)$, given the parameter vector $\theta^*$. The partial likelihood fof the observed vakue gien the parameters is then $P(observations\|\theta_i^*) = \exp(-\chi^2_{\theta_i^*})$ |
| 6 | Name | Name used to identify the measure in the model code (from Table 25). |
| 7 | Units | Units of the annual measure (from Table 25). |
| 8 | Description | Text describing each measure (from Table 25). |

## Writing your own code to extract and process data from the single-run output object

The ..$final.year.outputs element of the list object created by a model run, and the corresponding *.csv* files which are output to the results folder, contain a comprehensive set of derived results from the final year of a simulation. However, users may wish to generate their own additional derivatives, and guidance on how to do this is set out here.

For a set of model results created using the e2e_read() and e2e_run() functions :

```
model <- e2e_read(model.name, model.variant, model.ident = "base", model.subdir = "", user.path = "")
results <- e2e_run(model, nyears)
```

The raw data from the model run are contained in the objects results$output and results$aggregates.

The first row of the “$output” (and “$aggregates”) dataframe corresponds to time=0, i.e. the initial conditions passed to the differential equation solver at the start of the run. A calendar year of output corresponds to a time interval of 360 days, i.e. 361 rows of output data (time = 0:360), so the total number of rows of output will be ((360*nyears)+1), where nyears is the specified length of the model run in years.

Assuming that the “$output” (or “$aggregates”) dataframe has been extracted from the results object into a named dataframe “*out*” as follows:

```
out <- results$output
```

Data for any one year specified by *Y* (*Y* ≤ *nyears*) can be extracted by the R statement:

```
# all the output corresponding to year Y (e.g. Y<-2)
    Y<-2
    out[(((Y-1)*360)+1) : ((Y*360)+1),]

# All the output for a given state variable (e.g. “phyt_si”) in year Y
    out$phyt_si[(((Y-1)*360)+1) : ((Y*360)+1)]
```

To obtain annual average mass of a state variable over a given year, the R statement would be:

```
mean(out$phyt_si[(((Y-1)*360)+1) : ((Y*360)+1)])
                                                    # mean for state variable phyt_si over year Y
```

The flux terms in the dataframe are cumulative over the duration of the model run, beginning at 0 at time = 0. Hence, the time-series of instantaneous flux rates ($d^{-1}$) is the sequence of increments between successive rows of output. In R this can be generated e.g. for the column name “fluxphyt_omni”, by:

```
J <- nrow(out)                          # number of rows of data in the “out” dataframe
temp <- rep(0,J)                        # creates a vector to hold temporary data
temp[1: (J-1)] <- out$fluxphyt_omni[2 : J]# copies data from the “out” into “temp” offset by 1 time increment
temp[J] <- 2*(out$fluxphyt_omni[J]) - out$fluxphyt_omni[J-1]
                                                    # fills in the terminal value of the “temp” vector by extraplotion
rate <- temp - out$fluxphyt_omni        # “rate” is a vector of the increments between successive time steps
```

To obtain the annual integral of a flux variable over a given year, the R statement would be:

```
out$fluxphyt_omni[((Y*360)+1)] - out$fluxphyt_omni[(((Y-1)*360)+1)]
                                                    # integrated flux denoted by “fluxphyt_omni” over year Y
```

All of the terms in the *$output* dataframe are in mass units (mMN or mMC) in the model domain which is is scaled to a sea-surface area of 1 $m^2$. To express the outputs as area densities in the inshore or offshore zones (e.g. $mMN.m^{-2}$) or layer concentrations (e.g. $mMN.m^{-3}$), the mass values need to be re-scaled to the area-proportion of the relevant zone and/or layer thickness. In addition, terms relating to sediment or sediment porewater require to be scaled by the area-proportions of seabed habitats, sediment layer thicknesses and sediment porosity. These scaling parameters are accessible to the user as elements of the object *..$build$model.parameters* which forms part of the list-object generated by a model run as shown in Table 38. Examples of R statements for converting mass outputs into area-densities and layer concentrations are shown below.

```
# Run the model and extract the $output object into a dataframe
    model <- e2e_read("North_Sea", "1970-1999")
    results <- e2e_run(model,nyears=5)
    out <- results$output
```

```
# Extract some relevant area and volumetric parameters from the $build$model.parameters object (named vector)
        inshore_area       <- as.numeric(results$build$model.parameters["shallowprop"])
        offshore_upper_thick <- as.numeric(results$build$model.parameters["thik_so"])
        offshore_lower_thick <- as.numeric(results$build$model.parameters["thik_d"])
        inshore_sed1_area    <- as.numeric(results$build$model.parameters["area_s1"])
        inshore_sed1_thick   <- as.numeric(results$build$model.parameters["thik_x_s1"])
        inshore_sed1_poros   <- as.numeric(results$build$model.parameters["porosity_s1"])

# Time series of suspended detritus and bacteria concentration in the offshore upper layer (mMN.m-3)
        out$detritus_so/((1-inshore_area)*offshore_upper_thick)

# Time series of the area-density of omnivorous zooplankton in the inshore zone (mMN.m-2)
        out$omni_i/inshore_area

# Time series of the depth averaged concentration of omnivorous zooplankton in the offshore zone (mMN.m-3)
        out$omni_i/inshore_area

# Time series of the porewater concentration of ammonia in inshore sediment habitat 1 (mMN.m-3):
        out$x_ammonia_s1/(inshore_sed1_area*inshore_sed1_thick*inshore_sed1_poros)

# Time series of labile detritus & bacterial in inshore sediment habitat 1 as a % of sediment dry weight (%gN.g-1):
        100*(out$xR_detritus_s1*(14/1000))/(inshore_sed1_area*inshore_sed1_thick*(1-inshore_sed1_poros)*2650000 )
                # (nitrogen atomic weight = 14 g.mole-1; dry sediment density = quartz density = 2.65 x 10^6 g.m-3)
```

**OUTPUTS FROM OPTIMIZATION OF ECOLOGY MODEL PARAMETERS**

The function

e2e_optimize_eco()

uses simulated annealing to seek a set of ecology model parameters which maximizes the likelihood of the observed annual target data on the state of the ecosystem (in the file */Target_data/ annual_target_data*.csv*) given the model structure, drivers, and the fixed ecology and fishing fleet parameters.

In this case, the input files for initilaising a simulated annealing run MUST be located in a user-workspace folder (identified by the user.path argument), since the simulated annealing function writes the best-fit parameter files back into the model variant folder (the North Sea model variant folders embedded in the package are read-only). The *MODEL_SETUP.csv* file in the user model/variant folder should point to input files of ecology model parameters which represent initial guesses of the eventual best fit values.

The ecology model parameter files written back into the */Parameters* subfolder of the model/variant folder at the end of a simulated annealing run are:

*fitted_parameters_preference_matrix-*.csv* (see Table 11)
*fitted_parameters_uptake_and_mortality_rates-*.csv* (see Table 12)
*fitted_parameters_microbiology_and_others-*.csv* (see Table 13)

where the identifier (*) is set by the argument model.ident in the e2e_read() function call which loads the initial model setup.

On completion of a simulated annealing run, the *MODEL_SETUP.csv* file should then be manully edited to point to the newly created parameter files instead of the previous initial guesses before any new e2e_read() function calls and model runs are carried out.

In addition to writing the final best-fit parameters back to ecology model files in the */Parameters* folder, the simulated annealing function returns the history of “proposed” and “accepted” parameter sets and the associated likelihoods as dataframes within a list and optionally saves them to *.csv* files in the current default */results/model/variant* folder. The address for this folder can be set by the model.subdir argument in the e2e_read() function call.

File names for the ‘proposed’ and ‘accepted’ history files generated by the function are as follows:

*annealing_par-proposalhistory-*.csv*
*annealing_par-acceptedhistory-*.csv*

where the identifier (*) is set by the argument model.ident in the e2e_read() function call which loads the initial model setup.

The "proposed" and "accepted" parameter history data files both have the same structure – rows are sequential iterations of the parameter set, columns are the individual parameters, with the addition of a final column providing the likelihood of the target data (Table 49). Proposed values are variants from the most recent accepted set. New proposals are tested until a likelihood threshold is exceeded whereupon the current proposal becomes a new accepted. For details of the methodology see the separate document on Parameter optimization, sensitivity and Monte Carlo analysis accessible via links in the package overview - help(StrathE2E2).

The new parameter files which are written back into the */Parameters* sub-folder of *the model/variant* folder are assembled from the final row of the 'accepted' parameter history.

**Table 49. Column names and description for 'proposed' and 'accepted' parameter history files output from the e2e_optimize_eco() function.**

| Column number | Column name | Parameter description |
|---|---|---|
| 1 | PREF_NIT_kelp | Preference for uptake of nitrate uptake by macrophytes |
| 2 | PREF_AMM_kelp | Preference for uptake of ammonia uptake by macrophytes |
| 3 | PREF_NIT_phyt | Preference for uptake of nitrate uptake by phytoplankton |
| 4 | PREF_AMM_phyt | Preference for uptake of ammonia uptake by phytoplankton |
| 5 | PREF_phyt_omni | Preference for uptake of phytoplankton by omnivorous zooplankton |
| 6 | PREF_det_omni | Preference for uptake of suspended detritus by omnivorous |
| 7 | PREF_benthslar_omni | Preference for uptake of larvae of susp/dep feeding benthos by omnivorous zooplankton |
| 8 | PREF_benthclar_omni | Preference for uptake of larvae of carn/scav feeding benthos by omnivorous zooplankton |
| 9 | PREF_omni_carn | Preference for uptake of omnivorous zooplankton by carnivorous zooplankton |
| 10 | PREF_benthslar_carn | Preference for uptake of larvae of susp/dep feeding benthos by carnivorous zooplankton |
| 11 | PREF_benthclar_carn | Preference for uptake of larvae of carn/scav feeding benthos by carnivorous zooplankton |
| 12 | PREF_fishplar_carn | Preference for uptake of larvae of planktivorous fish by carnivorous zooplankton |
| 13 | PREF_fishdlar_carn | Preference for uptake of larvae of demersal fish by carnivorous zooplankton |
| 14 | PREF_omni_fishplar | Preference for uptake of omnivorous zooplankton by larvae of planktivorous fish |

| | | |
|---|---|---|
| 15 | PREF_benthslar_fishplar | Preference for uptake of larvae of susp/dep feeding benthos by larvae of planktivorous fish |
| 16 | PREF_benthclar_fishplar | Preference for uptake of larvae of carn/scav feeding benthos by larvae of planktivorous fish |
| 17 | PREF_omni_fishp | Preference for uptake of omnivorous zooplankton planktivorous fish |
| 18 | PREF_carn_fishp | Preference for uptake of carnivorous zooplankton planktivorous fish |
| 19 | PREF_benthslar_fishp | Preference for uptake of larvae of susp/dep feeding benthos by planktivorous fish |
| 20 | PREF_benthclar_fishp | Preference for uptake of larvae of carn/scav feeding benthos by planktivorous fish |
| 21 | PREF_fishdlar_fishp | Preference for uptake of larvae of demersal fish by planktivorous fish |
| 22 | PREF_fishplar_fishp | Preference for uptake of larvae of planktivorous fish by planktivorous fish |
| 23 | PREF_omni_fishm | Preference for uptake of omnivorous zooplankton by migratory fish |
| 24 | PREF_carn_fishm | Preference for uptake of carnivorous zooplankton migratory fish |
| 25 | PREF_benthslar_fishm | Preference for uptake of larvae of susp/dep feeding benthos by migratory fish |
| 26 | PREF_benthclar_fishm | Preference for uptake of larvae of carn/scav feeding benthos by migratory fish |
| 27 | PREF_fishdlar_fishm | Preference for uptake of larvae of demersal fish by migratory fish |
| 28 | PREF_fishplar_fishm | Preference for uptake of larvae of planktivorous fish by migratory fish |
| 29 | PREF_omni_fishdlar | Preference for uptake of omnivorous zooplankton by larvae of demersal fish |
| 30 | PREF_benthslar_fishdlar | Preference for uptake of larvae of susp/dep feeding benthos by larvae of demersal fish |
| 31 | PREF_benthclar_fishdlar | Preference for uptake of larvae of carn/scav feeding benthos by larvae of demersal fish |
| 32 | PREF_carn_fishd | Preference for uptake of carnivorous zooplankton by demersal fish |
| 33 | PREF_benths_fishd | Preference for uptake of susp/dep feeding benthos by demersal fish |
| 34 | PREF_benthc_fishd | Preference for uptake of carn/scav feeding benthos by demersal fish |
| 35 | PREF_fishplar_fishd | Preference for uptake of larvae of planktivorous fish by demersal fish |
| 36 | PREF_fishdlar_fishd | Preference for uptake of larvae of demersal fish by demersal fish |
| 37 | PREF_fishp_fishd | Preference for uptake of planktivorous fish by demersal fosh |
| 38 | PREF_fishm_fishd | Preference for uptake of migratory fish by demersal fish |
| 39 | PREF_fishd_fishd | Preference for uptake of demersal fish by demersal fish |
| 40 | PREF_disc_fishd | Preference for uptake of discards by demersal fish |
| 41 | PREF_corp_fishd | Preference for uptake of corpses by demersal fish |
| 42 | PREF_phyt_benthslar | Preference for uptake of phytoplankton by larvae of susp/dep feeding benthos |
| 43 | PREF_phyt_benthclar | Preference for uptake of phytoplankton by larvae of carn/scav feeding benthos |
| 44 | PREF_det_benthslar | Preference for uptake of suspended detritus by larvae of susp/dep feeding benthos |

| | | |
|---|---|---|
| 45 | PREF_det_benthclar | Preference for uptake of suspended detritus by larvae of carn/scav feeding benthos |
| 46 | PREF_phyt_benths | Preference for uptake of phytoplankton by susp/dep feeding benthos |
| 47 | PREF_det_benths | Preference for uptake of suspended detritus by susp/dep feeding benthos |
| 48 | PREF_sed_benths | Preference for uptake of sediment detritus by susp/dep feeding benthos |
| 49 | PREF_kelp_benthc | Preference for uptake of macrophytes by carn/scav feeding benthos |
| 50 | PREF_kelpdebris_benthc | Preference for uptake of macrophyte debris by carn/scav feeding benthos |
| 51 | PREF_benths_benthc | Preference for uptake of susp/dep feeding benthos by carn/scav feeding benthos |
| 52 | PREF_corp_benthc | Preference for uptake of corpses by carn/scav feeding benthos |
| 53 | PREF_carn_bird | Preference for uptake of carnivorous zooplankton by birds |
| 54 | PREF_benths_bird | Preference for uptake of susp/dep feeding benthos by birds |
| 55 | PREF_benthc_bird | Preference for uptake of carn/scav feeding benthos by birds |
| 56 | PREF_fishp_bird | Preference for uptake of planktivorous fish by birds |
| 57 | PREF_fishm_bird | Preference for uptake of migratory fish by birds |
| 58 | PREF_fishd_bird | Preference for uptake of demersal fish by birds |
| 59 | PREF_disc_bird | Preference for uptake of discards by birds |
| 60 | PREF_corp_bird | Preference for uptake of corpses by birds |
| 61 | PREF_carn_seal | Preference for uptake of carnivorous zooplankton by pinnipeds |
| 62 | PREF_benths_seal | Preference for uptake of susp/dep feeding benthos by pinniped |
| 63 | PREF_benthc_seal | Preference for uptake of carn/scav feeding benthos by pinniped |
| 64 | PREF_fishp_seal | Preference for uptake of planktivorous fish by pinniped |
| 65 | PREF_fishm_seal | Preference for uptake of migratory fish by pinniped |
| 66 | PREF_fishd_seal | Preference for uptake of demersal fish by pinniped |
| 67 | PREF_bird_seal | Preference for uptake of birds by pinnipeds |
| 68 | PREF_disc_seal | Preference for uptake of discards by pinnipeds |
| 69 | PREF_corp_seal | Preference for uptake of corpses by pinnipeds |
| 70 | PREF_omni_ceta | Preference for uptake of omnivorous zooplanktoin by cetaceans |
| 71 | PREF_carn_ceta | Preference for uptake of carnivorous zooplankton by cetaceans |
| 72 | PREF_benths_ceta | Preference for uptake of susp/dep feeding benthos by cetaceans |
| 73 | PREF_benthc_ceta | Preference for uptake of carn/scav feeding benthos by cetaceans |
| 74 | PREF_fishp_ceta | Preference for uptake of planktivorous fish by cetaceans |

| | | |
|---|---|---|
| 75 | PREF_fishm_ceta | Preference for uptake of migratory fish by cetaceans |
| 76 | PREF_fishd_ceta | Preference for uptake of demersal fish by cetaceans |
| 77 | PREF_bird_ceta | Preference for uptake of birds by cetaceans |
| 78 | PREF_seal_ceta | Preference for uptake of pinnipeds by cetaceans |
| 79 | PREF_disc_ceta | Preference for uptake of discards by cetaceans |
| 80 | uC_kelp | Maximum carbon uptake rate of macrophytes at the Q10 reference temperature |
| 81 | ddexudC_kelp | Density dependent exudation rate parameter for macrophytes |
| 82 | u_kelp | Maximum nitrogen uptake rate of macrophytes at the Q10 reference temperature |
| 83 | u_phyt | Maximum uptake rate of phytoplankton at the Q10 reference temperature |
| 84 | u_omni | Maximum uptake rate of omnivorous zooplankton at the Q10 reference temperature |
| 85 | u_carn | Maximum uptake rate of carnivorous zooplankton at the Q10 reference temperature |
| 86 | u_fishplar | Maximum uptake rate of larvae of planktivorous fish at the Q10 reference temperature |
| 87 | u_fishp | Maximum uptake rate of at the Q10 reference temperature |
| 88 | u_fishm | Maximum uptake rate of at the Q10 reference temperature |
| 89 | u_fishdlar | Maximum uptake rate of at the Q10 reference temperature |
| 90 | u_fishd | Maximum uptake rate of at the Q10 reference temperature |
| 91 | u_benthslar | Maximum uptake rate of at the Q10 reference temperature |
| 92 | u_benthclar | Maximum uptake rate of at the Q10 reference temperature |
| 93 | u_benths | Maximum uptake rate of at the Q10 reference temperature |
| 94 | u_benthc | Maximum uptake rate of at the Q10 reference temperature |
| 95 | u_bird | Maximum uptake rate of at the Q10 reference temperature |
| 96 | u_seal | Maximum uptake rate of at the Q10 reference temperature |
| 97 | u_ceta | Maximum uptake rate of at the Q10 reference temperature |
| 98 | h_kelp | Half-saturation coefficient for uptake by macrophytes |
| 99 | h_phyt | Half-saturation coefficient for uptake by phytoplankton |
| 100 | h_omni | Half-saturation coefficient for uptake by omnivorous zooplankton |
| 101 | h_carn | Half-saturation coefficient for uptake by carnivorous zooplankton |
| 102 | h_fishplar | Half-saturation coefficient for uptake by larvae of planktivorous fish |
| 103 | h_fishp | Half-saturation coefficient for uptake byplanktivorous fish |
| 104 | h_fishm | Half-saturation coefficient for uptake by migratory fish |

| | | |
|---|---|---|
| 105 | h_fishdlar | Half-saturation coefficient for uptake by larvae of demersal fish |
| 106 | h_fishd | Half-saturation coefficient for uptake by demersal fish |
| 107 | h_benthslar | Half-saturation coefficient for uptake by larvae of susp/dep feeding benthos |
| 108 | h_benthclar | Half-saturation coefficient for uptake by larvae of carn/scav feeding benthos |
| 109 | h_benths | Half-saturation coefficient for uptake by susp/dep feeding benthios |
| 110 | h_benthc | Half-saturation coefficient for uptake by carn/scav feeding benthos |
| 111 | h_bird | Half-saturation coefficient for uptake by birds |
| 112 | h_seal | Half-saturation coefficient for uptake by pinnipeds |
| 113 | h_ceta | Half-saturation coefficient for uptake by cetaceans |
| 114 | bda_par_bird | Beddington-DeAngelis uptake coefficient for birds |
| 115 | bda_par_seal | Beddington-DeAngelis uptake coefficient for pinnipeds |
| 116 | bda_par_ceta | Beddington-DeAngelis uptake coefficient for cetaceans |
| 117 | xmt | Water column detritus mineralisation rate at Q10 reference temperature |
| 118 | xnst | Upper layer water column ammonia nitrification rate at Q10 reference temperature |
| 119 | xdst | Upper layer water column nitrate nitrification rate at Q10 reference temperature |
| 120 | xndt | Lower layer water column ammonia nitrification rate at Q10 reference temperature |
| 121 | xddt | Lower layer water column nitrate nitrification rate at Q10 reference temperature |
| 122 | xqs_p1 | Proportion of sediment detritus or corpses converted to refractory detritus during the mineralisation or disintegration process |
| 123 | xqs_p2 | Mineralisation rate of refractory detritus is a proportion of the ambient rate for labile sediment detritus |
| 124 | xqs_p3 | Proportion of ingested refractory detritus digestible by benthos |
| 125 | xmsedt | Sediement detritus mineralisation rate in reference grain size and Q10 referencce temperatre |
| 126 | xmsens | Grain size sensitivity for sediment mineralisation rate |
| 127 | xnsedt | Sediement ammonia nitrification rate in reference grain size and Q10 referencce temperatre |
| 128 | xnsens | Grain size sensitivity for sediment nitrification rate |
| 129 | xdsedt | Sediement nitrate denitrification rate in reference grain size and Q10 referencce temperatre |
| 130 | xdsens | Grain size sensitivity for sediment denitrification rate |
| 131 | xdisc_corp | Conversion rate of discards to corpses |
| 132 | xxcorp_det | Conversion rate of corpses to detritus at Q10 reference temperature |
| 133 | xkelpdebris_det | Conversion rate of macrophyte debris to detritus at Q10 reference temperature |

| | | |
|---|---|---|
| 134 | xdsink_s | Suspended detritus sinking rate in the upper layers |
| 135 | xdsink_d | Suspended detruts sinking rate in the lower layer |
| 136 | xkelpshade | Self-shading coefficient for macrophytes |
| 137 | xwave_kelpdebris | Coefficent for wave-dependent export of macrophyte debris to beach-cast |
| 138 | xdfdp | Fitting coefficient for demersal fish nitrogen mass in the model to survey biomass |
| 139 | xxwave_kelp | Density dependent sensitivity of macrophytes to destruction by wave action |
| 140 | xxst | Density dependent mortality coefficient for phytoplankton in the upper layer |
| 141 | xxdt | Density dependent mortality coefficient for phytoplankton in the lower layer |
| 142 | xxomni | Density dependent mortality coefficient for omnivorous zooplankton |
| 143 | xxcarn | Density dependent mortality coefficient for carnivorous zooplankton |
| 144 | xxbenthslar | Density dependent mortality coefficient for larvae of susp/dep feeding benthos |
| 145 | xxbenthclar | Density dependent mortality coefficient for larvae of carn/scav feedinmg benthos |
| 146 | xxbenths | Density dependent mortality coefficient for susp/dep feeding benthos |
| 147 | xxbenthc | Density dependent mortality coefficient for carn/scav feeding benthos |
| 148 | xxpfishlar | Density dependent mortality coefficient for larvae of planktivorous fish |
| 149 | xxdfishlar | Density dependent mortality coefficient for larvae of demersal fish |
| 150 | xxpfish | Density dependent mortality coefficient for planktivorous fish |
| 151 | xxmfish | Density dependent mortality coefficient for migratory fish |
| 152 | xxdfish | Density dependent mortality coefficient for demersal fish |
| 153 | xxbird | Density dependent mortality coefficient for birds |
| 154 | xxseal | Density dependent mortality coefficient for pinnipeds |
| 155 | xxceta | Density dependent mortality coefficient for cetaceans |
| 156 | xpfish_migcoef | Active migration coefficient for planktivorous fish |
| 157 | xmfish_migcoef | ctive migration coefficient for migratory fish |
| 158 | xdfish_migcoef | ctive migration coefficient for demersal fish |
| 159 | xbird_migcoef | ctive migration coefficient for birds |
| 160 | xseal_migcoef | ctive migration coefficient for pinnipeds |
| 161 | xceta_migcoef | ctive migration coefficient for cetaceans |
| 162 | xmax_exploitable_f_KP | Maximum exploitable fration of biomass for macrophytes |
| 163 | xmax_exploitable_f_PF | Maximum exploitable fration of biomass for planktivorous fish |

| | | |
|---|---|---|
| 164 | xmax_exploitable_f_DF | Maximum exploitable fration of biomass for demersal fish |
| 165 | xmax_exploitable_f_MF | Maximum exploitable fration of biomass for migratory fish |
| 166 | xmax_exploitable_f_SB | Maximum exploitable fration of biomass for susp/dep feeding benthos |
| 167 | xmax_exploitable_f_CB | Maximum exploitable fration of biomass for carn/scav feeding benthos |
| 168 | xmax_exploitable_f_CZ | Maximum exploitable fration of biomass for carnivorous zooplankton |
| 169 | xmax_exploitable_f_BD | Maximum exploitable fration of biomass for birds |
| 170 | xmax_exploitable_f_SL | Maximum exploitable fration of biomass for pinnipeds |
| 171 | xmax_exploitable_f_CT | Maximum exploitable fration of biomass for cetaceans |
| 172 | annual_obj | Likelihood of the target data given the model, driving data and parameters |

**OUTPUTS FROM OPTIMIZATION OF HARVEST RATIO SCALING PARAMETERS**

The function

```
e2e_optimize_hr()
```

uses simulated annealing to seek a set of harvest ratio scaling parameters which maximize the likelihood of the observed annual target data (in the file */Target_data/ annual_target_data*.csv*) given the model structure, drivers, ecology parameters and fishing gear activity rates. This scheme would be used in a situation where ecology model parameters and gear gear activity rates are known or can be adopted e.g. from a neighbouring or similar region, but individual gear catching efficiencies (linking effort to harvest ratio) are unknown.

The argument model is the list object created by the e2e_read() function, exactly as for a basic single run of the model.

```
e2e_read(model.name, model.variant, model.ident = "base", model.subdir = "", user.path = "")
```

Harvest ratios of each resource guild in the ecology model are proportional to the fishing effort directed to each guild integrated across all gears, and scaled by a proportionality coefficient. 'Effort' is the product of activity and power for reach gear, and the integration across gears is performed by the fleet model. The proportionality coefficients are presented to the fleet model in rows 12-20 of the input file *fishing_fleet_parameters-*.csv* (see Table 14). In the process of constructing a model, these parameters need to be simply calculated if the harvest ratios are known from independent data anlaysis (see the function e2e_calculate_hrscale()), or fitted as described here using the e2e_optimize_hr() if the actual harvest ratios are unknown.

The actual harvest ratios which are applied in the ecology model are the product of values for each guild derived from gerar activity rates, power parameters and harvest ratio scaling values by the fleet model, and a set of multipler values for each guild coinhtauined in the input file */Parameters/harvest_ratio_multiplier-*.csv* (see Table 22). These multipliers are provided to facilitate the easy design of scenario experiments with the model. Starting from an initial combinatioin of harvest ratio scaling parameters in *fishing_fleet_parameters-*.csv* and multiplers in *harvest_ratio_multiplier-*.csv,* the e2e_optimize_hr() function generates a news set of multipliers which produces the maximum likelihood of the observed target data.

The new multiplier values generated at the end of simulated annealing run are written back to the */Parameters* folder for the model/variant, in a as a new version of *harvest_ratio_multiplier-*.csv* with an identifier defined by the model.ident argument in the initial e2e_read() call. Should the user wish to adopt the fitted activity rates in future runs, then there are two options:

1. Edit the *MODEL_SETUP.csv* file to point to the new version of *harvest_ratio_multiplier-*.csv*
2. Create a new version of *fishing_fleet_parameters-*.csv* in which the harvest ratio scaling parameters in rows 12-20 are the product of the original values and the new multiplier values; create a version of *harvest_ratio_multiplier-*.csv* in which the values are 1.0 for all guilds; and edit *MODEL_SETUP.csv* accordingly.

In addition to writing the final best-fit set of multiplier values back to the */Parameters* folder, the simulated annealing function returns the history of "proposed" and "accepted" parameter sets and the associated likelihoods as dataframes in a list object, and optionally saves them to *.csv* files in the current default */results/model/variant* folder. The address for this folder can be set by the model.subdir argument in the e2e_read() function call.

File names for the 'proposed' and 'accepted' history files generated by the function are as follows:

*annealing_HRmult_proposalhistory-*.csv*
*annealing_HRmult_acceptedhistory-*.csv*

where the identifier (*) is set by the argument model.ident in the e2e_read() function call which loads the initial model setup.

The "proposed" and "accepted" parameter history data files both have the same structure – rows are sequential iterations of the parameter set, columns are the multipliers for each model guild, with the addition of a final column providing the likelihood of the target data (Table 53). Proposed values are variants from the most recent accepted set. New proposals are tested until a likelihood threshold is exceeded whereupon the current proposal becomes a new accepted. For details of the methodology see the separate document on Parameter optimization, sensitivity and Monte Carlo analysis accessible via links in the package overview - help(StrathE2E2).

The new set of multiplier values which is written back into the */Parameters* sub-folder is assembled from the final row of the 'accepted' parameter history.

**Table 53. Column names and description for 'proposed' and 'accepted' parameter history files output from the** e2e_optimize_hr() **function.**

| Column number | Column name | Parameter description |
|---|---|---|
| 1 | PF | Multiplier applied to planktivorous fish |
| 2 | DF | Multiplier applied to demersal fish |
| 3 | MF | Multiplier applied to migratory fish |
| 4 | Bfd | Multiplier applied to susp/dep feeding benthos |
| 5 | Bcs | Multiplier applied to carn/scav feeding benthos |
| 6 | Zc | Multiplier applied to carnivorous zooplankton |
| 7 | BD | Multiplier applied to birds |
| 8 | SL | Multiplier applied to pinnipeds |
| 9 | CT | Multiplier applied to cetaceans |
| 10 | KP | Multiplier applied to macrophytes |
| 11 | Lik | Likelihood of the target data given the model, driving data, parameters and harvest ratio scalings |

**OUTPUTS FROM OPTIMIZATION OF FISHING GEAR ACTIVITY RATES AGAINST ECOSYSTEM TARGET DATA**

The function

e2e_optimize_act(… ,selection="ECO", …)

uses simulated annealing to seek a set of fishing gear activity rates which maximize the likelihood of the observed annual target data on the state of the ecosystem (in the file */Target_data/ annual_target_data*.csv*) given the model structure, drivers, and ecology and other fishing fleet parameters. This scheme would be used in a situation where ecology model parameters and gear efficiencies are known or can be adopted e.g. from a neighbouring or similar region, but individual gear activity rates and harvest ratios are unknown.

Activity rates of gears within the model are set by product of two input data sets – the activity densities defined in the file */Parameters/ fishing_activity_parameters-*.csv* (Table 16), and the activity rate multiplier values in the file */Parameters/fishing_activity_multiplier-*.csv* (Table 21). Typically, the baseline configuration of a model variant would be defined by the activity densities with the multipliers set to 1.0, and subsequent scenarios designed by manipulating the multipliers.

The initial activity conditions for an e2e_optimize_act(.. , selection="ECO", ,,) run (defined by the pointers to input files in *MODEL_SETUP.csv* ), can be based on any combinations of defined activity rates and associate multipliers which provide an initial guess at the activity rates of the individual gears. The outcome of the fitting process is a new set of multiplier values which, when applied to the initial activity rate file, produce the maximum likelihood of the target data.

The new multiplier values generated at the end of simulated annealing run are written back to the */Parameters* folder for the model/variant, in a as a new version of *fishing_activity_multiplier-*.csv* with an identifier defined by the model.ident argument in the initial e2e_read() call. Should the user wish to adopt the fitted activity rates in future runs, then there are two options:

1. Edit the *MODEL_SETUP.csv* file to point to the new version of *fishing_activity_multiplier-*.csv*
2. Create a new version of *fishing_activity_parameters-*.csv* in which the activity rates are the product of the original values and the new multiplier values; create a version of *fishing_activity_multiplier-*.csv* in which the values are 1.0 for all gears; and edit *MODEL_SETUP.csv* accordingly.

In addition to writing the final best-fit set of multiplier values back to the */Parameters* folder, the simulated annealing function returns the history of "proposed" and "accepted" parameter sets and the associated likelihoods as dataframes in a list object and optionally saves to *.csv* files in

the current default */results/model/variant* folder. The address for this folder can be set by the model.subdir argument in the e2e_read() function call.

File names for the 'proposed' and 'accepted' history files generated by the function are as follows:

*annealing_ACTmult_proposalhistory-*.csv*

*annealing_ACTmult_acceptedhistory-*.csv*

where the identifier (*) is set by the argument model.ident in the e2e_read() function call which loads the initial model setup.

The "proposed" and "accepted" parameter history data files both have the same structure – rows are sequential iterations of the parameter set, columns are the individual gear multipliers, with the addition of a final column providing the likelihood of the target data (Table 50). Proposed values are variants from the most recent accepted set. New proposals are tested until a likelihood threshold is exceeded whereupon the current proposal becomes a new accepted. For details of the methodology see the separate document on Parameter optimization, sensitivity and Monte Carlo analysis accessible via links in the package overview - help(StrathE2E2).

The new set of multiplier values which is written back into the */Parameters* sub-folder is assembled from the final row of the 'accepted' parameter history.

**Table 50. Column names and description for 'proposed' and 'accepted' parameter history files output from the** e2e_optimize_act(… ,selection="ECO", …) **function.**

| Column number | Column name | Parameter description |
|---|---|---|
| 1 | G1 | Multiplier applied to gear 1 |
| 2 | G2 | Multiplier applied to gear 2 |
| 3 | G3 | Multiplier applied to gear 3 |
| 4 | G5 | Multiplier applied to gear 4 |
| 5 | G5 | Multiplier applied to gear 5 |
| 6 | G6 | Multiplier applied to gear 6 |
| 7 | G7 | Multiplier applied to gear 7 |
| 8 | G8 | Multiplier applied to gear 8 |
| 9 | G9 | Multiplier applied to gear 9 |
| 10 | G10 | Multiplier applied to gear 10 |

| | | |
|---|---|---|
| 11 | G11 | Multiplier applied to gear 11 |
| 12 | G12 | Multiplier applied to gear 12 |
| 13 | Lik | Likelihood of the target data given the model, driving data, parameters and activity rates |

## OUTPUTS FROM OPTIMIZATION OF FISHING GEAR ACTIVITY RATES AGAINST KNOWN HARVEST RATIOS

The function

e2e_optimize_act(… ,selection="HR", …)

uses simulated annealing to seek a set of fishing gear activity rates which maximize the likelihood of known annual target data on the harvest ratios on each guild in each spatial zone (in the file */Target_data/ annual_target_data*.csv*) given the model structure, drivers, and ecology and other fishing fleet parameters. In this case the annealing process is plied only to the fishing fleet model, not to the whole linked fleey-ecology system. This scheme would be used in a situation where ecology model parameters and gear efficiencies are known or can be adopted e.g. from a neighbouring or similar region, but individual gear activity rates are unknown.

The implementation of simulated annealing in this function is slightly different to the other optimization functions in the package. In this case, because the problem of local maxima in the likelihood response surface is particularly acute (due to the potential overlap in the selectivities of different gears), so the annealing process is replicated many times from different randomly selected initial conditions. We refer to these replicates as 'trajectories'. Each trajectory follows a different pathway through the parameter space. At the end of the process, the best-fit set of activity multipliers is selected from across all the trajectories. In addition, the coefficient for jiggling the parameters is systematically attenuated with increasing iterations rather than remaining constant or potentailly being manually attenuated during the run by the user. Because the process uses only the fishing fleet model it is relatively fast so many trajectories can be run in a moderate time span.

Activity rates of gears within the model are set by product of two input data sets – the activity densities defined in the file */Parameters/ fishing_activity_parameters-*.csv* (Table 16), and the activity rate multiplier values in the file */Parameters/fishing_activity_multiplier-*.csv* (Table

21). Typically, the baseline configuration of a model variant would be defined by the activity densities with the multipliers set to 1.0, and subsequent scenarios designed by manipulating the multipliers.

The initial activity conditions for an e2e_optimize_act(… ,selection="HR", …) run (defined by the pointers to input files in *MODEL_SETUP.csv* ), can be based on any combinations of defined activity rates and associate multipliers which provide an initial guess at the activity rates of the individual gears. The outcome of the fitting process is a new set of multiplier values which, when applied to the initial activity rate file, produce the maximum likelihood of the target data.

The new multiplier values generated from the at the end of the maximum likelihood simulated annealing trajectory are written back to the */Parameters* folder for the model/variant, as a new version of *fishing_activity_multiplier-*.csv* with an identifier defined by the model.ident argument in the initial e2e_read() call. Should the user wish to adopt the fitted activity rates in future runs, then there are two options:

1. Edit the *MODEL_SETUP.csv* file to point to the new version of *fishing_activity_multiplier-*.csv*
2. Create a new version of *fishing_activity_parameters-*.csv* in which the activity rates are the product of the original values and the new multiplier values; create a version of *fishing_activity_multiplier-*.csv* in which the values are 1.0 for all gears; and edit *MODEL_SETUP.csv* accordingly.

In addition to writing the final best-fit set of multiplier values back to the */Parameters* folder, the simulated annealing function returns data on the end-state of eavj trajectory (parameter values and likelihoods, and resulting harvest ratios) as dataframes in a llts object and optionally saves these as *.csv* files in the current default */results/model/variant* folder. The address for this folder can be set by the model.subdir argument in the e2e_read() function call.

File names for the 'multipler' and 'harvest ratio' distribution files generated by the function are as follows:

*activity_optim_gearmult_history -*.csv*
*activity_optim_harvestratio_history -*.csv*
*activity_optim_gearmult_relinitial_history -*.csv*
*activity_optim_harvestratio_reltarget_history -*.csv*

where the identifier (*) is set by the argument model.ident in the e2e_read() function call which loads the initial model setup. The first pair of files contain the histories of the absolute values o fthe gear multipliers and the resulting harvest ratios. The second pair of files contains these data relative to the initial values of multiplers, or the target harvest ratios.

The output files (and dataframes) all have the same structure – rows are trajectories, columns are variables (multipliers or harvest ratios) and the final column is the associated likelihood. centiles of the distribution of likelihood-weighted properties (multipliers or difference between target and modelled harvest ratio), columns are either rthe gears, or the guilds. sequential iterations of the parameter set, columns are the individual gear multipliers, with the addition of a final column providing the likelihood of the target data (Table 51, 52).

For details of the methodology see the separate document on Parameter optimization, sensitivity and Monte Carlo analysis accessible via links in the package vignette ("*vignette("StrathE2E2")*") or package overview ("*help(StraathE2E2)*").

**Table 51. Column names for the table of gear multiplier histories (***activity_optim_gearmult_history* and *activity_optim_gearmult_relinitial_history*) **output from the** e2e_optimize_act(… , selection="HR", …) **function.** Rows are trajectories. G1-G12 in the Column names refers to the gear codes set up in the gear activity parameter file.

| Column number | Column name | Parameter description |
|---|---|---|
| 1 | G1 | Multiplier applied to gear 1 |
| 2 | G2 | Multiplier applied to gear 2 |
| 3 | G3 | Multiplier applied to gear 3 |
| 4 | G5 | Multiplier applied to gear 4 |
| 5 | G5 | Multiplier applied to gear 5 |
| 6 | G6 | Multiplier applied to gear 6 |
| 7 | G7 | Multiplier applied to gear 7 |
| 8 | G8 | Multiplier applied to gear 8 |
| 9 | G9 | Multiplier applied to gear 9 |
| 10 | G10 | Multiplier applied to gear 10 |
| 11 | G11 | Multiplier applied to gear 11 |
| 12 | G12 | Multiplier applied to gear 12 |
| 13 | lik | Likelihood |

**Table 52. Column names for the table of statistics on the difference beween target and modelled harvest ratios (*activity_optim_harvestratio_history* and *activity_optim_harvestratio_reltarget_history*) output from the** e2e_optimize_act(… , selection="HR", …) **function.**

| Column number | Column name | Parameter description |
|---|---|---|
| 1 | PFi | Planktivorous fish inshore |
| 2 | PFo | Planktivorous fish offshore |
| 3 | DFi | Demersal fish inshore |
| 4 | DFo | Demersal fish offshore |
| 5 | MFi | Migratory fish inshore |
| 6 | MFo | Migratory fish offshore |
| 7 | Bsdi | Benthos susp/dep feeders inshore |
| 8 | Bsdo | Benthos susp/dep feeders offshore |
| 9 | Bcsi | Benthos carn/scav feeders inshore |
| 10 | Bcso | Benthos carn/scav feeders offshore |
| 11 | CZi | Carniv. zooplankton inshore |
| 12 | CZo | Carniv. zooplankton offshore |
| 13 | BDi | Birds inshore |
| 14 | BDo | Birds offshore |
| 15 | SLi | Pinnipeds inshore |
| 16 | SLo | Pinnipeds offshore |
| 17 | CTi | Cetaceans inshore |
| 18 | CTo | Cetaceans offshore |
| 19 | KPi | Macrophytes inshore |
| 20 | KPo | Macrophytes offshore (always NA) |
| 21 | lik | Likelihood |

**OUTPUTS FROM SENSITIVITY ANALYSIS**

The function e2e_run_sens() conducts a "one-at-a-time" analysis of the sensitivity of the model (measured by likelihood of the observed target data in the file */Target_data/ annual_target_data*.csv* ) to the drivers and parameters of the ecology and fishing fleet models, using a factorial sampling scheme based on Morris (1991).

The function includes the physical configuration parameters (layer thickness and areas), all of the fixed and fitted parameters of the ecology model, the fishing fleet parameters and environmental driving data in the sensitivity analysis.

A list of initial parameter and driving data (θ) for the sampling method, referred to as the 'parent', is defined by the input files listed in the *MODEL_SETUP.csv* file which are loaded by the e2e_read() function. This could, for example, be the parameter set producing the maximum likelihood of the target date as generated by simulated annealing.

From this parent, child lists are generated ($\theta^*_k$ , $1 \le k \le r$) by applying a separate random increment to all the parameter; $\theta^*_k = \theta + \delta[k]$ where δ[k] is a vector of random values from a gaussian distribution of mean 0 and standard deviation given by a fixed coefficient of variation. The parent and each child-lists form the baslines for model 'trajectories'

For reach trajectory, each of the parameters ($1 \le i \le n$; n=453) is incremented one-at-a-time by a fixed proportionality from the baseline value, the model re-run to a stationary state (50 years to guarantee stationarity), and the likelihood computed ($P(observations|\theta^*_{k,i})$). The proportionality increment for a given trajectory is drawn at random from a set of four fixed levels in the range ±10% of the child parameter set (Δ = {0.9, 0.95, 0.05, 0.10}). Hence, for each trajectory the model runs are repeated n+1 times, where i=0 corresponds to the baseline run for each trajectory. The total number of nested runs to support the sensitivity analysis is thus r*(n+1). Even a modest number of trajectories the number of runs required represents a significant coimputing task and the run-time may require a few days depending on the processing capabilities of the machine.

For each level-run of a trajectory the "elementary effect" (EE) of the parameter is calculated from the difference in likelihood from the baseline, as follows:

$$EE_{k,i} = \frac{P\left(observations\middle|\theta^*_{k,i}\right) - P\left(observations\middle|\theta^*_{k,0}\right)}{\Delta}$$

On completion of the runs for all trajectories, the mean ($\mu_i$) and standard deviation ($S_i$) of the r elementary effects for each parameter ($i$) are calculated. For the mean,

$$\mu_i = \frac{1}{r}\sum_{k=1}^{r} EE_{k,i}$$

The magnitude of the mean represents the sensitivity of each parameter, and the corresponding standard deviation indicates the degree of non-linearity in the response or interaction with other parameters. The standard error of the mean for each parameter ($SEM_i$) is given by:

$$SEM_i = \frac{S_i}{\sqrt{r}}$$

If $S_i > |\mu_i| \cdot \frac{\sqrt{r}}{2}$ then we can approximately conclude that $\mu_i$ is significantly greater than zero.

The e2e_run_sens() function is computationally intensive, so arguments are include to enable the task to be shared across multiple processor/machines and for the results to be merged afterwards.

The e2e_run_sens() function saves a number of outputs to *.csv* files in the */results/model/variant* folder of the current user-workspace:

- table "*OAT_results-*.csv"* (Table 54) in which rows correspond to individual model runs, listing the trajectory and level identity, which parameter was incremented in the run and by what proportion, and the resulting likelihood value and elementary effect,
- table "*OAT_parameter_values-*.csv"* in which rows correspond to individual model runs as above, and the columns are the values of each parameter which was used in each run,
- table "*sorted_parameter_elemental_effects-*.csv"* (Table 55) of the mean ($\mu_i$) and standard deviation ($S_i$) and significance ($SEM_i$; sig/ns) of the elementary effects for each parameter identity (rows), sorted by the by values of mean ($\mu_i$).

In each case the identifier (*) for each file name is set my the model.ident argumed in the e2e_read() functiion call which loads the initial conditions for the analysis. A plotting function e2e_plot_sens_mc() is provided to visualise the data in the table of mean, sd and significance of the elementary effects.

Details of all the parameters included in the sensitivity analysis can be downloaded as a dataframe from the package using the function e2e_get_parmdoc() (Table 56).

**Table 54. Details of the columns in the *OAT_results-*.csv* output file from the sensitivity analysis. Rows correspond to individual trajectory/level model runs.**

| Column number | Column name | Description |
|---|---|---|
| 1 | parametername | Text labels the single parameter which was incremented for a given trajectory/level model run (see Table 56 for details). Baseline runs for each trajectory (in which all parameters were randomly varied) are identified by the label “baseline”. |
| 2 | parameterid | Numeric code identifying the single parameter which was incremented for a given trajectory/level model run (see Table 56 for details). Baseline runs for each trajectory are identified by the code 0 |
| 3 | trajectoryid | Trajectory number |
| 4 | levelid | Level identifier for the runs within each trajectory (values 1,2,3,4). All level runs for a given trajectory use the same level identifier. |
| 5 | delta_p | Proportionaly increment applied to each parameters in the set of levl runs for a a given trajectory. All level runs for a given trajectory use the same proportionality increment. |
| 6 | likelihood | Likelihood of the target data given the parameter values for a given trajectory/level run |
| 7 | EE | Elementary effect for the parameter incremented in a given trajectory/levl run. The elementery effects for the baseline runs of each trajectory are set to zero |

**Table 55. Details of the columns in the *sorted_parameter_elementary_effects-*.csv* output file from the sensitivity analysis**. Rows correspond to individual parameters.

| Column number | Column name | Description |
|---|---|---|
| 1 | parametername | Text labels the single parameter which was incremented for a given trajectory/level model run (see Table 56 for deaiils). Baseline runs for each trajectory (in which all parameters were randomly varied) are identified by the label “baseline”. |
| 2 | parameterid | Numeric code identifying the single parameter which was incremented for a given trajectory/level model run (see Table 56 for details). Baseline runs for each trajectory are identified by the code 0 |
| 3 | fixfit | Numeric code identifying the type of parameter: 0 = fitted ecology model parameter, 1 = fixed ecology model parameter, 2 = fishing fleet parameter, 3 = harvest ratio values, 4 = environmental drivers, 5 = physical configuration parameters (see Table 56 for details). |
| 4 | EEmean | Value of the mean elementary effect ($\mu_i$) for a given parameter (i) |
| 5 | EEsd | Value of the standard deviation of elementary effects ($S_i$) for a given parameter (i) |
| 6 | EEmean_non_0 | Significance of the elementary effect ($SEM_i$) for a given parameter (i), values = “sig” or “ns” |
| 7 | Ntrajectories | Number of trajectories in the analysis |
| 8 | Parameter.class | Group to which the parameter belongs (Text field corresponding to column 3; Ecology model fixed, Ecology model |

| | | |
|---|---|---|
| | | fitted, Fishing fleet model, Harvest ratio Environmental drivers, Physical configuration) |
| 9 | Parameter.description | Text description of the parameter |
| 10 | Model.guild.or.feature | Text description o fthe guild or feature associated with the parameter |

**Table 56. Details of the parameters documentation available as a dataframe using the function e2e_get_parmdoc()**. The column names "parametername", "parameterid" and "fixfit" refer to column names described in Tables 54 and 55. The values of "parametername" also correspond to the column header in the output file "*OAT_parameter_values-*.csv".*

| parametername | parameterid | fixfit | Parameter class | Parameter description | Model guild or feature |
|---|---|---|---|---|---|
| thik_so | 1 | 5 | Physical configuration | Vertical thickness | Offshore zone upper layer |
| thik_d | 2 | 5 | Physical configuration | Vertical thickness | Offshore zone lower layer |
| thik_si | 3 | 5 | Physical configuration | Vertical thickness | Inshore zone |
| thik_b | 4 | 5 | Physical configuration | Vertical thickness | Benthic boundary feeding layer |
| porosity_s1 | 28 | 5 | Physical configuration | Sediment porosity | Inshore muddy sediments |
| porosity_s2 | 29 | 5 | Physical configuration | Sediment porosity | Inshore sandy sediments |
| porosity_s3 | 30 | 5 | Physical configuration | Sediment porosity | Inshore coarse sediments |
| porosity_d1 | 31 | 5 | Physical configuration | Sediment porosity | Offshore muddy sediments |
| porosity_d2 | 32 | 5 | Physical configuration | Sediment porosity | Offshore sandy sediments |
| porosity_d3 | 33 | 5 | Physical configuration | Sediment porosity | Offshore coarse sediments |
| sed_wat_dif_s1 | 34 | 5 | Physical configuration | Hydraulic conductivity | Inshore muddy sediments |
| sed_wat_dif_s2 | 35 | 5 | Physical configuration | Hydraulic conductivity | Inshore sandy sediments |
| sed_wat_dif_s3 | 36 | 5 | Physical configuration | Hydraulic conductivity | Inshore coarse sediments |
| sed_wat_dif_d1 | 37 | 5 | Physical configuration | Hydraulic conductivity | Offshore muddy sediments |
| sed_wat_dif_d2 | 38 | 5 | Physical configuration | Hydraulic conductivity | Offshore sandy sediments |
| sed_wat_dif_d3 | 39 | 5 | Physical configuration | Hydraulic conductivity | Offshore coarse sediments |
| sed_ref_Kxw | 40 | 5 | Physical configuration | Hydraulic conductivity | Reference value for sediment-dependent processes |
| bioturb_depth_s1 | 41 | 5 | Physical configuration | Bioturbation depth | Inshore muddy sediments |
| bioturb_depth_s2 | 42 | 5 | Physical configuration | Bioturbation depth | Inshore sandy sediments |
| bioturb_depth_s3 | 43 | 5 | Physical configuration | Bioturbation depth | Inshore coarse sediments |
| bioturb_depth_d1 | 44 | 5 | Physical configuration | Bioturbation depth | Offshore muddy sediments |
| bioturb_depth_d2 | 45 | 5 | Physical configuration | Bioturbation depth | Offshore sandy sediments |
| bioturb_depth_d3 | 46 | 5 | Physical configuration | Bioturbation depth | Offshore coarse sediments |
| erosion_depth_s1 | 47 | 5 | Physical configuration | Physical disturbance depth | Inshore muddy sediments |
| erosion_depth_s2 | 48 | 5 | Physical configuration | Physical disturbance depth | Inshore sandy sediments |
| erosion_depth_s3 | 49 | 5 | Physical configuration | Physical disturbance depth | Inshore coarse sediments |
| erosion_depth_d1 | 50 | 5 | Physical configuration | Physical disturbance depth | Offshore muddy sediments |
| erosion_depth_d2 | 51 | 5 | Physical configuration | Physical disturbance depth | Offshore sandy sediments |
| erosion_depth_d3 | 52 | 5 | Physical configuration | Physical disturbance depth | Offshore coarse sediments |

| | | | | | |
|---|---|---|---|---|---|
| lightSPM_intercept | 53 | 5 | Physical configuration | Intercept | Light attenuation coefficient vs SPM |
| lightSPM_slope | 54 | 5 | Physical configuration | Coefficient | Light attenuation coefficient vs SPM |
| inshore_phyt_prop_depth | 55 | 5 | Physical configuration | Proportion of depth range occupied | Phytoplankton inshore |
| inshore_kelp_prop_depth | 56 | 5 | Physical configuration | Proportion of depth range occupied | Macrophytes inshore |
| F_inshore_pelagic | 57 | 3 | Harvest ratio | Harvest ratio inshore | Planktivorous fish |
| F_offshore_pelagic | 58 | 3 | Harvest ratio | Harvest ratio offshore | Planktivorous fish |
| F_inshore_demersal | 59 | 3 | Harvest ratio | Harvest ratio inshore | Demersal fish |
| F_offshore_demersal | 60 | 3 | Harvest ratio | Harvest ratio offshore | Demersal fish |
| F_inshore_migratory | 61 | 3 | Harvest ratio | Harvest ratio inshore | Migratory fish |
| F_offshore_migratory | 62 | 3 | Harvest ratio | Harvest ratio offshore | Migratory fish |
| F_inshore_filtben | 63 | 3 | Harvest ratio | Harvest ratio inshore | Suspension/deposit feeding benthos |
| F_offshore_filtben | 64 | 3 | Harvest ratio | Harvest ratio offshore | Suspension/deposit feeding benthos |
| F_inshore_carnben | 65 | 3 | Harvest ratio | Harvest ratio inshore | Carnivore/scavenge feeding benthos |
| F_offshore_carnben | 66 | 3 | Harvest ratio | Harvest ratio offshore | Carnivore/scavenge feeding benthos |
| F_inshore_carnzoo | 67 | 3 | Harvest ratio | Harvest ratio inshore | Carnivorous zooplankton |
| F_offshore_carnzoo | 68 | 3 | Harvest ratio | Harvest ratio offshore | Carnivorous zooplankton |
| F_inshore_bird | 69 | 3 | Harvest ratio | Harvest ratio inshore | Birds |
| F_offshore_bird | 70 | 3 | Harvest ratio | Harvest ratio offshore | Birds |
| F_inshore_seal | 71 | 3 | Harvest ratio | Harvest ratio inshore | Pinnipeds |
| F_offshore_seal | 72 | 3 | Harvest ratio | Harvest ratio offshore | Pinnipeds |
| F_inshore_ceta | 73 | 3 | Harvest ratio | Harvest ratio inshore | Cetaceans |
| F_offshore_ceta | 74 | 3 | Harvest ratio | Harvest ratio offshore | Cetaceans |
| F_inshore_kelp | 75 | 3 | Harvest ratio | Harvest ratio inshore | Macrophytes |
| F_offshore_kelp | 76 | 3 | Harvest ratio | Harvest ratio offshore | Macrophytes |
| QnQ_coef | 77 | 2 | Fishing fleet model | Coefficient | Demersal fish non-quota proportion in catch vs nitrogen mass |
| QnQ_exp | 78 | 2 | Fishing fleet model | Exponent | Demersal fish non-quota proportion in catch vs nitrogen mass |
| NQus_coef | 79 | 2 | Fishing fleet model | Coefficient | Demersal fish non-quota undersize vs nitrogen mass |
| NQus_exp | 80 | 2 | Fishing fleet model | Exponent | Demersal fish non-quota undersize vs nitrogen mass |
| QLus_coef | 81 | 2 | Fishing fleet model | Coefficient | Demersal fish quota-limited undersize vs nitrogen mass |
| QLus_exp | 82 | 2 | Fishing fleet model | Exponent | Demersal fish quota-limited undersize vs nitrogen mass |
| D_inshore_pelagic | 83 | 2 | Fishing fleet model | Discard rate inshore | Planktivorous fish |
| D_offshore_pelagic | 84 | 2 | Fishing fleet model | Discard rate offshore | Planktivorous fish |
| D_inshore_demersal | 85 | 2 | Fishing fleet model | Discard rate inshore | Demersal fish |
| D_offshore_demersal | 86 | 2 | Fishing fleet model | Discard rate offshore | Demersal fish |
| D_demersal | 87 | 2 | Fishing fleet model | Discard rate all areas | Demersal fish all areas |

| | | | | | |
|---|---|---|---|---|---|
| D_inshore_migratory | 88 | 2 | Fishing fleet model | Discard rate inshore | Migratory fish |
| D_offshore_migratory | 89 | 2 | Fishing fleet model | Discard rate offshore | Migratory fish |
| D_inshore_filtben | 90 | 2 | Fishing fleet model | Discard rate inshore | Suspension/deposit feeding benthos |
| D_offshore_filtben | 91 | 2 | Fishing fleet model | Discard rate offshore | Suspension/deposit feeding benthos |
| D_inshore_carnben | 92 | 2 | Fishing fleet model | Discard rate inshore | Carnivore/scavenge feeding benthos |
| D_offshore_carnben | 93 | 2 | Fishing fleet model | Discard rate offshore | Carnivore/scavenge feeding benthos |
| D_inshore_carnzoo | 94 | 2 | Fishing fleet model | Discard rate inshore | Carnivorous zooplankton |
| D_offshore_carnzoo | 95 | 2 | Fishing fleet model | Discard rate offshore | Carnivorous zooplankton |
| D_inshore_bird | 96 | 2 | Fishing fleet model | Discard rate inshore | Birds |
| D_offshore_bird | 97 | 2 | Fishing fleet model | Discard rate offshore | Birds |
| D_inshore_seal | 98 | 2 | Fishing fleet model | Discard rate inshore | Pinnipeds |
| D_offshore_seal | 99 | 2 | Fishing fleet model | Discard rate offshore | Pinnipeds |
| D_inshore_ceta | 100 | 2 | Fishing fleet model | Discard rate inshore | Cetaceans |
| D_offshore_ceta | 101 | 2 | Fishing fleet model | Discard rate offshore | Cetaceans |
| D_inshore_kelp | 102 | 2 | Fishing fleet model | Discard rate inshore | Macrophytes |
| D_offshore_kelp | 103 | 2 | Fishing fleet model | Discard rate offshore | Macrophytes |
| G_inshore_pelagic | 104 | 2 | Fishing fleet model | Processing at sea rate inshore | Planktivorous fish |
| G_offshore_pelagic | 105 | 2 | Fishing fleet model | Processing at sea rate offshore | Planktivorous fish |
| G_inshore_demersal | 106 | 2 | Fishing fleet model | Processing at sea rate inshore | Demersal fish |
| G_offshore_demersal | 107 | 2 | Fishing fleet model | Processing at sea rate offshore | Demersal fish |
| G_inshore_migratory | 108 | 2 | Fishing fleet model | Processing at sea rate inshore | Migratory fish |
| G_offshore_migratory | 109 | 2 | Fishing fleet model | Processing at sea rate offshore | Migratory fish |
| G_inshore_filtben | 110 | 2 | Fishing fleet model | Processing at sea rate inshore | Suspension/deposit feeding benthos |
| G_offshore_filtben | 111 | 2 | Fishing fleet model | Processing at sea rate offshore | Suspension/deposit feeding benthos |
| G_inshore_carnben | 112 | 2 | Fishing fleet model | Processing at sea rate inshore | Carnivore/scavenge feeding benthos |
| G_offshore_carnben | 113 | 2 | Fishing fleet model | Processing at sea rate offshore | Carnivore/scavenge feeding benthos |
| G_inshore_carnzoo | 114 | 2 | Fishing fleet model | Processing at sea rate inshore | Carnivorous zooplankton |
| G_offshore_carnzoo | 115 | 2 | Fishing fleet model | Processing at sea rate offshore | Carnivorous zooplankton |
| G_inshore_bird | 116 | 2 | Fishing fleet model | Processing at sea rate inshore | Birds |
| G_offshore_bird | 117 | 2 | Fishing fleet model | Processing at sea rate offshore | Birds |
| G_inshore_seal | 118 | 2 | Fishing fleet model | Processing at sea rate inshore | Pinnipeds |
| G_offshore_seal | 119 | 2 | Fishing fleet model | Processing at sea rate offshore | Pinnipeds |
| G_inshore_ceta | 120 | 2 | Fishing fleet model | Processing at sea rate inshore | Cetaceans |
| G_offshore_ceta | 121 | 2 | Fishing fleet model | Processing at sea rate offshore | Cetaceans |
| G_inshore_kelp | 122 | 2 | Fishing fleet model | Processing at sea rate inshore | Macrophytes |
| G_offshore_kelp | 123 | 2 | Fishing fleet model | Processing at sea rate offshore | Macrophytes |
| ploughdaily_S0 | 286 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Inshore rock |
| ploughdaily_S1 | 287 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Inshore muddy sediments |
| ploughdaily_S2 | 288 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Inshore sandy sediments |
| ploughdaily_S3 | 289 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Inshore coarse sediments |
| ploughdaily_D0 | 290 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Offshore rock |

| | | | | | |
|---|---|---|---|---|---|
| ploughdaily_D1 | 291 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Offshore muddy sediments |
| ploughdaily_D2 | 292 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Offshore sandy sediments |
| ploughdaily_D3 | 293 | 2 | Fishing fleet model | Abrasion rate by fishing gears | Offshore coarse sediments |
| inshore_bensdamage | 294 | 2 | Fishing fleet model | Damage mortality rate by fishing gears | Suspension/deposit feeding benthos inshore |
| offshore_bensdamage | 295 | 2 | Fishing fleet model | Damage mortality rate by fishing gears | Suspension/deposit feeding benthos offshore |
| inshore_bencdamage | 296 | 2 | Fishing fleet model | Damage mortality rate by fishing gears | Carnivore/scavenge feeding benthos inshore |
| offshore_bencdamage | 297 | 2 | Fishing fleet model | Damage mortality rate by fishing gears | Carnivore/scavenge feeding benthos offshore |
| offal_prop_live_weight | 298 | 2 | Fishing fleet model | Offal as proportion of live weight | All guilds |
| ploughdepth_S0 | 299 | 2 | Fishing fleet model | Penetration depth by fishing gears | Inshore rock |
| ploughdepth_S1 | 300 | 2 | Fishing fleet model | Penetration depth by fishing gears | Inshore muddy sediments |
| ploughdepth_S2 | 301 | 2 | Fishing fleet model | Penetration depth by fishing gears | Inshore sandy sediments |
| ploughdepth_S3 | 302 | 2 | Fishing fleet model | Penetration depth by fishing gears | Inshore coarse sediments |
| ploughdepth_D0 | 303 | 2 | Fishing fleet model | Penetration depth by fishing gears | Offshore rock |
| ploughdepth_D1 | 304 | 2 | Fishing fleet model | Penetration depth by fishing gears | Offshore muddy sediments |
| ploughdepth_D2 | 305 | 2 | Fishing fleet model | Penetration depth by fishing gears | Offshore sandy sediments |
| ploughdepth_D3 | 306 | 2 | Fishing fleet model | Penetration depth by fishing gears | Offshore coarse sediments |
| qtena | 307 | 1 | Ecology model fixed | Q10 | Autotrophic uptake |
| qtenh | 308 | 1 | Ecology model fixed | Q10 | Heterotrophic uptake |
| qtenm | 309 | 1 | Ecology model fixed | Q10 | Metabolism and microbial rates |
| qtenr | 310 | 1 | Ecology model fixed | Q10 reference temperature | All temperature dependent processes |
| Lmaxup_phyt | 311 | 1 | Ecology model fixed | Saturation light intensity for uptake | Nutrient by phytoplankton |
| Lmaxup_kelp | 312 | 1 | Ecology model fixed | Saturation light intensity for uptake | Nutrient by macrophytes |
| NCmax_kelp | 313 | 1 | Ecology model fixed | N:C molar ratio maximum | Macrophytes |
| NCmin_kelp | 314 | 1 | Ecology model fixed | N:C molar ratio minimum | Macrophytes |
| wave_beach_kelpdebris | 315 | 0 | Ecology model fitted | Conversion rate | Macrophyte debris to beach-cast |
| umaxC_kelp | 316 | 0 | Ecology model fitted | Maximum uptake rate | Carbon by macrophytes |
| exudeC_kelp | 317 | 0 | Ecology model fitted | Carbon exudation rate | Macrophytes |
| selfshade_kelp | 318 | 0 | Ecology model fitted | Coefficient | Macrophyte self shading |
| uNIT_kelpt | 319 | 0 | Ecology model fitted | Maximum uptake rate | Nitate by macrophytes |
| hsNIT_kelp | 320 | 0 | Ecology model fitted | Uptake half saturation coefficient | Nitrate by macrophytes |
| uAMM_kelpt | 321 | 0 | Ecology model fitted | Maximum uptake rate | Ammonia by macrophytes |
| hsAMM_kelp | 322 | 0 | Ecology model fitted | Uptake half saturation coefficient | Ammonia by macrophytes |
| uNIT_phytt | 323 | 0 | Ecology model fitted | Maximum uptake rate | Nitrate by phytoplankton |
| hsNIT_phyt | 324 | 0 | Ecology model fitted | Uptake half saturation coefficient | Nitrate by phytoplankton |
| uAMM_phytt | 325 | 0 | Ecology model fitted | Maximum uptake rate | Ammonia by phytoplankton |
| hsAMM_phyt | 326 | 0 | Ecology model fitted | Uptake half saturation coefficient | Ammonia by phytoplankton |
| uphyt_omnit | 327 | 0 | Ecology model fitted | Maximum uptake rate | Phytoplankton by omnivorous zooplankton |
| hsphyt_omni | 328 | 0 | Ecology model fitted | Uptake half saturation coefficient | Phytoplankton by omnivorous zooplankton |
| udet_omnit | 329 | 0 | Ecology model fitted | Maximum uptake rate | Suspended detritus by omnivorous zooplankton |
| hsdet_omni | 330 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspended detritus by omnivorous |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | zooplankton |
| ubenthslar_omnit | 331 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by omnivorous zooplankton |
| hsbenthslar_omni | 332 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae by omnivorous zooplankton |
| ubenthclar_omnit | 333 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by omnivorous zooplankton |
| hsbenthclar_omni | 334 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by omnivorous zooplankton |
| uomni_carnt | 335 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by carnivorous zooplankton |
| hsomni_carn | 336 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by carnivorous zooplankton |
| ubenthslar_carnt | 337 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by carnivorous zooplankton |
| hsbenthslar_carn | 338 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae by carnivorous zooplankton |
| ubenthclar_carnt | 339 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by carnivorous zooplankton |
| hsbenthclar_carn | 340 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by carnivorous zooplankton |
| ufishplar_carnt | 341 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish larvae by carnivorous zooplankton |
| hsfishplar_carn | 342 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish larvae by carnivorous zooplankton |
| ufishdlar_carnt | 343 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish larvae by carnivorous zooplankton |
| hsfishdlar_carn | 344 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish larvae by carnivorous zooplankton |
| uomni_fishplart | 345 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by planktivorous fish larvae |
| hsomni_fishplar | 346 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by planktivorous fish larvae |
| ubenthslar_fishplart | 347 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by planktivorous fish larvae |
| hsbenthslar_fishplar | 348 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae by planktivorous fish larvae |
| ubenthclar_fishplart | 349 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by planktivorous fish larvae |
| hsbenthclar_fishplar | 350 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by planktivorous fish larvae |
| uomni_fishpt | 351 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by planktivorous |

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|---|---|---|---|---|---|
| | | | | | fish |
| hsomni_fishp | 352 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by planktivorous fish |
| ucarn_fishpt | 353 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by planktivorous fish |
| hscarn_fishp | 354 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by planktivorous fish |
| ubenthslar_fishpt | 355 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by planktivorous fish |
| hsbenthslar_fishp | 356 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae by planktivorous fish |
| ubenthclar_fishpt | 357 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by planktivorous fish |
| hsbenthclar_fishp | 358 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by planktivorous fish |
| ufishdlar_fishpt | 359 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish larvae by planktivorous fish |
| hsfishdlar_fishp | 360 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish larvae by planktivorous fish |
| ufishplar_fishpt | 361 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish larvae by planktivorous fish |
| hsfishplar_fishp | 362 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish larvae by planktivorous fish |
| uomni_fishmt | 363 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by migratory fish |
| hsomni_fishm | 364 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by migratory fish |
| ucarn_fishmt | 365 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by migratory fish |
| hscarn_fishm | 366 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by migratory fish |
| ubenthslar_fishmt | 367 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by migratory fish |
| hsbenthslar_fishm | 368 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae by migratory fish |
| ubenthclar_fishmt | 369 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by migratory fish |
| hsbenthclar_fishm | 370 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by migratory fish |
| ufishdlar_fishmt | 371 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish larvae by migratory fish |
| hsfishdlar_fishm | 372 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish larvae by migratory fish |
| ufishplar_fishmt | 373 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish larvae by migratory fish |
| hsfishplar_fishm | 374 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish larvae by migratory fish |
| uomni_fishdlart | 375 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by demersal fish larvae |
| hsomni_fishdlar | 376 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by demersal fish larvae |
| ubenthslar_fishdlart | 377 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos larvae by demersal fish larvae |
| hsbenthslar_fishdlar | 378 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos larvae |

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|---|---|---|---|---|---|
| | | | | | by demersal fish larvae |
| ubenthclar_fishdlart | 379 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos larvae by demersal fish larvae |
| hsbenthclar_fishdlar | 380 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos larvae by demersal fish larvae |
| ucarn_fishdt | 381 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by demersal fish |
| hscarn_fishd | 382 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by demersal fish |
| ubenths_fishdt | 383 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos by demersal fish |
| hsbenths_fishd | 384 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos by demersal fish |
| ubenthc_fishdt | 385 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos by demersal fish |
| hsbenthc_fishd | 386 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos by demersal fish |
| ufishplar_fishdt | 387 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish larvae by demersal fish |
| hsfishplar_fishd | 388 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish larvae by demersal fish |
| ufishdlar_fishdt | 389 | 0 | Ecology model fitted | Maximum uptake rate | demersal fish larvae by demersal fish |
| hsfishdlar_fishd | 390 | 0 | Ecology model fitted | Uptake half saturation coefficient | demersal fish larvae by demersal fish |
| ufishp_fishdt | 391 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish by demersal fish |
| hsfishp_fishd | 392 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish by demersal fish |
| ufishm_fishdt | 393 | 0 | Ecology model fitted | Maximum uptake rate | Migratory fish by demersal fish |
| hsfishm_fishd | 394 | 0 | Ecology model fitted | Uptake half saturation coefficient | Migratory fish by demersal fish |
| ufishd_fishdt | 395 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish by demersal fish |
| hsfishd_fishd | 396 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish by demersal fish |
| udisc_fishdt | 397 | 0 | Ecology model fitted | Maximum uptake rate | Discards by demersal fish |
| hsdisc_fishd | 398 | 0 | Ecology model fitted | Uptake half saturation coefficient | Discards by demersal fish |
| ucorp_fishdt | 399 | 0 | Ecology model fitted | Maximum uptake rate | Corpses by demersal fish |
| hscorp_fishd | 400 | 0 | Ecology model fitted | Uptake half saturation coefficient | Corpses by demersal fish |
| uphyt_benthslart | 401 | 0 | Ecology model fitted | Maximum uptake rate | Phytoplankton by suspension/deposit feeding benthos larvae |
| hsphyt_benthslar | 402 | 0 | Ecology model fitted | Uptake half saturation coefficient | Phytoplankton by suspension/deposit feeding benthos larvae |
| udet_benthslart | 403 | 0 | Ecology model fitted | Maximum uptake rate | Suspended detritus by suspension/deposit feeding benthos larvae |
| hsdet_benthslar | 404 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspended detritus by suspension/deposit feeding benthos larvae |
| uphyt_benthclart | 405 | 0 | Ecology model fitted | Maximum uptake rate | Phytoplankton by carnivore/scavenge feeding benthos larvae |
| hsphyt_benthclar | 406 | 0 | Ecology model fitted | Uptake half saturation coefficient | Phytoplankton by carnivore/scavenge feeding benthos larvae |
| udet_benthclart | 407 | 0 | Ecology model fitted | Maximum uptake rate | Suspended detritus by carnivore/scavenge |

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|---|---|---|---|---|---|
| | | | | | feeding benthos larvae |
| hsdet_benthclar | 408 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspended detritus by carnivore/scavenge feeding benthos larvae |
| uphyt_benthst | 409 | 0 | Ecology model fitted | Maximum uptake rate | Phytoplankton by suspension/deposit feeding benthos |
| hsphyt_benths | 410 | 0 | Ecology model fitted | Uptake half saturation coefficient | Phytoplankton by suspension/deposit feeding benthos |
| udet_benthst | 411 | 0 | Ecology model fitted | Maximum uptake rate | Suspended detritus by suspension/deposit feeding benthos |
| hsdet_benths | 412 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspended detritus by suspension/deposit feeding benthos |
| used_benthst | 413 | 0 | Ecology model fitted | Maximum uptake rate | Sediment detritus by suspension/deposit feeding benthos |
| hssed_benths | 414 | 0 | Ecology model fitted | Uptake half saturation coefficient | Sediment detritus by suspension/deposit feeding benthos |
| ubenths_benthct | 415 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos by carnivore/scavenge feeding benthos |
| hsbenths_benthc | 416 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos by carnivore/scavenge feeding benthos |
| ukelp_benthct | 417 | 0 | Ecology model fitted | Maximum uptake rate | Macrophytes by carnivorous/scavenge feeding benthos |
| hskelp_benthc | 418 | 0 | Ecology model fitted | Uptake half saturation coefficient | Macrophytes by carnivorous/scavenge feeding benthos |
| ukelpdebris_benthct | 419 | 0 | Ecology model fitted | Maximum uptake rate | Macrophyte debris by carnivorous/scavenge feeding benthos |
| hskelpdebris_benthc | 420 | 0 | Ecology model fitted | Uptake half saturation coefficient | Macrophyte debris by carnivorous/scavenge feeding benthos |
| ucorp_benthct | 421 | 0 | Ecology model fitted | Maximum uptake rate | Corpses by carnivore/scavenge feeding benthos |
| hscorp_benthc | 422 | 0 | Ecology model fitted | Uptake half saturation coefficient | Corpses by carnivore/scavenge feeding benthos |
| ucarn_bird | 423 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by birds |
| hscarn_bird | 424 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by birds&mammala |
| ubenths_bird | 425 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos by birds |
| hsbenths_bird | 426 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos by birds |
| ubenthc_bird | 427 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos by birds |
| hsbenthc_bird | 428 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos by birds |
| ufishp_bird | 429 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish by birds |
| hsfishp_bird | 430 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish by birds |
| ufishm_bird | 431 | 0 | Ecology model fitted | Maximum uptake rate | Migratory fish by birds |
| hsfishm_bird | 432 | 0 | Ecology model fitted | Uptake half saturation coefficient | Migratory fish by birds |
| ufishd_bird | 433 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish by birds |

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|---|---|---|---|---|---|
| hsfishd_bird | 434 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish by birds |
| udisc_bird | 435 | 0 | Ecology model fitted | Maximum uptake rate | Discards by birds |
| hsdisc_bird | 436 | 0 | Ecology model fitted | Uptake half saturation coefficient | Discards by birds |
| ucorp_bird | 437 | 0 | Ecology model fitted | Maximum uptake rate | Corpses by birds |
| hscorp_bird | 438 | 0 | Ecology model fitted | Uptake half saturation coefficient | Corpses by birds |
| bdapar_bird | 439 | 0 | Ecology model fitted | Bedding DeAngelis parameter | Birds |
| ucarn_seal | 440 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by pinnipeds |
| hscarn_seal | 441 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by pinnipeds |
| ubenths_seal | 442 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos by pinnipeds |
| hsbenths_seal | 443 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos by pinnipeds |
| ubenthc_seal | 444 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos by pinnipeds |
| hsbenthc_seal | 445 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos by pinnipeds |
| ufishp_seal | 446 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish by pinnipeds |
| hsfishp_seal | 447 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish by pinnipeds |
| ufishm_seal | 448 | 0 | Ecology model fitted | Maximum uptake rate | Migratory fish by pinnipeds |
| hsfishm_seal | 449 | 0 | Ecology model fitted | Uptake half saturation coefficient | Migratory fish by pinnipeds |
| ufishd_seal | 450 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish by pinnipeds |
| hsfishd_seal | 451 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish by pinnipeds |
| ubird_seal | 452 | 0 | Ecology model fitted | Maximum uptake rate | Birds by pinnipeds |
| hsbird_seal | 453 | 0 | Ecology model fitted | Uptake half saturation coefficient | Birds by pinnipeds |
| udisc_seal | 454 | 0 | Ecology model fitted | Maximum uptake rate | Discards by pinnipeds |
| hsdisc_seal | 455 | 0 | Ecology model fitted | Uptake half saturation coefficient | Discards by pinnipeds |
| ucorp_seal | 456 | 0 | Ecology model fitted | Maximum uptake rate | Corpses by pinnipeds |
| hscorp_seal | 457 | 0 | Ecology model fitted | Uptake half saturation coefficient | Corpses by pinnipeds |
| bdapar_seal | 458 | 0 | Ecology model fitted | Bedding DeAngelis parameter | Pinnipeds |
| uomni_ceta | 459 | 0 | Ecology model fitted | Maximum uptake rate | Omnivorous zooplankton by cetaceans |
| hsomni_ceta | 460 | 0 | Ecology model fitted | Uptake half saturation coefficient | Omnivorous zooplankton by cetaceans |
| ucarn_ceta | 461 | 0 | Ecology model fitted | Maximum uptake rate | Carnivorous zooplankton by cetaceans |
| hscarn_ceta | 462 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivorous zooplankton by cetaceans |
| ubenths_ceta | 463 | 0 | Ecology model fitted | Maximum uptake rate | Suspension/deposit feeding benthos by cetaceans |
| hsbenths_ceta | 464 | 0 | Ecology model fitted | Uptake half saturation coefficient | Suspension/deposit feeding benthos by cetaceans |
| ubenthc_ceta | 465 | 0 | Ecology model fitted | Maximum uptake rate | Carnivore/scavenge feeding benthos by cetaceans |
| hsbenthc_ceta | 466 | 0 | Ecology model fitted | Uptake half saturation coefficient | Carnivore/scavenge feeding benthos by cetaceans |

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|---|---|---|---|---|---|
| ufishp_ceta | 467 | 0 | Ecology model fitted | Maximum uptake rate | Planktivorous fish by cetaceans |
| hsfishp_ceta | 468 | 0 | Ecology model fitted | Uptake half saturation coefficient | Planktivorous fish by cetaceans |
| ufishm_ceta | 469 | 0 | Ecology model fitted | Maximum uptake rate | Migratory fish by cetaceans |
| hsfishm_ceta | 470 | 0 | Ecology model fitted | Uptake half saturation coefficient | Migratory fish by cetaceans |
| ufishd_ceta | 471 | 0 | Ecology model fitted | Maximum uptake rate | Demersal fish by cetaceans |
| hsfishd_ceta | 472 | 0 | Ecology model fitted | Uptake half saturation coefficient | Demersal fish by cetaceans |
| ubird_ceta | 473 | 0 | Ecology model fitted | Maximum uptake rate | Birds by cetaceans |
| hsbird_ceta | 474 | 0 | Ecology model fitted | Uptake half saturation coefficient | Birds by cetaceans |
| useal_ceta | 475 | 0 | Ecology model fitted | Maximum uptake rate | Pinnipeds by cetaceans |
| hsseal_ceta | 476 | 0 | Ecology model fitted | Uptake half saturation coefficient | Pinnipeds by cetaceans |
| udisc_ceta | 477 | 0 | Ecology model fitted | Maximum uptake rate | Discards by cetaceans |
| hsdisc_ceta | 478 | 0 | Ecology model fitted | Uptake half saturation coefficient | Discards by cetaceans |
| bdapar_ceta | 479 | 0 | Ecology model fitted | Bedding DeAngelis parameter | Cetaceans |
| aH | 480 | 1 | Ecology model fixed | Assimilation efficiency | Omnivorous zooplankton |
| aC | 481 | 1 | Ecology model fixed | Assimilation efficiency | Carnivorous zooplankton |
| aBslar | 482 | 1 | Ecology model fixed | Assimilation efficiency | Suspension/deposit feeding benthos larvae |
| aBclar | 483 | 1 | Ecology model fixed | Assimilation efficiency | Carnivore/scavenge feeding benthos larvae |
| aBs | 484 | 1 | Ecology model fixed | Assimilation efficiency | Suspension/deposit feeding benthos |
| aBc | 485 | 1 | Ecology model fixed | Assimilation efficiency | Carnivore/scavenge feeding benthos |
| aFplar | 486 | 1 | Ecology model fixed | Assimilation efficiency | Planktivorous fish larvae |
| aFdlar | 487 | 1 | Ecology model fixed | Assimilation efficiency | Demersal fish lavae |
| aFp | 488 | 1 | Ecology model fixed | Assimilation efficiency | Planktivorous fish |
| aFm | 489 | 1 | Ecology model fixed | Assimilation efficiency | Migratory fish |
| aFd | 490 | 1 | Ecology model fixed | Assimilation efficiency | Demersal fish |
| abird | 491 | 1 | Ecology model fixed | Assimilation efficiency | Birds |
| aseal | 492 | 1 | Ecology model fixed | Assimilation efficiency | Pinnipeds |
| aceta | 493 | 1 | Ecology model fixed | Assimilation efficiency | Cetaceans |
| eHt | 494 | 1 | Ecology model fixed | Background metabolic rate coefficient | Omnivorous fish |
| eCt | 495 | 1 | Ecology model fixed | Background metabolic rate coefficient | Carnivorous zooplankton |
| eBslart | 496 | 1 | Ecology model fixed | Background metabolic rate coefficient | Suspension/deposit feeding benthos larvae |
| eBclart | 497 | 1 | Ecology model fixed | Background metabolic rate coefficient | Carnivore/scavenge feeding benthos larvae |
| eBst | 498 | 1 | Ecology model fixed | Background metabolic rate coefficient | Suspension/deposit feeding benthos |
| eBct | 499 | 1 | Ecology model fixed | Background metabolic rate coefficient | Carnivore/scavenge feeding benthos |
| eFplart | 500 | 1 | Ecology model fixed | Background metabolic rate coefficient | Planktivorous fish larvae |
| eFdlart | 501 | 1 | Ecology model fixed | Background metabolic rate coefficient | Demersal fish larvae |
| eFpt | 502 | 1 | Ecology model fixed | Background metabolic rate coefficient | Planktivorous fish |
| eFmt | 503 | 1 | Ecology model fixed | Background metabolic rate coefficient | Migratory fish |
| eFdt | 504 | 1 | Ecology model fixed | Background metabolic rate coefficient | Demersal fish |
| ebirdt | 505 | 1 | Ecology model fixed | Background metabolic rate coefficient | Birds |
| esealt | 506 | 1 | Ecology model fixed | Background metabolic rate coefficient | Pinnipeds |
| ecetat | 507 | 1 | Ecology model fixed | Background metabolic rate coefficient | Cetaceans |

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|---|---|---|---|---|---|
| mt | 508 | 0 | Ecology model fitted | Mineralisation rate coefficient | Suspended detritus |
| nst | 509 | 0 | Ecology model fitted | Nitrification rate coefficient | Upper layer ammonia |
| dst | 510 | 0 | Ecology model fitted | Denitrification rate coefficient | Upper layer nitrate |
| ndt | 511 | 0 | Ecology model fitted | Nitrification rate coefficient | Lower layer ammonia |
| ddt | 512 | 0 | Ecology model fitted | Denitrification rate coefficient | Lower layer nitrate |
| qs_p1 | 513 | 0 | Ecology model fitted | Conversion rate coefficient | Labile to refractory sediment detritus |
| qs_p2 | 514 | 0 | Ecology model fitted | Mineralistation rate scaling parameter | Refractory sediment detritus |
| qs_p3 | 515 | 0 | Ecology model fitted | Remobilisation parameter | Refractory to labile sediment detritus |
| msedt | 516 | 0 | Ecology model fitted | Mineralisation rate coefficient | Labile sediment detritus |
| msens | 517 | 0 | Ecology model fitted | Mineralisation rate sensitivity to grain size | Labile sediment detritus |
| nsedt | 518 | 0 | Ecology model fitted | Nitrification rate coefficient | Sediment porewater ammonia |
| nsens | 519 | 0 | Ecology model fitted | Nitrification rate sensitivity to grain size | Sediment porewater ammonia |
| dsedt | 520 | 0 | Ecology model fitted | Denitrification rate coefficient | Sediment porewater nitrate |
| dsens | 521 | 0 | Ecology model fitted | Denitrification rate sensitivity to grain size | Sediment porewater nitrate |
| xwave_kelp | 522 | 0 | Ecology model fitted | Wave height dependent conversion rate | Macrophytes to macrophyte debris |
| xst | 523 | 0 | Ecology model fitted | Density dependent mortality coefficient | Phytoplankton upper layer |
| xdt | 524 | 0 | Ecology model fitted | Density dependent mortality coefficient | Phytoplankton lower layer |
| xomni | 525 | 0 | Ecology model fitted | Density dependent mortality coefficient | Omnivorous zooplankton |
| xcarn | 526 | 0 | Ecology model fitted | Density dependent mortality coefficient | Carnivorous zooplankton |
| xbenthslar | 527 | 0 | Ecology model fitted | Density dependent mortality coefficient | Suspension/deposit feeding benthos larvae |
| xbenthclar | 528 | 0 | Ecology model fitted | Density dependent mortality coefficient | Carnivore/scavenge feeding benthos larvae |
| xbenths | 529 | 0 | Ecology model fitted | Density dependent mortality coefficient | Suspension/deposit feeding benthos |
| xbenthc | 530 | 0 | Ecology model fitted | Density dependent mortality coefficient | Carnivore/scavenge feeding benthos |
| xpfishlar | 531 | 0 | Ecology model fitted | Density dependent mortality coefficient | Planktivorous fish larvae |
| xdfishlar | 532 | 0 | Ecology model fitted | Density dependent mortality coefficient | Demersal fish larvae |
| xpfish | 533 | 0 | Ecology model fitted | Density dependent mortality coefficient | Planktivorous fish |
| xmfish | 534 | 0 | Ecology model fitted | Density dependent mortality coefficient | Migratory fish |
| xdfish | 535 | 0 | Ecology model fitted | Density dependent mortality coefficient | Demersal fish |
| xbird | 536 | 0 | Ecology model fitted | Density dependent mortality coefficient | Birds |
| xseal | 537 | 0 | Ecology model fitted | Density dependent mortality coefficient | Pinnipeds |
| xceta | 538 | 0 | Ecology model fitted | Density dependent mortality coefficient | Cetaceans |
| kelpdebris_det | 539 | 0 | Ecology model fitted | Disintigration rate | Macrophyte debris to detritus |
| corp_det | 540 | 0 | Ecology model fitted | Conversion rate coefficient | Corpses to labile sediment detritus |
| disc_corp | 541 | 0 | Ecology model fitted | Conversion rate coefficient | Discards to corpses |
| dsink_s | 542 | 0 | Ecology model fitted | Sinking rate coefficient | Upper layer suspended detritus |
| dsink_d_ | 543 | 0 | Ecology model fitted | Sinking rate coefficient | Lower layer suspended detritus |
| dfdp | 544 | 0 | Ecology model fitted | Scaling parameter | Linking demersal fish survey and model abundance |
| pfish_migcoef | 545 | 0 | Ecology model fitted | Active migration coefficient | Planktivorous fish |
| mfish_migcoef | 546 | 0 | Ecology model fitted | Active migration coefficient | Migratory fish |
| dfish_migcoef | 547 | 0 | Ecology model fitted | Active migration coefficient | Demersal fish |

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|---|---|---|---|---|---|
| bird_migcoef | 548 | 0 | Ecology model fitted | Active migration coefficient | Birds |
| seal_migcoef | 549 | 0 | Ecology model fitted | Active migration coefficient | Pinnipeds |
| ceta_migcoef | 550 | 0 | Ecology model fitted | Active migration coefficient | Cetaceans |
| protect_PF_o | 551 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Planktivorous fish offshore |
| protect_DF_o | 552 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Demersal fish offshore |
| protect_MF_o | 553 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Migratory fish offshore |
| protect_SB_o | 554 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Suspension/deposit feeding benthos offshore |
| protect_CB_o | 555 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Carnivore/scavenge feeding benthos offshore |
| protect_CZ_o | 556 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Carnivorous zooplankton offshore |
| protect_BD_o | 557 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Birds offshore |
| protect_SL_o | 558 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Pinnipeds offshore |
| protect_CT_o | 559 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Cetaceans offshore |
| protect_PF_i | 560 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Planktivorous fish inshore |
| protect_DF_i | 561 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Demersal fish inshore |
| protect_MF_i | 562 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Migratory fish inshore |
| protect_SB_i | 563 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Suspension/deposit feeding benthos inshore |
| protect_CB_i | 564 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Carnivore/scavenge feeding benthos inshore |
| protect_CZ_i | 565 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Carnivorous zooplankton inshore |
| protect_BD_i | 566 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Birds inshore |
| protect_SL_i | 567 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Pinnipeds inshore |
| protect_CT_i | 568 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Cetaceans inshore |
| protect_KP_i | 569 | 0 | Ecology model fitted | Threshold biomass for zero exploitable stock remaining | Macrophytes inshore |
| max_exploitable_f_PF | 570 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Planktivorous fish |

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|---|---|---|---|---|---|
| max_exploitable_f_DF | 571 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Demersal fish |
| max_exploitable_f_MF | 572 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Migratory fish |
| max_exploitable_f_SB | 573 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Suspension/deposit feeding benthos |
| max_exploitable_f_CB | 574 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Carnivore/scavenge feeding benthos |
| max_exploitable_f_CZ | 575 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Carnivorous zooplankton |
| max_exploitable_f_BD | 576 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Birds |
| max_exploitable_f_SL | 577 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Pinnipeds |
| max_exploitable_f_CT | 578 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Cetaceans |
| max_exploitable_f_KP | 579 | 1 | Ecology model fixed | Maximum exploitable fraction of stock | Macrophytes |
| PF_fec | 580 | 1 | Ecology model fixed | Annual fecundity | Planktivorous fish |
| DF_fec | 581 | 1 | Ecology model fixed | Annual fecundity | Demersal fish |
| BS_fec | 582 | 1 | Ecology model fixed | Annual fecundity | Suspension/deposit feeding benthos |
| BC_fec | 583 | 1 | Ecology model fixed | Annual fecundity | Carnivore/scavenge feeding benthos |
| CZ_inedible_biomass_o | 584 | 1 | Ecology model fixed | Inedible biomass offshore | Carnivorous zooplankton |
| CZ_inedible_biomass_i | 585 | 1 | Ecology model fixed | Inedible biomass inshore | Carnivorous zooplankton |
| fdriversslight | 1001 | 4 | Environmental driver | Sea surface irradiance | Inshore and offshore zones |
| fdriverso_logespm | 1002 | 4 | Environmental driver | Suspended particulate matter | Offshore zone |
| fdriversi_logespm | 1003 | 4 | Environmental driver | Suspended particulate matter | Inshore zone |
| fdriverso_temp | 1004 | 4 | Environmental driver | Temperature | Offshore zone upper layer |
| fdriverd_temp | 1005 | 4 | Environmental driver | Temperature | Lower layer offshore |
| fdriversi_temp | 1006 | 4 | Environmental driver | Temperature | Inshore zone |
| fdriverv_dif | 1007 | 4 | Environmental driver | Vertical diffusion rate | Offshore zone |
| fdriverso_inflow | 1008 | 4 | Environmental driver | Boundary volume inflow rate | Inshore zone |
| fdriverd_inflow | 1009 | 4 | Environmental driver | Boundary volume inflow rate | Lower layer offshore |
| fdriversi_inflow | 1010 | 4 | Environmental driver | Boundary volume inflow rate | Inshore zone |
| fdriverso_outflow | 1011 | 4 | Environmental driver | Volumne outflow rate | Offshore surface |
| fdriverd_outflow | 1012 | 4 | Environmental driver | Volume outflow rate | Lower layer offshore |
| fdriversi_outflow | 1013 | 4 | Environmental driver | Volume outflow rate | Inshore zone |
| fdriverso_si_flow | 1014 | 4 | Environmental driver | Volume exchange rate | Offshore to inshore zone |
| fdriversi_so_flow | 1015 | 4 | Environmental driver | Volume exchange rate | Inshore to offshore zone |
| fdrivers_upwell | 1016 | 4 | Environmental driver | Upwelling rate | Offshore zone |
| fdriverriver | 1017 | 4 | Environmental driver | River volume inflow rate | Inshore zone |
| fdriverboundso_det | 1018 | 4 | Environmental driver | Boundary concentration | Upper layer offshore detritus |
| fdriverboundd_det | 1019 | 4 | Environmental driver | Boundary concentration | Lower layer detritus |
| fdriverboundsi_det | 1020 | 4 | Environmental driver | Boundary concentration | Inshore detritus |
| fdriverboundso_amm | 1021 | 4 | Environmental driver | Boundary concentration | Upper layer offshore ammonia |
| fdriverboundd_amm | 1022 | 4 | Environmental driver | Boundary concentration | Lower layer ammonia |
| fdriverboundsi_amm | 1023 | 4 | Environmental driver | Boundary concentration | Inshore ammonia |
| fdriverboundso_nit | 1024 | 4 | Environmental driver | Boundary concentration | Upper layer offshore nitrate |
| fdriverboundd_nit | 1025 | 4 | Environmental driver | Boundary concentration | Lower layer nitrate |
| fdriverboundsi_nit | 1026 | 4 | Environmental driver | Boundary concentration | Inshore nitrate |

| | | | | | |
|---|---|---|---|---|---|
| fdriverboundso_phyt | 1027 | 4 | Environmental driver | Boundary concentration | Upper layer offshore phytoplankton |
| fdriverboundd_phyt | 1028 | 4 | Environmental driver | Boundary concentration | Lower layer phytoplankton |
| fdriverboundsi_phyt | 1029 | 4 | Environmental driver | Boundary concentration | Inshore phytoplankton |
| fdriverboundriv_amm | 1030 | 4 | Environmental driver | Boundary concentration | River ammonia |
| fdriverboundriv_nit | 1031 | 4 | Environmental driver | Boundary concentration | River nitrate |
| fdriverboundriv_det | 1032 | 4 | Environmental driver | Boundary concentration | River detritus |
| fdriverso_atm_amm | 1033 | 4 | Environmental driver | Atmospheric deposition rate | Offshore ammonia |
| fdriverso_atm_nit | 1034 | 4 | Environmental driver | Atmospheric deposition rate | Offshore nitrate |
| fdriversi_atm_amm | 1035 | 4 | Environmental driver | Atmospheric deposition rate | Inshore ammonia |
| fdriversi_atm_nit | 1036 | 4 | Environmental driver | Atmospheric deposition rate | Inshore nitrate |
| fdriver_s1_erosion | 1037 | 4 | Environmental driver | Natural disturbance rate | Inshore muddy sediments |
| fdriver_s2_erosion | 1038 | 4 | Environmental driver | Natural disturbance rate | Inshore sandy sediments |
| fdriver_s3_erosion | 1039 | 4 | Environmental driver | Natural disturbance rate | Inshore coarse sediments |
| fdriver_d1_erosion | 1040 | 4 | Environmental driver | Natural disturbance rate | Offshore muddy sediments |
| fdriver_d2_erosion | 1041 | 4 | Environmental driver | Natural disturbance rate | Offshore sandy sediments |
| fdriver_d3_erosion | 1042 | 4 | Environmental driver | Natural disturbance rate | Offshore coarse sediments |
| fdriver_s_wave | 1043 | 4 | Environmental driver | Significant wave height | Inshore zone |
| fdriverpfish_sp | 1044 | 4 | Biological event driver | Spawning rate | Planktivorous fish |
| fdriverpfish_rec | 1045 | 4 | Biological event driver | Recruitment rate | Planktivorous fish |
| fdriverdfish_sp | 1046 | 4 | Biological event driver | Spawning rate | Demersal fish |
| fdriverdfish_rec | 1047 | 4 | Biological event driver | Recruitment rate | Demersal fish |
| fdriverbs_sp | 1048 | 4 | Biological event driver | Spawning rate | Suspension/deposit feeding benthos |
| fdriverbs_rec | 1049 | 4 | Biological event driver | Recruitment rate | Suspension/deposit feeding benthos |
| fdriverbc_sp | 1050 | 4 | Biological event driver | Spawning rate | Carnivore/scavenge feeding benthos |
| fdriverbc_rec | 1051 | 4 | Biological event driver | Recruitment rate | Carnivore/scavenge feeding benthos |
| fdrivermfish_im | 1052 | 4 | Biological event driver | Immigration rate | Migratory fish |
| fdrivermfish_em | 1053 | 4 | Biological event driver | Emigration rate | Migratory fish |

## OUTPUTS FROM MONTE CARLO ANALYSIS

The function e2e_run_mc() carries out a Monte Carlo analysis to estimate credible intervals of model outputs given uncertainty in the fitted values of the ecology model parameters.

The computation begins with a parent parameter set ($\theta$) loaded by the e2e_read() function, which should be the maximum-likelihood set produced by the simulated annealing scheme. From this parent set, a series of child-sets ($\theta^*_k$ , $1 \le k \le r$, $r$ = e.g. 1000), is generated by applying a separate random increment to each of the parameters; $\theta^*_k = \theta + \delta[k]$ where $\delta[k]$ is a vector of random values from a uniform (rather than a gaussian) distribution of mean 0 and given range.

For each of the parameter sets, the likelihood of the observed annual target data (in the file */Target_data/ annual_target_data*.csv*) $P(observations|\theta^*_k)$ is calculated following a run of the model to stationary state, and all the raw and derived outputs from the final, stationary year of each run is saved (here $k$ = 0 to $r$, where $k$ = 0 corresponds to the maximum likelihood (parent) parameter set).

To calculate the credible interval for any direct or derived model output variable (e.g. annual average mass density of a state variable, or the mass density on a given day in the final year), the values from the individual model runs ($V_k$) and the associated likelihoods ($P_k$) are assembled as a list of $(r + 1; k = 0$ to $r)$ pairs ($a_k = (V_k,P_k)$). The list is then sorted by ascending values of $V$ ($a_j ; j$ = 1 to $(r + 1)$ such that $V_j \ge V_{(j - 1)}$). The vector of cumulative likelihoods is then calculated as follows:

$C_j = ( P_{j=1}, \sum_{j=1}^{j=2} P_j , \sum_{j=1}^{j=3} P_j , \sum_{j=1}^{j=4} P_j \ \dots \ \sum_{j=1}^{j=(r+1)} P_j )$

and the proportions of maximum cumulative likelihood as $Q_j = C_j/C_{(r+1)}$

Finally, values of $V$ corresponding to discrete values of $Q$ = {0.005, 0.25, 0.5, 0.75, 0.995} are extracted by interpolation. These values span the 0.5% and 99.5% credible intervals of the model output given uncertainty in the fitted ecology parameters. Note that uncertainties in the fixed ecology parameters, fishing fleet parameters, and environmental driving data are not reflected in these credible intervals.

The function generates two types of outputs. First is an accumulation of the run-by-run output from all of the simulations exectuted by the function call (Table 57). Second is outputs from processing of the accumulated run data to generate the credible intervals of each of the state variable and derived outputs (Table 58).

The e2e_run_mc() function is computationally intensive, so arguments are include to enable the task to be shared across multiple processor/machines and for the results to be merged afterwards.

**Table 57. File names and details for each of the accumulated sets of run-by-run output from the e2e_run_mc()function.**

| File-name | Description |
|---|---|
| *CredInt_cumulative_parameters-*,csv* | Accumulated sets of ecology model parameters for each run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. . The remaining data on each row are a "column to row" transformation of most of the values in the output structure *results$build$model.parameters* from each model run (see Table 38). |
| *CredInt_cumulative_lastyear-*,csv* | Accumulated final year on daily outputs from each model run. Succesive blocks of 361 rows represent the the last 361 rows of the output structures *results$output* (Table 39) and *results$aggregates* (Table 40) from each model run. Two additional column provide the interation number and the likelihood of the target data given the parameter set respectively. This file can accumulate to several Gb in size. |
| *CredInt_cumulative_monthly-*,csv* | Accumulated final year data on monthly averaged output from each model run. Succesive blocks of 12 rows (1 per month) represent the individual model runs. The first 9 columns are "column to row" transformation of the values in the output structure *results$final.year.outputs$monthly.averages* from each model run (Table 43). Columns 10, 11 and 12 provide the month, interation number and the likelihood of the target data given the parameter set respectively. |
| *CredInt_cumulative_targetresults-*,csv* | Accumulated outputs of final-year simulated annual target data for each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$opt_results$Model_data* from each model run (see Table 48). |
| *CredInt_cumulative_offshoreaamass-*,csv* | Accumulated outputs of final year annual averaged state variable mass data for the offshore zone of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$mass_results_offshore$Model_annual_mean* from each model run. This includes the volumetric and layer thickness data required to convert mass into concentrations or area-densities (see Table 44). |
| *CredInt_cumulative_inshoreaamass-*,csv* | Accumulated outputs of final year annual averaged state variable mass data for the inshore zone of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$mass_results_inshore$Model_annual_mean* from each model run. This includes the volumetric and layer thickness data required to convert mass into concentrations or area-densities (see Table 44). |
| *CredInt_cumulative_wholeaamass-*,csv* | Accumulated outputs of final year annual averaged state variable mass data for the whole domain of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a |

| | |
|---|---|
| | "column to row" transformation of the values in the output structure *results$final.year.outputs$mass_results_wholedomain$Model_annual_mean* from each model run. This includes the volumetric and layer thickness data required to convert mass into concentrations or area-densities (see Table 44). |
| *CredInt_cumulative_offshoreannualflux-*,csv* | Accumulated outputs of final year annual flux data for the offshore zone of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$annual_flux_results_offshore$Model_annual_flux* from each model run. This includes the volumetric and layer thickness data required to convert mass fluxes into volume or area flux-densities (see Table 45). |
| *CredInt_cumulative_inshoreannualflux-*,csv* | Accumulated outputs of final year annual flux data for the inshore zone of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$annual_flux_results_inshore$Model_annual_flux* from each model run. This includes the volumetric and layer thickness data required to convert mass fluxes into volume or area flux-densities (see Table 45). |
| *CredInt_cumulative_wholeannualflux-*,csv* | Accumulated outputs of final year annual flux data for the whole domain of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$annual_flux_results_wholedomain$Model_annual_flux* from each model run. This includes the volumetric and layer thickness data required to convert mass fluxes into volume or area flux-densities (see Table 45). |
| *CredInt_cumulative_network-*,csv* | Accumulated outputs of final year annual network index data for the whole domain of each model run. Rows represent individual model runs. Columns 1 and 2 provide the interation number and the likelihood of the target data given the parameter set. The remaining data on each row are a "column to row" transformation of the values in the output structure *results$final.year.outputs$NetworkIndexResults$NetworkData* from each model run (see Table 47). |

**Table 58. File names and details for each of the post-processed outputs from the e2e_run_mc() or the e2e_process_sens_mc(selection="MC") function.**

| File-name | Description |
|---|---|
| *CredInt_processeed_parameters-*,csv* | Likelihood thresholds of each parameter relative to the maximum likelihood value (level_value/max.likelihood_value) – 1 |

| | |
|---|---|
| *CredInt_processed_daily_mass-*,csv* | Likelihood threshold values of each of the final year daily variable outputs from the model (in blocks of 6 rows for each variable). Columns are the values for each day of the year. |
| *CredInt_ processed _monthly_mass-*,csv* | Likelihood threshold values of each of the final year monthly averaged variable outputs from the model (in blocks of 6 rows for each variable). Columns are the values for each month of the year. |
| *CredInt_ processed _targetresults-*,csv* | Likelihood threshold values of each of the simulated target data outputs from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables. |
| *CredInt_ processed _AAMresults_offshore-*,csv* | Likelihood threshold values of the annual averaged mass-densities ($mMN.m^{-2}$) of state variables in the offshore zone from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables. |
| *CredInt_ processed _AAMresults_inshore-*,csv* | Likelihood threshold values of the annual averaged mass-densities ($mMN.m^{-2}$) of state variables in the inshore zone from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables. |
| *CredInt_ processed _AAMresults_whole-*,csv* | Likelihood threshold values of the annual averaged mass-densities ($mMN.m^{-2}$) of state variables in the whole domain from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables. |
| *CredInt_ processed _annualflux_offshore-*,csv* | Likelihood threshold values of the annual integrated fluxes ($mMN.m^{-2}.y^{-1}$) of state variables in the offshore zone from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables. |
| *CredInt_ processed _annualflux_inshore-*,csv* | Likelihood threshold values of the annual integrated fluxes ($mMN.m^{-2}.y^{-1}$) of state variables in the inshore zone from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables |
| *CredInt_ processed _annualflux_whole-*,csv* | Likelihood threshold values of the annual integrated fluxes ($mMN.m^{-2}.y^{-1}$) of state variables in the whole domain from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables |
| *CredInt_ processed _daily_fluxes-*,csv* | Likelihood threshold values of various daily fluxes ($mMN.m^{-2}.d^{-1}$) of state variables in the inshore zone from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables |
| *CredInt_ processed _daily_migrations*,csv* | Likelihood threshold values of the daily net migration fluxes ($mMN.m^{-2}.d^{-1}$) between ofshoire and inshore zones (+ve indicates offshore to inshore and vice versa) of the three fish guilds, birds, pinnipeds and cetaceans from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables |
| *CredInt_ processed _networkresults-*,csv* | Likelihood threshold values of the annual network indices in the whole domain from the final years of each of the model runs. Rows are the 6 threshold levels, columns are the variables |

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