

# Package ‘gadget3’

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**Type** Package

**Title** Globally-Applicable Area Disaggregated General Ecosystem Toolbox  
V3

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**Description** A framework to assist creation of marine ecosystem models, generating either 'R' or 'C++' code which can then be optimised using the 'TMB' package and standard 'R' tools. Principally designed to reproduce gadget2 models in 'TMB', but can be extended beyond gadget2's capabilities.

Kasper Kristensen, An-

ders Nielsen, Casper W. Berg, Hans Skaug, Bradley M. Bell (2016) <[doi:10.18637/jss.v070.i05](https://doi.org/10.18637/jss.v070.i05)> ``TMB: Automatic Differentiation and Laplace Approximation.".

Begley, J., & Howell, D. (2004) <<https://core.ac.uk/download/pdf/225936648.pdf>> ``An overview of Gadget, the globally applicable area-disaggregated general ecosystem toolbox. ICES.".

**URL** <https://gadget-framework.github.io/gadget3/>,  
<https://github.com/gadget-framework/gadget3/>

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aaa_lang	<i>Gadget3 language utilities</i>
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## Description

Produce objects with special meaning to gadget3

## Usage

```
g3_native(r, cpp, depends = c())
g3_global_formula(f = quote(noop), init_val = NULL)
```

## Arguments

r	An R <a href="#">function</a> to decorate with a 'C++' equivalent
cpp	Either: <ol style="list-style-type: none"> <li>1. A character string containing the 'C++' equivalent as a Lambda function</li> <li>2. A character string containing 'C++' function template definition, calling the function <code>__fn__</code></li> <li>3. A <a href="#">list</a> of type-casts to use when calling an equivalently named native function</li> </ol>
depends	A <a href="#">list</a> of string names of dependent functions. The content of this and the initial <code>[]</code> for any Lambda function should match.
f	An optional <a href="#">formula</a> to modify the content of a globally-defined variable
init_val	An optiona <a href="#">formula</a> to set the initial value of a globally-defined variable

## Details

These functions are generally for gadget3 development, but made available so actions can be produced outside the package.

## Value

**g3\_native:** Returns a function that can be used in formulas for both R and TMB-based models.

**g3\_global\_formula:** Returns a [formula](#) that will be defined globally, and this can preserve state across timesteps.

## Examples

```
# The definition of g3_env$ratio_add_vec looks like:
eg_ratio_add_vec <- g3_native(r = function(orig_vec, orig_amount,
                                         new_vec, new_amount) {
  ((orig_vec * orig_amount + new_vec * new_amount)
   /
   avoid_zero_vec(orig_amount + new_amount))
}, cpp = '[](vector<Type> orig_vec, vector<Type> orig_amount,
            vector<Type> new_vec, vector<Type> new_amount)
-> vector<Type> {
  return (orig_vec * orig_amount + new_vec * new_amount)
  /
  avoid_zero_vec(orig_amount + new_amount);
}', depends = c('avoid_zero_vec'))
# eg_ratio_add_vec() can then be used in formulas, both in R & TMB.

# Define a random walk action, using g3_global_formula to keep track of
# previous value. NB: my_randomwalk_prevrec must be unique in a model
random_walk_action <- g3_formula(quote({
  if (cur_time > 0) nll <- nll + dnorm(x, stock__prevrec, 1, 1)
  my_randomwalk_prevrec <- x
}), x = 'TODO', my_randomwalk_prevrec = g3_global_formula(init_val = 0.0))
```

---

aab\_env

*Gadget3 global environment*

---

## Description

Functions available to any gadget3 model

## Details

`g3_env` is the top-level [environment](#) that any gadget3 model uses, populated with utility functions.

NB: Several functions have `_vec` variants. Due to TMB limitations these should be used when you have a vector not scalar input.

## ADREPORT

TMB's ADREPORT function. See [sdreport](#) documentation

## as\_integer

C++ compatible equivalent to [as.integer](#)

## as.numeric

R [as.numeric](#) or TMB `asDouble`

**assert\_msg**

C++/R function that ensures expression is true, or stops model.

```
assert_msg(x > 0, "x must be positive")
```

**avoid\_zero**

Adds small value to input to ensure output is never zero `avoid_zero_vec` is identical to `avoid_zero`, and is only present for backward compatibility.

**bounded / bounded\_vec**

Ensures  $x$  is within limits  $b$  &  $a$ .

If  $x$  positive, return  $a$ . If  $x$  negative,  $b$ . If  $x \in [-10, 10]$ , smoothly transition from  $b$  to  $a$

```
bounded_vec(x, 200, 100)
```

**g3\_matrix\_vec**

Apply matrix transformation  $tf$  to vector  $vec$ , return resultant vector.

```
g3_matrix_vec(tf, vec)
```

**lgamma\_vec**

Vector equivalent of [lgamma](#)

**logspace\_add**

TMB's `logspace_add`, essentially a differentiable version of [pmax](#).

**normalize\_vec**

Divide vector  $a$  by its sum, i.e. so it now sums to 1. If vector is all-zero, return an all-zero vector instead.

**nvl**

Return first non-null argument. NB: No C++ implementation.

**print\_array**

Utility to pretty-print array  $ar$

**ratio\_add\_vec**

Sum  $orig\_vec$  &  $new\_vec$  according to ratio of  $orig\_amount$  &  $new\_amount$

**nonconform\_add / nonconform\_mult / nonconform\_div / nonconform\_div\_avz**

Scalar sum/multiply/divide 2 non-conforming arrays, by treating the latter as a vector and repeating as many times as required. Results will be structured identically to the first array.

`nonconform_div_avz(x, y)` is equivalent to `nonconform_div(x, avoid_zero_vec(y))`

**REPORT**

TMB's REPORT function.

**REprintf**

Equivalent of RCpp [REprintf](#)

**Rprintf**

Equivalent of RCpp [Rprintf](#)

**Examples**

```
## avoid_zero
g3_eval(quote( c( avoid_zero(0), avoid_zero(10) ) ))
g3_eval(quote( avoid_zero(0:5) ))

## bounded / bounded_vec
curve(g3_eval(quote( bounded(x, 200, 100) ), x = x), -100, 100)

## logspace_add
curve(g3_eval(quote( logspace_add(x, 10) ), x = x), 0, 40)

## normalize_vec
g3_eval(quote( normalize_vec(c( 4, 4, 8, 2 )) ))

## nonconform_mult
g3_eval(quote( nonconform_mult(
  array(seq(0, 4*5*6), dim = c(4,5,6)),
  c(1e1, 1e2, 1e3, 1e4) ) ))

## nonconform_div_avz
g3_eval(quote( nonconform_div_avz(
  array(seq(0, 4*5*6), dim = c(4,5,6)),
  c(1e1, 1e2, 0, 1e4) ) ))
g3_eval(quote( nonconform_div(
  array(seq(0, 4*5*6), dim = c(4,5,6)),
  avoid_zero(c(1e1, 1e2, 0, 1e4)) ) ))
```

---

action_age	<i>Gadget3 age action</i>
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---

## Description

Add ageing actions to a g3 model

## Usage

```
g3a_age(
  stock,
  output_stocks = list(),
  output_ratios = rep(1/length(output_stocks),
    times = length(output_stocks)),
  run_f = ~cur_step_final,
  run_at = g3_action_order$age,
  transition_at = g3_action_order$age)
```

## Arguments

stock	<a href="#">g3_stock</a> to age.
output_stocks	List of <a href="#">g3_stocks</a> that oldest specimens in <i>stock</i> should move into.
output_ratios	Vector of proportions for how to distribute into <i>output_stocks</i> , default evenly spread.
run_f	<a href="#">formula</a> specifying a condition for running this action, default is end of model year.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .
transition_at	Integer order that transition actions will be run within model, see <a href="#">g3_action_order</a> .

## Value

An action (i.e. list of formula objects) that will, for the given *stock*...

1. Move the final age group into temporary storage, `stock__transitioning_num/stock__transitioning_wgt`
2. Move the contents of all other age groups into the age group above
3. Move the contents of the temporary storage into *output\_stocks*

If *stock* has only one age, and *output\_stocks* has been specified, then the contentes will be moved, if *output\_stocks* is empty, then the action will do nothing.

## See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockmature>,  
[g3\\_stock](#)

**Examples**

```

ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock('ling_mat', seq(20, 156, 4)) %>% g3s_age(5, 15)

# Ageing for immature ling
age_action <- g3a_age(ling_imm,
  output_stocks = list(ling_mat))

```

---

action\_grow

*Gadget3 growth action*


---

**Description**

Add growth/maturity actions to a g3 model

**Usage**

```

g3a_grow_lengthvbsimple(
  linf_f = g3_parameterized('Linf', by_stock = by_stock),
  kappa_f = g3_parameterized('K', by_stock = by_stock),
  by_stock = TRUE)

g3a_grow_weightssimple(
  alpha_f = g3_parameterized('walpha', by_stock = by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = by_stock),
  by_stock = TRUE)

g3a_grow_impl_bbinom(
  delta_len_f = g3a_grow_lengthvbsimple(by_stock = by_stock),
  delta_wgt_f = g3a_grow_weightssimple(by_stock = by_stock),
  beta_f = g3_parameterized('bbin', by_stock = by_stock),
  maxlengthgroupgrowth,
  by_stock = TRUE)

g3a_grow_length_multispec(
  p0 = g3_parameterized('multispec.p0', value = 1, by_stock = by_stock),
  p1 = g3_parameterized('multispec.p1', value = 1, by_stock = by_stock),
  p2 = g3_parameterized('multispec.p2', value = 1, by_stock = by_stock),
  p3 = g3_parameterized('multispec.p3', value = 0, by_stock = by_stock),
  temperature = 0,
  by_stock = TRUE)

g3a_grow_weight_multispec(
  p4 = g3_parameterized('multispec.p4', value = 1, by_stock = by_stock),
  p5 = g3_parameterized('multispec.p5', value = 1, by_stock = by_stock),
  p6 = g3_parameterized('multispec.p6', value = 0, by_stock = by_stock),
  p7 = g3_parameterized('multispec.p7', value = 1, by_stock = by_stock),

```

```

p8 = g3_parameterized('multispec.p8', value = 0, by_stock = by_stock),
temperature = 0,
by_stock = TRUE)

g3a_grow_length_weightjones(
  p0 = g3_parameterized('weightjones.p0', value = 0, by_stock = by_stock),
  p1 = g3_parameterized('weightjones.p1', value = 0, by_stock = by_stock),
  p2 = g3_parameterized('weightjones.p2', value = 1, by_stock = by_stock),
  p3 = g3_parameterized('weightjones.p3', value = 0, by_stock = by_stock),
  p4 = g3_parameterized('weightjones.p4', value = 1, by_stock = by_stock),
  p5 = g3_parameterized('weightjones.p5', value = 100, by_stock = by_stock),
  p6 = g3_parameterized('weightjones.p6', value = 1, by_stock = by_stock),
  p7 = g3_parameterized('weightjones.p7', value = 1, by_stock = by_stock),
  reference_weight = 0,
  temperature = 0,
  by_stock = TRUE)

g3a_grow_weight_weightjones(
  q0 = g3_parameterized('weightjones.q0', value = 1, by_stock = by_stock),
  q1 = g3_parameterized('weightjones.q1', value = 1, by_stock = by_stock),
  q2 = g3_parameterized('weightjones.q2', value = 1, by_stock = by_stock),
  q3 = g3_parameterized('weightjones.q3', value = 1, by_stock = by_stock),
  q4 = g3_parameterized('weightjones.q4', value = 1, by_stock = by_stock),
  q5 = g3_parameterized('weightjones.q5', value = 0, by_stock = by_stock),
  max_consumption = g3a_predate_maxconsumption(temperature = temperature),
  temperature = 0,
  by_stock = TRUE)

g3a_growmature(stock, impl_f, maturity_f = ~0, output_stocks = list(),
  output_ratios = rep(1/length(output_stocks), times = length(output_stocks)),
  transition_f = ~cur_step_final, run_f = ~TRUE,
  run_at = g3_action_order$grow,
  transition_at = g3_action_order$mature)

```

## Arguments

linf_f	A <a href="#">formula</a> to substitute for $L_\infty$ .
kappa_f	A <a href="#">formula</a> to substitute for $\kappa$ .
alpha_f	A <a href="#">formula</a> to substitute for $\alpha$ .
beta_f	A <a href="#">formula</a> to substitute for $\beta$ .
p0, p1, p2, p3, p4, p5, p6, p7, p8, q0, q1, q2, q3, q4, q5	A <a href="#">formula</a> to substitute for the equivalent value.
max_consumption	Maximum predator consumption, see <a href="#">g3a_predate_maxconsumption</a> .
temperature	A <a href="#">formula</a> providing values for the current temperature, likely implemented with <a href="#">g3_timeareadata</a> .

maxlengthgroupgrowth	An integer with the maximum length groups an individual can jump in one step.
reference_weight	Reference weight. see formula for <a href="#">g3a_grow_length_weightjones</a> .
stock	<a href="#">g3_stock</a> to grow.
delta_len_f	A <a href="#">formula</a> defining a non-negative vector for mean increase in length for stock for each lengthgroup, as defined by <a href="#">g3a_grow_lengthvbsimple</a> .
delta_wgt_f	A <a href="#">formula</a> defining the corresponding weight increase as a matrix of lengthgroup to lengthgroup delta for stock, as defined by <a href="#">g3a_grow_weightssimple</a> .
by_stock	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
impl_f	A pair of <a href="#">formula</a> objects, as defined by <a href="#">g3a_grow_impl_bbinom</a> . Both define a matrix of length groups $i$ to length group deltas $j$ ( $0..maxlengthgroupgrowth$ ), the values in the first indicate the proportion of individuals moving from $i$ to $i + j$ , the values in the second indicate the corresponding weight increase of individuals moving from $i$ to $i + j$ .
maturity_f	A maturity <a href="#">formula</a> , as defined by <a href="#">g3a_mature_constant</a> .
output_stocks	List of <a href="#">g3_stocks</a> that maturing <i>stock</i> should move into.
output_ratios	Vector of proportions for how to distribute into <i>output_stocks</i> , summing to 1, default evenly spread.
transition_f	<a href="#">formula</a> specifying a condition for running maturation steps as well as growth, default final step of year.
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .
transition_at	Integer order that transition actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

A model can have any number of `g3a_growmature` actions, so long as the calling arguments are different. For instance, `run_f = ~age == 5` and `run_f = ~age == 7`.

*impl\_f*'s dependent variables are analysed to see what will affect growth. If nothing but `cur_step_size` will affect growth, then growth will only be recalculated when the step size changes.

### Value

**g3a\_grow\_lengthvbsimple:** Returns a [formula](#) for use as *delta\_len\_f*:

$$\Delta L_i = (L_\infty - L_i)(1 - e^{-\kappa \Delta t})$$

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in [g3a\\_time](#)

**g3a\_grow\_weightssimple:** Returns a [formula](#) for use as *delta\_wgt\_f*:

$$\Delta W_{i,j} = \alpha((L_i + \Delta L_j)^\beta - L_i^\beta)$$

$\Delta L$  Vector of all possible length group increases i.e  $0..maxlengthgroupgrowth$

**g3a\_grow\_length\_multspec:** Returns a [formula](#) for use as *delta\_len\_f*:

$$\Delta L_i = \Delta t p_0 L_i^{p_1} \psi_i (p_2 T + p_3)$$

$p_x$  Supplied parameters

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See *cur\_step\_size* in [g3a\\_time](#)

$L_i$  Current length

$\psi_i$  Feeding level of stock. See [g3a\\_predate\\_catchability\\_predator](#)

$T$  Temperature of current region

**g3a\_grow\_weight\_multspec:** Returns a [formula](#) for use as *delta\_wgt\_f*:

$$\Delta W_{i,j} = \Delta t p_4 W_i^{p_5} (\psi_i - p_6) (p_7 T + p_8)$$

$p_x$  Supplied parameters

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See *cur\_step\_size* in [g3a\\_time](#)

$W_i$  Current mean weight

$\psi_i$  Feeding level of stock. See [g3a\\_predate\\_catchability\\_predator](#)

$T$  Temperature of current region

Note that the equation is not dependent on the change in length, the value will be the same for each  $j$ .

**g3a\_grow\_length\_weightjones:** Returns a [formula](#) for use as *delta\_len\_f*:

$$r = \frac{W_i - (p_0 + \psi_i(p_1 + p_2 \psi_i)) W_{ref}}{W_i}$$

$$\Delta L_i = \minmax(p_3 + p_4 r, 0, p_5) \frac{\Delta W_{i,j}}{p_6 p_7 L_i^{(p_7-1)}}$$

$W_i$  Current mean weight

$p_x$  Supplied parameters

$\psi_i$  Feeding level of stock. See [g3a\\_predate\\_catchability\\_predator](#)

$W_{ref}$  Reference weight, from the *reference\_weight* parameter

$\Delta W_{i,j}$  Change in weight, i.e. the output from the *delta\_wgt\_f* formula, probably [g3a\\_grow\\_weight\\_weightjones](#).

**g3a\_grow\_weight\_weightjones:** Returns a [formula](#) for use as *delta\_wgt\_f*:

$$\Delta W_{i,j} = \Delta t \left( \frac{M \psi_i}{q_0 W_i^{q_1}} - q_2 W_i^{q_3} e^{(q_4 T + q_5)} \right)$$

$q_x$  Supplied parameters

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See *cur\_step\_size* in [g3a\\_time](#)

$M$  Maximum theoretical consumption, as defined by [g3a\\_predate\\_maxconsumption](#)

$\psi_i$  Feeding level of stock. See [g3a\\_predate\\_catchability\\_predator](#)

$W_i$  Current mean weight

$T$  Temperature of current region

Note that the equation is not dependent on the change in length, the value will be the same for each  $j$ .

**g3a\_grow\_impl\_bbinom:** `formula` object converting mean growths using beta-binomial distribution. See <https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#beta-binomial>

**g3a\_growmature:** An action (i.e. list of formula objects) that will, for the given *stock*...

1. Move any maturing individuals into temporary storage, `stock__transitioning_num/stock__transitioning_wgt`
2. Calculate increase in length/weight using `growth_f` and `impl_f`
3. Move the contents of the temporary storage into `output_stocks`

### See Also

[https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockgrowth,g3\\_stock](https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockgrowth,g3_stock)

### Examples

```
ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4))
ling_mat <- g3_stock(c(species = 'ling', 'mat'), seq(20, 156, 4))

# Growth / maturity for immature ling
growth_action <- g3a_growmature(ling_imm,
  impl_f = g3a_grow_impl_bbinom(
    # Parameters will be ling.Linf, ling.K
    g3a_grow_lengthvbsimple(by_stock = 'species'),
    # Parameters will be ling_imm.walpha, ling_imm.wbeta
    g3a_grow_weightssimple(),
    maxlengthgroupgrowth = 15),
  maturity_f = g3a_mature_constant(
    alpha = g3_parameterized('ling.mat1', scale = 0.001),
    150 = g3_parameterized('ling.mat2')),
  output_stocks = list(ling_mat))

# Multspec growth - define a data frame with temperature
temperature <- g3_timeareadata(
  'temp',
  data.frame(year = 2000, step=c(1,2), temp=c(10, 14)),
  value_field = "temp" )

ms_growth_actions <- list(
  g3a_growmature(ling_imm, g3a_grow_impl_bbinom(
    g3a_grow_length_multspec(temperature = temperature),
    g3a_grow_weight_multspec(temperature = temperature),
    maxlengthgroupgrowth = 8 )),
  NULL)
```

---

action_mature	<i>Gadget3 maturity action</i>
---------------	--------------------------------

---

### Description

Add maturity actions to a g3 model

### Usage

```
g3a_mature_continuous(
  alpha = g3_parameterized('mat.alpha', by_stock = by_stock),
  l50 = g3_parameterized('mat.l50', by_stock = by_stock),
  beta = 0,
  a50 = 0,
  bounded = TRUE,
  by_stock = TRUE)
```

```
g3a_mature_constant(alpha = NULL, l50 = NA, beta = NULL, a50 = NA, gamma = NULL,
  k50 = NA)
```

```
g3a_mature(stock, maturity_f, output_stocks, output_ratios = rep(1/length(output_stocks),
  times = length(output_stocks)), run_f = ~TRUE,
  run_at = g3_action_order$grow,
  transition_at = g3_action_order$mature)
```

### Arguments

alpha	A <a href="#">formula</a> to substitute for $\alpha$ .
l50	A <a href="#">formula</a> to substitute for $l_{50}$ . Must be defined if <i>alpha</i> is defined.
beta	A <a href="#">formula</a> to substitute for $\beta$ .
a50	A <a href="#">formula</a> to substitute for $a_{50}$ . Must be defined if <i>beta</i> is defined.
gamma	A <a href="#">formula</a> to substitute for $\gamma$ .
k50	A <a href="#">formula</a> to substitute for $k_{50}$ . Must be defined if <i>gamma</i> is defined.
bounded	Should the maturity ratio be bounded to 0..1? Set TRUE if maturity is producing negative numbers of individuals.
by_stock	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
stock	<a href="#">g3_stock</a> to mature.
maturity_f	A maturity <a href="#">formula</a> , as defined by <a href="#">g3a_mature_constant</a> .
output_stocks	List of <a href="#">g3_stocks</a> that maturing <i>stock</i> should move into.
output_ratios	Vector of proportions for how to distribute into <i>output_stocks</i> , summing to 1, default evenly spread.
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .
transition_at	Integer order that transition actions will be run within model, see <a href="#">g3_action_order</a> .

## Details

Generally you would use `g3a_growmature`, which does both growth and maturity at the same time.

A model can have any number of `g3a_mature` actions, so long as the calling arguments are different. For instance, `run_f = ~age == 5` and `run_f = ~age == 7`.

## Value

**g3a\_mature\_continuous:** A `formula` object representing

$$m_0 * (\alpha \Delta L + \beta \Delta t)^\top$$

$m_0$  The `g3a_mature_constant` formula, as defined below, using parameters supplied to `g3a_mature_continuous`

$\Delta L$  Vector of all possible changes in length, as per current growth matrix (see `g3a_grow_impl_bbinom`)

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in `g3a_time`

**g3a\_mature\_constant:** A `formula` object with the following equation

$$\frac{1}{1 + e^{-\alpha(l-l_{50}) - \beta(a-a_{50}) - \gamma(k-k_{50})}}$$

$l$  length of stock

$l_{50}$  length of stock when 50% are mature

$a$  age of stock

$a_{50}$  age of stock when 50% are mature

$k$  weight of stock

$k_{50}$  weight of stock when 50% are mature

**g3a\_mature:** An action (i.e. list of formula objects) that will, for the given `stock`...

1. Move any maturing individuals into temporary storage, `stock__transitioning_num/stock__transitioning_wgt`
2. Move the contents of the temporary storage into `output_stocks`

## See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockmature>,  
[g3a\\_growmature](#), [g3\\_stock](#)

## Examples

```
ling_imm <- g3_stock('ling_imm', seq(20, 156, 4))
ling_mat <- g3_stock('ling_mat', seq(20, 156, 4))

# Maturity for immature ling
maturity_action <- g3a_mature(ling_imm,
  maturity_f = g3a_mature_continuous(),
  output_stocks = list(ling_mat))
```

---

action_migrate	<i>Gadget3 migration action</i>
----------------	---------------------------------

---

### Description

Add migration to a g3 model

### Usage

```
g3a_migrate_normalize(row_total = 1)

g3a_migrate(stock, migrate_f, normalize_f = g3a_migrate_normalize(),
            run_f = TRUE,
            run_at = g3_action_order$migrate)
```

### Arguments

row_total	When calculating the proportion of individuals that will stay in place, use this total for what rows are expected to sum to.
stock	The <a href="#">g3_stock</a> that will migrate in this action.
migrate_f	A formula describing the migration in terms of (source) area and dest_area.
normalize_f	Function to normalize a vector of possible destinations, to make sure fish aren't added or destroyed.
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that spawning actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

To restrict movement to a particular step in a year, or a particular area, use *run\_f*. For example:

`cur_step == 1` Migration will happen on first step of every year

`cur_step == 1 && cur_year >= 1990` Migration will happen on first step of every year after 1990

`cur_step == 2 && area = 1` Migration will happen on second step of every year, in the first area

Multiple migration actions can be added, for a separate spring and autumn migration, for instance.

The action will define the following stock instance variables for each given *stock*:

*stock\_\_migratematrix*  $a \times a$  array, containing proportion of (stock) moved from one area to another.  
If NaN, no movement has occurred

**Value**

**g3a\_migrate\_normalize:** A formula transforming `stock__migratematrix[,stock__area_idx]` (i.e. all possible destinations from a given area) by:

1. Squaring so values are all positive
2. Altering the proportion of static individuals so a row sums to *row\_total*
3. Dividing by *row\_total* so a row sums to 1

**g3a\_migrate:** An action (i.e. list of formula objects) that will, for the given *stock...*

1. Fill in *stock\_\_migratematrix* using *migrate\_f* and *normalize\_f*
2. Apply movement to *stock*

**See Also**

[g3\\_stock](#)

**Examples**

```
areas <- list(a=1, b=2, c=3, d=4)

# NB: stock doesn't live in b, so won't figure in stock_acd__migratematrix
stock_acd <- (g3_stock('stock_acd', seq(10, 40, 10))
  %>% g3s_livesonareas(areas[c('a', 'c', 'd')]))

movement_action <- list(
  g3a_migrate(
    stock_acd,
    # In spring, individuals in area 'a' will migrate to 'd'.
    ~if (area == area_a && dest_area == area_d) 0.8 else 0,
    run_f = ~cur_step == 2),
  g3a_migrate(
    stock_acd,
    # In autumn, individuals in all areas will migrate to 'a'
    ~if (dest_area == area_a) 0.8 else 0,
    run_f = ~cur_step == 4),
  list())
```

---

action\_naturalmortality

*Gadget3 natural mortality action*

---

**Description**

Add natural mortality to a g3 model

**Usage**

```

g3a_naturalmortality_exp(
  param_f = g3_parameterized('M', by_stock = by_stock, by_age = TRUE),
  by_stock = TRUE,
  action_step_size_f = ~cur_step_size)

g3a_naturalmortality(
  stock,
  mortality_f = g3a_naturalmortality_exp(),
  run_f = TRUE,
  run_at = g3_action_order$naturalmortality)

```

**Arguments**

param_f	A <a href="#">formula</a> to substitute for <i>m</i> .
action_step_size_f	How much model time passes in between runs of action? defaults to <code>~cur_step_size</code> , i.e. every step. Use <code>action_step_size_f = 1</code> if action only runs yearly.
by_stock	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
stock	<a href="#">g3_stock</a> mortality applies to.
mortality_f	A mortality <a href="#">formula</a> , as defined by <a href="#">g3a_naturalmortality_exp</a> .
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

**Details**

A model can have any number of `g3a_naturalmortality` actions, so long as the calling arguments are different. For instance, `run_f = ~age == 5` and `run_f = ~age == 7`.

**Value**

**g3a\_naturalmortality\_exp:** A [formula](#) object with the following equation

$$e^{-m\Delta t}$$

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in [g3a\\_time](#)

**g3a\_naturalmortality:** An action (i.e. list of formula objects) that will, for the given *stock*...

1. Remove a proportion of each stock group as calculated by the mortality formula `mortality_f`

**See Also**

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stocknatmort>, [g3a\\_growmature](#), [g3\\_stock](#)

**Examples**

```

ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)

# Natural mortality for immature ling
naturalmortality_action <- g3a_naturalmortality(ling_imm)

# NB: M is used in both g3a_naturalmortality and g3a_renewal_initabund, to
# customise, you need to make sure the definitions are in sync, for example:

M <- g3_parameterized('M', by_stock = TRUE, by_age = FALSE)
actions <- list(
  g3a_naturalmortality(ling_imm,
    g3a_naturalmortality_exp(M)),
  g3a_initialconditions_normalparam(ling_imm,
    factor_f = g3a_renewal_initabund(M = M)),
  NULL)

```

---

action\_order

*Standard gadget3 order of actions*


---

**Description**

Constant defining standard order of actions

**Usage**

```
g3_action_order
```

**Details**

All gadget3 actions have a *run\_at* parameter. This decides the point in the model that the action will happen relative to others.

The defaults for these are set via *g3\_action\_order*.

**Value**

A named integer list

**See Also**

<https://gadget-framework.github.io/gadget2/userguide/chap-order.html>

**Examples**

```
# The default action order
unlist(g3_action_order)

# View single value
g3_action_order$age
```

---

action_predate	<i>Gadget3 predation actions</i>
----------------	----------------------------------

---

**Description**

Add predation to a g3 model

**Usage**

```
g3a_predate_catchability_totalfleet(E)

g3a_predate_catchability_numberfleet(E)

g3a_predate_catchability_linearfleet(E)

g3a_predate_catchability_project(
  quota_f = NULL,
  landings_f = NULL,
  quota_prop = g3_parameterized("quota.prop", by_predator = TRUE, value = 1),
  cons_step = g3_parameterized("cons.step", by_predator = TRUE, by_step = TRUE,
    value = quote( step_lengths / 12.0 )),
  unit = c("biomass", "biomass-year", "harvest-rate", "harvest-rate-year",
    "individuals", "individuals-year") )

g3a_predate_catchability_effortfleet(catchability_fs, E)

g3a_predate_catchability_quotafleet(quota_table, E,
  sum_stocks = list(),
  recalc_f = NULL)

g3a_predate_maxconsumption(
  m0 = g3_parameterized('consumption.m0', value = 1,
    by_predator = TRUE, optimise = FALSE),
  m1 = g3_parameterized('consumption.m1', value = 0,
    by_predator = TRUE, optimise = FALSE),
  m2 = g3_parameterized('consumption.m2', value = 0,
    by_predator = TRUE, optimise = FALSE),
  m3 = g3_parameterized('consumption.m3', value = 0,
    by_predator = TRUE, optimise = FALSE),
```

```

    temperature = 0 )

g3a_predate_catchability_predator(
  prey_preferences = 1,
  energycontent = g3_parameterized('energycontent', value = 1,
    by_stock = by_stock, optimise = FALSE),
  half_feeding_f = g3_parameterized('halffeeding',
    by_predator = by_predator, optimise = FALSE),
  max_consumption = g3a_predate_maxconsumption(temperature = temperature),
  temperature = 0,
  by_predator = TRUE,
  by_stock = TRUE )

g3a_predate(
  predstock,
  prey_stocks,
  suitabilities,
  catchability_f,
  overconsumption_f = quote( dif_pmin(stock__consratio, 0.95, 1e3) ),
  run_f = ~TRUE,
  run_at = g3_action_order$predate )

# NB: Deprecated interface, use g3a_predate()
g3a_predate_fleet(fleet_stock, prey_stocks, suitabilities, catchability_f,
  overconsumption_f = quote( dif_pmin(stock__consratio, 0.95, 1e3) ),
  run_f = ~TRUE, run_at = g3_action_order$predate)

# NB: Deprecated interface, use g3a_predate() with g3a_predate_catchability_totalfleet
g3a_predate_totalfleet(fleet_stock, prey_stocks, suitabilities, amount_f,
  overconsumption_f = quote( dif_pmin(stock__consratio, 0.95, 1e3) ),
  run_f = ~TRUE, run_at = g3_action_order$predate)

```

## Arguments

predstock, fleet_stock	<a href="#">g3_stock</a> that describes the harvesting predators/fleet, or a list of <a href="#">g3_stock</a> objects, in which case <a href="#">g3a_predate</a> will be run for each in turn.
prey_stocks	List of <a href="#">g3_stocks</a> that maturing <i>stock</i> should move into.
suitabilities	Either a list of stock names to <a href="#">formula</a> objects, with an optional unnamed default option, or a <a href="#">formula</a> object (which is always used). Each <a href="#">formula</a> should define suitability of a stock, for example by using <a href="#">g3_suitability_exponential15</a>
catchability_f	A list of <a href="#">formulas</a> generated by one of the <code>g3a_predate_catchability_*</code> functions, which define the total biomass a fleet is able to catch.
E, landings_f	A <a href="#">formula</a> defining total catch a fleet can harvest at the current time/area (totalfleet/numberfleet), or a scaling factor used to define the stock caught (linearfleet/effortfleet/quotafleet).
quota_f	A per-year quota for use during projection time periods, or for the whole model if <i>landings_f</i> is NULL. Generally, this will be produced by <a href="#">g3_quota</a> .

quota_prop	A quota can apply to multiple fleets, in which case use this parameter to assign the proportion of quota available to the current fleet. Note that ideally all <i>quota_prop</i> values sum to 1, but this doesn't have to be the case (e.g. over/under-utilisation of quotas).
cons_step	The proportion of the per-year quota that is used in each step. As with <i>quota_prop</i> ideally all values sum to 1.
unit	The unit that <i>quota_f</i> / <i>landings_f</i> is provided in. "biomass", "effort", "individuals" are equivalent to totalfleet / linearfleet & numberfleet respectively.
catchability_fs	Either a list of stock names to <a href="#">formula</a> objects, with an optional unnamed default option, or a <a href="#">formula</a> object (which is always used).
quota_table	A data.frame with 'biomass' and 'quota' columns, 'biomass' a numeric column, an upper bound for total biomass amount, the final value always being Inf. 'quota' being a list of <a href="#">formulas</a> , defining the quota for each, e.g. with <a href="#">g3_parameterized</a> .
sum_stocks	Either a list of <a href="#">g3_stock</a> objects to sum when choosing a value from <i>quote_table</i> , or NULL, in which case choose the quota based on the current prey.
recalc_f	A <a href="#">formula</a> denoting when to recalculate the current quota. For example $\sim cur\_step == 1$ will ensure the quota is only recalculated at the beginning of the year.
amount_f	Equivalent to <i>E</i> passed to <a href="#">g3a_predate_catchability_totalfleet</a> .
prey_preferences	Either 1, indicating a Type II functional response, or >1 for a Type III functional response. Either a list of stock names to numbers, with an optional unnamed default option, or a single number to be used for all stocks.
energycontent	A <a href="#">formula</a> object for the energy content of the current prey, in in kilojoules per kilogram.
half_feeding_f	The biomass of prey required to allow the predator to consume prey at half the maximum consumption level.
max_consumption	A <a href="#">formula</a> for maximum consumption of the predator, in kilojoules per month. Generally generated by <a href="#">g3a_predate_maxconsumption</a>
m0, m1, m2, m3	Parameters for maximum possible consumption formula, see below.
temperature	A <a href="#">formula</a> object for the current temperature, probably generated by <a href="#">g3_timeareadata</a> .
overconsumption_f	Overconsumption rule, a formula that should cap all values in <i>stock__consratio</i> to $\leq 95$
by_stock	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
by_predator	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

## Details

`g3a_predate` will, given a `g3_fleet` "predator" and a set of `g3_stock` preys, add predation into a model. The behaviour is driven by 2 parameters:

*suitabilities* Defines a predator's preference within a prey stock, normally one of the suitability functions, e.g. `g3_suitability_exponential150`

*catchability\_f* Defines a predator's overall requirements, set with one of the catchability functions, e.g. `g3a_predate_catchability_totalfleet`

For the definition of each catchability function, see the values section below.

**Details for custom actions:** The actions will define the following stock instance variables for each given *fleet\_stock* and *prey\_stock*:

*(predstock)\_\_totalsuit* Total suitable prey for (predstock), i.e.  $\sum_{preys}^p \sum_{lengths}^l F_{pl}$

*prey\_stock\_\_suit\_fleet\_stock* Suitability of (prey\_stock) for (fleet\_stock), i.e.  $F_{pl}$

*(predstock)\_(prey\_stock)\_\_cons* Biomass of (prey\_stock) caught by (predstock), by predator & prey dimensions

*prey\_stock\_\_totalpredate* Biomass of total consumed (prey\_stock), in a prey array

*prey\_stock\_\_consratio* Ratio of *prey\_stock\_\_totalpredate* / (current biomass), capped by *overconsumption\_f*

In addition, `g3a_predate_fleet` will generate *prey\_stock\_\_predby\_predstock*, Biomass of (prey\_stock) caught by (fleet\_stock), in a prey array, for compatibility with older models. It is otherwise identical to `g3a_predate`.

A model can have any number of `g3a_predate_*` actions, so long as the calling arguments are different. For instance, `run_f = ~age == 5` and `run_f = ~age == 7`.

## Value

**g3a\_predate\_catchability\_totalfleet:** *formula* objects that define a fleet's desired catch by total biomass (e.g. landings data):

$$F_{pl} = SN_{pl}W_{pl}$$

$$C_{pl} = \frac{EF_{pl}}{\sum_{preys}^p \sum_{lengths}^l F_{pl}}$$

*S* Suitability form *suitabilities* argument

*E* *E* argument, biomass caught by fleet. Generally a `g3_timeareadata` table containing landings data, with year/step/area/weight columns

$N_{pl}$  Number of prey in length cell for prey *p*, length *l*

$W_{pl}$  Mean weight of prey in length cell for prey *p*, length *l*

**g3a\_predate\_catchability\_numberfleet:** *formula* objects that define a fleet's desired catch by total number of stock landed (individuals, not biomass):

$$F_{pl} = SN_{pl}$$

$$C_{pl} = \frac{EF_{pl}W_{pl}}{\sum_{preys} \sum_{lengths} F_{pl}}$$

*S* Suitability form *suitabilities* argument

*E* *E* argument, numbers caught by fleet. Generally a `g3_timeareadata` table containing landings data, or a constant quota

$N_{pl}$  Number of prey in length cell for prey *p*, length *l*

$W_{pl}$  Mean weight of prey in length cell for prey *p*, length *l*

**g3a\_predate\_catchability\_linearfleet:** `formula` objects that define a linear relationship between desired catch and available biomass:

$$F_{pl} = SN_{pl}W_{pl}$$

$$C_{pl} = E\Delta t F_{pl}$$

*S* Suitability form *suitabilities* argument

*E* *E* argument, scaling factor for the stock that is to be caught, per month

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in `g3a_time`

$N_{pl}$  Number of prey in length cell for prey *p*, length *l*

$W_{pl}$  Mean weight of prey in length cell for prey *p*, length *l*

**g3a\_predate\_catchability\_project:** The formula used depends on the *unit* parameter. "biomass", "effort", "individuals" are equivalent to totalfleet / linearfleet & numberfleet respectively. However, *E* will switch from landings to quota once the model is projecting.

**g3a\_predate\_catchability\_effortfleet:** This is a multi-species extension to linearfleet, allowing differently-parameterized catchability per-stock:

$$F_{pl} = SN_{pl}W_{pl}$$

$$C_{pl} = c_s E\Delta t F_{pl}$$

*S* Suitability form *suitabilities* argument

$c_s$  *catchability\_fs* argument for the current stock

*E* *E* argument, scaling factor for the stock that is to be caught, per month

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in `g3a_time`

$N_{pl}$  Number of prey in length cell for prey *p*, length *l*

$W_{pl}$  Mean weight of prey in length cell for prey *p*, length *l*

**g3a\_predate\_catchability\_quotafleet:** A `formula` object that defines catch based on the available biomass of the stock multiplied by a scaling factor set according to a simple harvest control rule:

$$F_{pl} = SN_{pl}W_{pl}$$

$$C_{pl} = qE\Delta t F_{pl}$$

*q* quota selected from *quota\_table*, corresponding to the total biomass of *sum\_stocks*. For example, given `data.frame(biomass = c(10000, Inf), quota = I(list(g3_parameterized('quota.low'), g3_parameterized('quota.high'))))`, 'quota.low' will be chosen when total biomass is less than 10000, otherwise 'quota.high' will be used.

$S$  Suitability form *suitabilities* argument

$E$   $E$  argument, scaling factor for the stock that is to be caught, per month

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in [g3a\\_time](#)

$N_{pl}$  Number of prey in length cell for prey  $p$ , length  $l$

$W_{pl}$  Mean weight of prey in length cell for prey  $p$ , length  $l$

...if `recalc_f` is set, this will only be recalculated when true. Any other step will use the previous value.

**g3a\_predate\_maxconsumption:** [formula](#) objects that define a predator's maximum consumption:

$$M_L = m_0 \Delta t e^{(m_1 T - m_2 T^3)} L^{m_3}$$

$m_x$   $mx$  parameter, for  $M_L$ , maximum possible consumption for the predator on the current timestep

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in [g3a\\_time](#)

$T$  *temperature* parameter, formula representing current temperature

**g3a\_predate\_catchability\_predator:** [formula](#) objects that define the predator/prey relationship:

$$F_{pl} = (SE_p N_{pl} W_{pl})^{d_p}$$

$$C_{pl} = \frac{N_L M_L \psi_L F_{pl}}{E_p \sum_{preys}^p \sum_{lengths}^l F_{pl}}$$

$$\psi_L = \frac{\sum_{preys}^p \sum_{lengths}^l F_{pl}}{H \Delta t + \sum_{preys}^p \sum_{lengths}^l F_{pl}}$$

$S$  Suitability form *suitabilities* argument

$\Delta t$  Length of current step as a proportion of the year, e.g. 0.25. See `cur_step_size` in [g3a\\_time](#)

$N_{pl}$  Number of prey in length cell for prey  $p$ , length  $l$

$W_{pl}$  Mean weight of prey in length cell for prey  $p$ , length  $l$

$M_L$  Maximum possible consumption for the predator on the current timestep, in in kilojoules per month. See [g3a\\_predate\\_maxconsumption](#)

$L$  Length of the current predator

$E_p$  *energycontent* parameter, the energy content of prey

$H$  *half\_feeding\_f* parameter, the biomass of prey required to allow the predator to consume prey at half the maximum consumption level

$T$  *temperature* parameter, formula representing current temperature

**g3a\_predate:** An action (i.e. list of formula objects) that will...

1. For each prey, collect all suitable stock into a `predstock_preystock_suit` variable, using the `catchability_f F_p l` formula. The units here will depend on the `catchability_f` method used.

2. After all predator consumption is done, scale consumption using the *catchability\_f*  $C_{pl}$  formula into *predstock\_preystock\_cons*, summed into *preystock\_totalpredate*
3. Calculate *preystock\_consratio* (ratio of consumed to available), capping using *overconsumption\_f*. Update *preystock\_num*
4. Recalculate *predstock\_preystock\_cons*, *predstock\_preystock\_suit*, post-overconsumption

## See Also

[https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockpredator, g3\\_stock](https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockpredator, g3_stock)

## Examples

```
areas <- c(a = 1, b = 2)
ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock(c(species = 'ling', 'mat'), seq(20, 156, 4)) %>% g3s_age(5, 15)
lln <- g3_fleet('lln') %>% g3s_livesonareas(areas[c('a', 'b')])

# Invent a lln_landings table
lln_landings <- expand.grid(
  year = 1999:2000,
  step = c(1, 2),
  area = areas[c('a', 'b')])
lln_landings$total_weight <- floor(runif(nrow(lln_landings), min=100, max=999))

# g3a_predate_catchability_totalfleet(): Set catch accordings to landings data
predate_action <- g3a_predate_fleet(
  lln,
  list(ling_imm, ling_mat),
  suitabilities = g3_suitability_exponentiall50(by_stock = 'species'),
  catchability_f = g3a_predate_catchability_totalfleet(
    g3_timeareadata('lln_landings', lln_landings, "total_weight") ))

# g3a_predate_catchability_numberfleet(): Fixed quota of 1000 fish
predate_action <- g3a_predate_fleet(
  lln,
  list(ling_imm, ling_mat),
  suitabilities = g3_suitability_exponentiall50(by_stock = 'species'),
  catchability_f = g3a_predate_catchability_numberfleet(
    g3_parameterized(
      'quota',
      value = 1000,
      by_predator = TRUE,
      scale = 0.5,
      optimise = FALSE) ))
attr(suppressWarnings(g3_to_r(list(predate_action))), 'parameter_template')
```

---

action_renewal	<i>Gadget3 renewal actions</i>
----------------	--------------------------------

---

**Description**

Add renewal / initialconditions to a g3 model

**Usage**

```

g3a_renewal_vonb_recl(
  Linf = g3_parameterized('Linf', value = 1, by_stock = by_stock),
  K = g3_parameterized('K', value = 1, by_stock = by_stock),
  recl = g3_parameterized('recl', by_stock = by_stock),
  recage = g3_parameterized('recage', by_stock = FALSE, optimise = FALSE),
  by_stock = TRUE)

g3a_renewal_vonb_t0(
  Linf = g3_parameterized('Linf', value = 1, by_stock = by_stock),
  K = g3_parameterized('K', value = 1, by_stock = by_stock),
  t0 = g3_parameterized('t0', by_stock = by_stock),
  by_stock = TRUE)

g3a_renewal_initabund(
  scalar = g3_parameterized('init.scalar', value = 1, by_stock = by_stock),
  init = g3_parameterized('init', value = 1, by_stock = by_stock, by_age = TRUE),
  M = g3_parameterized('M', by_stock = by_stock, by_age = TRUE),
  init_F = g3_parameterized('init.F', by_stock = by_stock_f),
  recage = g3_parameterized('recage', by_stock = FALSE, optimise = FALSE),
  proportion_f = ~1,
  by_stock = TRUE,
  by_stock_f = FALSE)

##### g3a_initialconditions

g3a_initialconditions(stock, num_f, wgt_f, run_f = ~cur_time == 0L,
  run_at = g3_action_order$initial)

g3a_initialconditions_normalparam(
  stock,
  factor_f = g3a_renewal_initabund(by_stock = by_stock),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  stddev_f = g3_parameterized('init.sd', value = 10,
    by_stock = by_stock, by_age = by_age),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  age_offset = quote( cur_step_size ),
  by_stock = TRUE,

```

```

    by_age = FALSE,
    wgt_by_stock = TRUE,
    run_f = ~cur_time == 0L,
    run_at = g3_action_order$initial)

g3a_initialconditions_normalcv(
  stock,
  factor_f = g3a_renewal_initabund(by_stock = by_stock),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  cv_f = g3_parameterized('lencv', by_stock = by_stock, value = 0.1,
    optimise = FALSE),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  age_offset = quote( cur_step_size ),
  by_stock = TRUE,
  by_age = FALSE,
  wgt_by_stock = TRUE,
  run_f = ~cur_time == 0L,
  run_at = g3_action_order$initial)

##### g3a_renewal

g3a_renewal(stock, num_f, wgt_f, run_f = ~TRUE,
  run_at = g3_action_order$renewal)

g3a_renewal_normalparam(
  stock,
  factor_f = g3_parameterized('rec',
    by_stock = by_stock,
    by_year = TRUE,
    scale = g3_parameterized(
      name = 'rec.scalar',
      by_stock = by_stock),
    ifmissing = g3_parameterized(
      name = 'rec.proj',
      optimise = FALSE,
      by_stock = by_stock )),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  stddev_f = g3_parameterized('rec.sd', value = 10, by_stock = by_stock),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  by_stock = TRUE,
  wgt_by_stock = TRUE,
  run_age = quote(stock__minage),
  run_projection = TRUE,
  run_step = 1,
  run_f = NULL,
  run_at = g3_action_order$renewal)

```

```

g3a_renewal_normalcv(
  stock,
  factor_f = g3_parameterized('rec',
    by_stock = by_stock,
    by_year = TRUE,
    scale = g3_parameterized(
      name = 'rec.scalar',
      by_stock = by_stock),
    ifmissing = g3_parameterized(
      name = 'rec.proj',
      optimise = FALSE,
      by_stock = by_stock )),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  cv_f = g3_parameterized('lencv', by_stock = by_stock, value = 0.1,
    optimise = FALSE),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  by_stock = TRUE,
  wgt_by_stock = TRUE,
  run_age = quote(stock__minage),
  run_projection = TRUE,
  run_step = 1,
  run_f = NULL,
  run_at = g3_action_order$renewal)

##### g3a_otherfood

g3a_otherfood(
  stock,
  num_f = g3_parameterized('of_abund', by_year = TRUE, by_stock = by_stock,
    scale = g3_parameterized(
      'of_abund.step', value = 1, by_step = TRUE, by_stock = by_stock),
    ifmissing = "of_abund.proj" ),
  wgt_f = g3_parameterized('of_meanwgt', by_stock = by_stock),
  by_stock = TRUE,
  force_lengthvector = !any(grepl("__midlen$", all.vars(num_f))),
  run_f = quote( cur_time <= total_steps ),
  run_at = g3_action_order$initial)

g3a_otherfood_normalparam(
  stock,
  factor_f = g3_parameterized(
    'of_abund', by_year = TRUE, by_stock = by_stock,
    scale = g3_parameterized(
      'of_abund.step', value = 1, by_step = TRUE, by_stock = by_stock),
    ifmissing = "of_abund.proj" ),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),

```

```

stddev_f = g3_parameterized('init.sd', value = 10,
  by_stock = by_stock, by_age = by_age),
alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
by_stock = TRUE,
by_age = FALSE,
wgt_by_stock = TRUE,
run_f = quote( cur_time <= total_steps ),
run_at = g3_action_order$initial)

```

```

g3a_otherfood_normalcv(
  stock,
  factor_f = g3_parameterized(
    'of_abund', by_year = TRUE, by_stock = by_stock,
    scale = g3_parameterized(
      'of_abund.step', value = 1, by_step = TRUE, by_stock = by_stock),
    ifmissing = "of_abund.proj" ),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  cv_f = g3_parameterized('lencv', by_stock = by_stock, value = 0.1,
    optimise = FALSE),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  by_stock = TRUE,
  by_age = FALSE,
  wgt_by_stock = TRUE,
  run_f = quote( cur_time <= total_steps ),
  run_at = g3_action_order$initial)

```

## Arguments

stock	The <a href="#">g3_stock</a> to apply to
num_f	<a href="#">formula</a> that produces a lengthgroup vector of number of individuals for the current age/area/... length group.
wgt_f	<a href="#">formula</a> that produces a lengthgroup vector of mean weight for the current age/area/... length group.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .
factor_f, mean_f, stddev_f, alpha_f, beta_f	<a href="#">formula</a> substituted into normalparam calculations, see below.
cv_f	<a href="#">formula</a> substituted into normalcv calculations, basically $stddev\_f = mean\_f * cv\_f$ , see below.
age_offset	Replace age with age - age_offset in <i>mean_f</i> . Used to simulate initial conditions at time "-1".
force_lengthvector	Should we assume that num_f is a constant, and needs repeating enough times to turn into a length vector?
run_age	Age to run renewals for, used as age == (run_age) into default <i>run_f</i>

run_projection	Boolean. Run renewal in projection years? If false adds !cur_year_projection into default <i>run_f</i>
run_step	Which step to perform renewal in, or NULL for continuous renewal. Adds cur_step == (run_step) into default <i>run_f</i>
run_f	<a href="#">formula</a> specifying a condition for running this action, For initialconditions defaults to first timestep. For renewal, the default is a combination of <i>run_age</i> , <i>run_step</i> & <i>run_projection</i> . For otherfood, the default is to always run, apart from when the model is ending.
Linf, K, t0, recl	<a href="#">formula</a> substituted into vonb calculations, see below.
recage	<a href="#">formula</a> substituted into initial abundance and vonb calculations, see below.
proportion_f, scalar, init, M, init_F	<a href="#">formula</a> substituted into initial abundance calculations, see below.
by_stock, wgt_by_stock, by_stock_f, by_age	Controls how parameters are grouped, see <a href="#">g3_parameterized</a>

## Details

All of the following actions will renew stock in a model. The differences are when and what they apply to by default:

- g3a\_initialconditions\_\* Will run at the start of the model, building an initial state of all ages
- g3a\_renewal\_\* Will run at every step but only for the minimal age, adding new recruits as an alternative to [g3a\\_spawn\(\)](#)
- g3a\_otherfood\_\* Will run at every step, replacing the previous state, creating a non-dynamic stock for predators to consume

Specifying the quantities and mean-weights in each case works identically.

A model can have any number of g3a\_renewal\_\* actions, so long as the calling arguments are different. For instance, run\_f = ~age == 5 and run\_f = ~age == 7.

The g3a\_renewal\_\* actions will define the following stock instance variables for *stock*:

- stock\_\_renewalnum* Extra individuals added to the stock
- stock\_\_renewalwgt* Mean weight of added individuals

## Value

**g3a\_renewal\_vonb\_recl:** A [formula](#) object representing

$$L_{\infty} \left( 1 - e^{-\kappa \left( a - a_0 + \frac{\log(1 - L_0/L_{\infty})}{\kappa} \right)} \right)$$

$L_{\infty}$  *Linf* argument, by default model parameter named (stock).Linf

$\kappa$  *K* argument, by default model parameter named (stock).K

$L_0$  *recl* argument, by default model parameter named (stock).recl

$a_0$  *recage* argument, by default model parameter named recage

**NB:** [g3a\\_initialconditions\\_normalparam](#) will replace  $a$  with  $a - \Delta t$ , see *age\_offset*

**g3a\_renewal\_vonb\_t0:** A [formula](#) object representing

$$L_{\infty}(1 - e^{-\kappa(a-t_0)})$$

$L_{\infty}$  *Linf* argument, by default model parameter named (stock).Linf

$\kappa$  *K* argument, by default model parameter named (stock).K

$t_0$  *t0* argument, by default model parameter named (stock).t0

**NB:** [g3a\\_initialconditions\\_normalparam](#) will replace  $a$  with  $a - \Delta t$ , see [age\\_offset](#)

**g3a\_renewal\_vonb:** An alias for [g3a\\_renewal\\_vonb\\_recl\(\)](#)

**g3a\_renewal\_initabund:** A [formula](#) object representing

$$ps_0 s_a e^{-1(M+F_0)(a-a_0)}$$

$s_0$  *scalar* argument, by default model parameter named (stock).init.scalar

$s_a$  *init* argument, by default model parameter named (stock).init.(age)

$M$  *M* argument, by default model parameter named (stock).M.(age)

$F_0$  *init\_F* argument, by default model parameter named init.F

$a_0$  *recage* argument, by default model parameter named recage

**p** *proportion* argument, by default 1

**g3a\_initialconditions / g3a\_renewal / g3a\_otherfood:** An action (i.e. list of formula objects) that will, for the given *stock*, iterate over each area/age/etc. combination, and generate a length-group vector of new individuals and weights using *num\_f* and *wgt\_f*.

renewal will add fish to the existing stock, whereas initialconditions & otherfood will replace any previous values.

**g3a\_initialconditions\_normalparam / g3a\_renewal\_normalparam / g3a\_otherfood\_normalparam:**

As [g3a\\_initialconditions](#) / [g3a\\_renewal](#), but the following formulae are used to calculate abundance ( $N$ ) and mean weight ( $W$ ):

$$n = dnorm(L, \mu, \sigma)$$

$$N = F10000 \frac{n}{\sum n}$$

$$W = \alpha L^{\beta}$$

$L$  *Midlength* of all length groups for current area/age/...

$F$  *factor\_f* argument, by default output of [g3a\\_renewal\\_initabund](#)

$\mu$  *mean\_f* argument, by default output of [g3a\\_renewal\\_vonb\\_t0](#)

$\sigma$  *stddev\_f* argument, by default model parameter named (stock).(init|rec).sd

$\alpha$  *alpha\_f* argument, by default model parameter named (stock).walpha

$\beta$  *beta\_f* argument, by default model parameter named (stock).wbeta

**g3a\_initialconditions\_normalcv / g3a\_renewal\_normalcv / g3a\_otherfood\_normalcv:** As [g3a\\_initialconditions](#) / [g3a\\_renewal](#), but the following formulae are used to calculate abundance ( $N$ ) and mean weight ( $W$ ):

$$n = e^{-\left(\frac{L-\mu}{\mu \cdot CV}\right)^2/2}$$

$$N = F10000 \frac{n}{\sum n}$$

$$W = \alpha L^\beta$$

$L$  Midlength of all length groups for current area/age/...

$F$  *factor\_f* argument, by default output of [g3a\\_renewal\\_initabund](#)

$\mu$  *mean\_f* argument, by default output of [g3a\\_renewal\\_vonb\\_t0](#)

$CV$  *cv\_f* argument, by default model parameter named (stock).lencv

$\alpha$  *alpha\_f* argument, by default model parameter named (stock).walpha

$\beta$  *beta\_f* argument, by default model parameter named (stock).wbeta

### See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockinitial>,  
<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec:stockrenew>,  
<https://gadget-framework.github.io/gadget2/userguide/chap-other.html#chap-other>,  
[g3\\_stock](#)

### Examples

```
stocks <- list(
  imm = g3_stock(c('ling', maturity = "imm"), seq(10, 100, 10)) %>% g3s_age(3, 7),
  mat = g3_stock(c('ling', maturity = "mat"), seq(10, 100, 10)) %>% g3s_age(5, 10) )

actions <- list(
  g3a_time(2000, 2000),
  g3a_initialconditions_normalcv(stocks$imm),
  g3a_initialconditions_normalcv(stocks$mat),
  NULL)
model_fn <- g3_to_r(c(actions, list(
  g3a_report_detail(actions) )))
attr(model_fn, 'parameter_template') |>
  g3_init_val("init.F", 0.4) |>
  g3_init_val("ling_imm.Linf", 80) |>
  g3_init_val("ling_mat.Linf", 160) |>
  g3_init_val("ling_*.K", 90) |>
  g3_init_val("ling_*.t0", 0) |>
  g3_init_val("ling_*.lencv", 0.1) |>
  g3_init_val("ling_imm.init.#", 3:7 * 100) |>
  g3_init_val("ling_mat.init.#", 5:10 * 200) |>
  g3_init_val("ling_*.init.scalar", 200) |>
  g3_init_val("ling_*.walpha", 2.275e-06) |>
  g3_init_val("ling_*.wbeta", 3.2020) |>
  g3_init_val("ling_*.M.#", 0.15) |>
  identity() -> params.in
```

```

r <- model_fn(params.in)

g3_array_plot(attr(r, "dstart_ling_imm__num")[,time=1])
g3_array_plot(attr(r, "dstart_ling_mat__num")[,time=1])

## Plots
par(mar = c(4,2,2,1), cex.main = 1)
curve(g3_eval(g3a_renewal_vonb_t0(Linf = 20, K = 0.8, t0 = 0), age = x),
      0, 10, col = 2, xlab = "age", main = "g3a_renewal_vonb_t0(Linf = 20, K = 0.8..1.4, t0 = 0)")
curve(g3_eval(g3a_renewal_vonb_t0(Linf = 20, K = 1.0, t0 = 0), age = x),
      0, 10, col = 1, add = TRUE)
curve(g3_eval(g3a_renewal_vonb_t0(Linf = 20, K = 1.2, t0 = 0), age = x),
      0, 10, col = 3, add = TRUE)
curve(g3_eval(g3a_renewal_vonb_t0(Linf = 20, K = 1.4, t0 = 0), age = x),
      0, 10, col = 4, add = TRUE)

## Otherfood
# "Otherfood" stocks are defined in a similar manner to any other stock
# Note that _normalparam & _normalcv need both length & age dimensions
other_wgt <- g3_stock('other_wgt', 0)
other_cv <- g3_stock('other_cv', seq(50, 100, by = 10)) %>% g3s_age(5,10)

actions <- list(
  g3a_time(2000, 2010),
  # Will get other_wgt.of_abund.1998.1, other_wgt.of_meanwgt parameters
  g3a_otherfood(other_wgt),
  # Use standard vonB parameters (Linf/K/t0) to define abundance
  g3a_otherfood_normalcv(other_cv),
  NULL)
model_fn <- g3_to_r(c(actions, list(
  g3a_report_detail(actions) )))
attr(model_fn, 'parameter_template') |>
  g3_init_val("other_cv.Linf", 80) |>
  g3_init_val("other_cv.K", 90) |>
  g3_init_val("other_cv.t0", 0) |>
  g3_init_val("other_cv.of_abund.#", 100:110) |>
  g3_init_val("other_wgt.of_abund.#", 100:110) |>
  g3_init_val("other_wgt.of_abund.step.#", 1) |>
  g3_init_val("other_cv.of_abund.proj", 80) |>
  g3_init_val("other_wgt.of_abund.proj", 70) |>
  g3_init_val("project_years", 5) |>
  identity() -> params.in
r <- model_fn(params.in)

g3_array_plot(t(attr(r, "dstart_other_wgt__num")))
g3_array_plot(t(attr(r, "dstart_other_cv__num")[,age="age7",]))

```

**Description**

Add report to a g3 model

**Usage**

```
g3a_report_stock(report_stock, input_stock, report_f,
  include_adreport = FALSE,
  run_f = TRUE,
  run_at = g3_action_order$report)
```

```
g3a_report_history(
  actions,
  var_re = "__num$|__wgt$",
  out_prefix = "hist_",
  run_f = TRUE,
  run_at = g3_action_order$report)
```

```
g3a_report_detail(actions,
  run_f = quote( g3_param('report_detail', optimise = FALSE, value = 1L,
    source = "g3a_report_detail") == 1 ),
  abundance_run_at = g3_action_order$report_early,
  run_at = g3_action_order$report)
```

**Arguments**

report_stock	The <a href="#">g3_stock</a> to aggregate into
input_stock	The <a href="#">g3_stock</a> that will be aggregated
report_f	<a href="#">formula</a> specifying what to collect, for instance <code>g3_formula( stock_ss(input_stock__num) )</code> or <code>g3_formula( stock_ss(input_stock__wgt) )</code> .
actions	List of actions that model will consist of.
var_re	Regular expression specifying variables to log history for.
out_prefix	Prefix to add to history report output, e.g. <code>hist_ling_imm__num</code> .
include_adreport	Should the aggregated value get ADREPORT'ed?
abundance_run_at	Integer order that abundance will be collected within the model. Note that by default it's collected at the start, not the end
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

**Details**

The `g3a_report_detail` defines a selection of default reports from your model, using `g3a_report_history`:

```
*_surveyindices*___params The slope/intercept as used by g3l\_distribution\_surveyindices\_log
step_lengths
```

\*\_weight The weighting of likelihood components  
 nll\_\* Breakdown of nll for each likelihood component  
 dstart\_\*\_\_num Abundance in numbers, at start of each model step  
 dstart\_\*\_\_wgt Mean weight of individuals, at start of each model step  
 detail\_\*\_\_renewalnum Numbers produced by renewal at each model step  
 detail\_\*\_\_spawnednum Numbers produced by spawning at each model step  
 detail\_\*\_\*\_\_cons Total biomass of prey consumed by predator, at each model step  
 detail\_\*\_\*\_\_suit Total suitable biomass of prey for predator, at each model step

The reports produced by `g3a_report_history` will vary based on the provided inputs. A model can have any number of `g3a_report_*` actions, so long as the calling arguments are different. For instance, `run_f = ~age == 5` and `run_f = ~age == 7`.

### Value

**g3a\_report\_stock:** An action (i.e. list of formula objects) that will...

1. Iterate over `input_stock`, collecting data into `report_stock`
2. Add the contents of `report_stock__instance_name` to the model report

**g3a\_report\_history:** An action (i.e. list of formula objects) that will store the current state of each variable found matching `var_re`.

**g3a\_report\_detail:** Uses `g3a_report_history` to generate detailed reports suitable for use in `g3_fit`.

### See Also

[g3\\_stock](#)

### Examples

```
ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)

# Report that aggregates ages together
agg_report <- g3_stock('agg_report', c(1)) %>%
  g3s_agegroup(list(young = 1:3, old = 4:5)) %>%
  g3s_time(year = 2000:2002)
# Generate dissaggregated report by cloning the source stock, adding time
raw_report <- g3s_clone(ling_imm, 'raw_report') %>%
  g3s_time(year = 2000:2002)

actions <- list(
  g3a_age(ling_imm),
  g3a_report_stock(agg_report, ling_imm, g3_formula( stock_ss(ling_imm__num) ),
    include_adreport = TRUE),
  g3a_report_stock(raw_report, ling_imm, g3_formula( stock_ss(ling_imm__num) )))
# "raw_report__num" and "agg_report__num" will be available in the model report
# In addition, agg_report__num will be included in TMB::sdreport() output
```

```
# Report history of all "__num" and "__wgt" variables
actions <- c(actions, list(g3a_report_history(actions)))

# Report history of just "ling_imm__num"
actions <- c(actions, list(g3a_report_history(actions, "^ling_imm__num$")))

# Add a detail report suitable for g3_fit
actions <- c(actions, list(g3a_report_detail(actions)))
```

---

action\_spawn

*Gadget3 spawning action*


---

## Description

Add spawning to a g3 model

## Usage

```
g3a_spawn_recruitment_fecundity(
  p0 = g3_parameterized('spawn.p0', value = 1, by_stock = by_stock),
  p1 = g3_parameterized('spawn.p1', value = 1, by_stock = by_stock),
  p2 = g3_parameterized('spawn.p2', value = 1, by_stock = by_stock),
  p3 = g3_parameterized('spawn.p3', value = 1, by_stock = by_stock),
  p4 = g3_parameterized('spawn.p4', value = 1, by_stock = by_stock),
  by_stock = TRUE )

g3a_spawn_recruitment_simplessb(
  mu = g3_parameterized('spawn.mu', by_stock = by_stock),
  by_stock = TRUE )

g3a_spawn_recruitment_ricker(
  mu = g3_parameterized('spawn.mu', by_stock = by_stock),
  lambda = g3_parameterized('spawn.lambda', by_stock = by_stock),
  by_stock = TRUE )

g3a_spawn_recruitment_bevertonholt(
  mu = g3_parameterized('spawn.mu', by_stock = by_stock),
  lambda = g3_parameterized('spawn.lambda', by_stock = by_stock),
  by_stock = TRUE )

g3a_spawn_recruitment_bevertonholt_ss3(
  # Steepness parameter
  h = g3_parameterized('spawn.h', lower = 0.1, upper = 1, value = 0.5,
    by_stock = by_stock ),
  # Recruitment deviates
  R = g3_parameterized('spawn.R', by_year = TRUE, exponentiate = TRUE,
    # Unfished equilibrium recruitment
    scale = "spawn.R0",
```

```

        by_stock = by_stock),
# Unfished equilibrium spawning biomass (corresponding to R0)
B0 = g3_parameterized('spawn.B0', by_stock = by_stock),
by_stock = TRUE )

g3a_spawn_recruitment_hockeystick(
  r0 = g3_parameterized('spawn.r0', by_stock = by_stock),
  blim = g3_parameterized('spawn.blim', value = 1, by_stock = by_stock),
  by_stock = TRUE )

g3a_spawn(
  stock,
  recruitment_f,
  proportion_f = 1,
  mortality_f = 0,
  weightloss_f = 0,
  weightloss_args = list(),
  output_stocks = list(),
  output_ratios = rep(1 / length(output_stocks), times = length(output_stocks)),
  mean_f = g3a_renewal_vonb_t0(by_stock = by_stock),
  stddev_f = g3_parameterized('rec.sd', value = 10, by_stock = by_stock),
  alpha_f = g3_parameterized('walpha', by_stock = wgt_by_stock),
  beta_f = g3_parameterized('wbeta', by_stock = wgt_by_stock),
  by_stock = TRUE,
  wgt_by_stock = TRUE,
  run_step = NULL,
  run_f = ~TRUE,
  run_at = g3_action_order$spawn,
  recruit_at = g3_action_order$renewal)

```

## Arguments

$\rho_0$ ,  $p_1$ ,  $p_2$ ,  $p_3$ ,  $p_4$  Substituted into `g3a_spawn_recruitment_fecundity` formula, see below.  
 $\mu$ ,  $\lambda$ ,  $h$ ,  $R$ ,  $B_0$ ,  $r_0$ ,  $blim$   
 Substituted into `g3a_spawn_recruitment_*` formula, see below.

`stock` The mature `g3_stock` that will spawn in this action.

`recruitment_f` A list of [formula](#) generated by one of the `g3a_spawn_recruitment_*` functions, containing  
`s` Formula run for each subset of stock  
`r` Final formula for calculating number of recruits for spawning action

`proportion_f` [formula](#) generated by one of the `g3_suitability_*` functions, describing the proportion of stock that will spawn at this timestep.

`mortality_f` [formula](#) generated by one of the `g3_suitability_*` functions, describing the proportion of spawning stock that will die during spawning.

`weightloss_f` [formula](#) generated by one of the `g3_suitability_*` functions, describing the overall weight loss during spawning.  
 DEPRECATED: Use `weightloss_args` for new models.

weightloss_args	<a href="#">list</a> of options to pass to <a href="#">g3a_weightloss</a> , e.g. <i>rel_loss</i> & <i>abs_loss</i> . If not empty, a weightloss action will be included as part of spawning.
output_stocks	List of <a href="#">g3_stocks</a> that will be spawned into.
output_ratios	Vector of proportions for how to distribute into <i>output_stocks</i> , summing to 1, default evenly spread.
mean_f, stddev_f, alpha_f, beta_f	<a href="#">formula</a> substituted into stock structure calculations, see <a href="#">g3a_renewal_normalparam</a> for details.
run_step	Which step to perform renewal in, or NULL for continuous spawning. Adds <code>cur_step == (run_step)</code> into default <i>run_f</i> .
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that spawning actions will be run within model, see <a href="#">g3_action_order</a> .
recruit_at	Integer order that recruitment from spawning will be run within model, see <a href="#">g3_action_order</a> .
by_stock, wgt_by_stock	Controls how parameters are grouped, see <a href="#">g3_parameterized</a>

### Details

To restrict spawning to a particular step in a year, or a particular area, use *run\_f*. For example:

`cur_step == 1` Spawning will happen on first step of every year

`cur_step == 1 && cur_year >= 1990` Spawning will happen on first step of every year after 1990

`cur_step == 2 && area = 1` Spawning will happen on second step of every year, in the first area

The action will define the following stock instance variables for each given *stock* and *output\_stock*:

*stock\_\_spawnprop* Proportion of (stock) that are spawning in this spawning event

*stock\_\_spawningnum* Numbers of (stock) that are spawning in this spawning event

*output\_stock\_\_spawnednum* Numbers of (output\_stock) that will be produced in this spawning event

### Value

**g3a\_spawn\_recruitment\_fecundity:** A pair of [formula](#) objects:

$$S = l^{p_1} a^{p_2} (pN_{al})^{p_3} W_{al}^{p_4}$$

$$R = p_0 S$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$p_{0..4}$  Arguments provided to function

**g3a\_spawn\_recruitment\_simpleb:** A pair of [formula](#) objects:

$$S = N_{al}pW_{al}$$

$$R = \mu S$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$\mu$  Argument provided to function

**g3a\_spawn\_recruitment\_ricker:** A pair of [formula](#) objects:

$$S = N_{al}pW_{al}$$

$$R = \mu S e^{-\lambda S}$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$\mu$  Argument provided to function

$\lambda$  Argument provided to function

**g3a\_spawn\_recruitment\_bevertonholt:** A pair of [formula](#) objects:

$$S = N_{al}pW_{al}$$

$$R = \frac{\mu S}{\lambda + S}$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$\mu$  Argument provided to function

$\lambda$  Argument provided to function

**g3a\_spawn\_recruitment\_bevertonholt\_ss3:** A [modified beverton-holt implementation from SS3](#) returning a pair of [formula](#) objects:

$$S = N_{al}pW_{al}$$

$$R = \frac{4hR_0sR}{B_0(1-h) + S(5h-1)}$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$h$  Steepness parameter, by default provided by the *srr\_h* parameter

$R_0$  Unfished equilibrium recruitment, by default provided by the *R0* parameter

$R$  Recruitment deviates, by default provided by the *R* parameter table

$B_0$  Unfished equilibrium spawning biomass (corresponding to  $R_0$ ), by default provided by the  $B_0$  parameter

$\lambda$  Argument provided to function

**g3a\_spawn\_recruitment\_hockeystick:** A pair of [formula](#) objects:

$$S = N_{al}pW_{al}$$

$$R = R_0 \min(S/B_{lim}, 1)$$

$N_{al}$  Number of parent stock

$W_{al}$  Weight of parent stock

$p$  Proportion of parent stock spawning, from *proportion\_f*

$R_0$  Argument  $r_0$  provided to function

$B_{lim}$  Argument  $blim$  provided to function

**NB:** This formula is differentiable, despite using `min()` in the definition above.

**g3a\_spawn:** An action (i.e. list of formula objects) that will, for the given *stock*...

1. Use *proportion\_f* to calculate the total parent *stock* that will spawn
2. Use *recruitment\_f* to derive the total newly spawned stock
3. Apply *weightloss* and *mortality\_f* to the parent *stock*

... then, at recruitment stage ...

1. Recruit evenly into *output\_stocks*, using *mean\_f*, *stddev\_f*, *alpha\_f*, *beta\_f* as-per [g3a\\_renewal\\_normalparam](#)

## See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec-stockspawn>,  
[https://nmfs-ost.github.io/ss3-doc/SS330\\_User\\_Manual\\_release.html#beverton-holt](https://nmfs-ost.github.io/ss3-doc/SS330_User_Manual_release.html#beverton-holt),  
[g3a\\_naturalmortality](#), [g3\\_stock](#)

## Examples

```
ling_imm <- g3_stock(c('ling', maturity = 'imm'), seq(20, 156, 4)) |> g3s_age(0, 10)
ling_mat <- g3_stock(c('ling', maturity = 'mat'), seq(20, 156, 4)) |> g3s_age(3, 10)

actions <- list(
  g3a_time(1990, 1994, c(6, 6)),
  g3a_initialconditions_normalcv(ling_imm),
  g3a_initialconditions_normalcv(ling_mat),
  g3a_age(ling_imm),
  g3a_age(ling_mat),

  g3a_spawn(
    # Spawn from ling_mat
    ling_mat,
    # Use Ricker Recruitment Function to calculate # of recruits from total biomass
    recruitment_f = g3a_spawn_recruitment_ricker(),
    # Proportion of ling_mat spawning exponential relationship based on length
    proportion_f = g3_suitability_exponential150(
```

```

        alpha = g3_parameterized("spawn.prop.alpha", value = 4, scale = -1),
        150 = g3_parameterized("spawn.prop.150", value = 60)),
    # Proportion of ling_mat dying during spawning linear relationship to length
    mortality_f = g3_suitability_straightline(
        alpha = g3_parameterized("spawn.mort.alpha"),
        beta = g3_parameterized("spawn.mort.beta")),
    # Weight of spawning ling_imm should reduce by a fixed absolute amount (see g3a_weightloss)
    weightloss_args = list( abs_loss = g3_parameterized("spawn.weightloss", value = 0.1) ),
    # Spawn into ling_imm
    output_stocks = list(ling_imm),
    # Spawning should happen on the first step of every year
    run_f = ~cur_step==1 ),
    NULL )
model_fn <- g3_to_r(c(actions,
  g3a_report_detail(actions),
  g3a_report_history(actions, "__spawningnum$|__offspringnum$") ))

attr(model_fn, "parameter_template") |>
  # g3a_initialconditions_normalcv()
  g3_init_val("*.Linf", 50) |>
  g3_init_val("*.t0", -1.4) |>
  g3_init_val("*.walpha", 0.1) |>
  g3_init_val("*.wbeta", 1) |>
  # g3a_spawn_recruitment_ricker()
  g3_init_val("*.spawn.mu", 1e6) |>
  g3_init_val("*.spawn.lambda", 30) |>
  identity() -> params

r <- attributes(model_fn(params))
colSums(r$start_ling_imm__num)
colSums(r$start_ling_mat__wgt)

```

---

action\_spmodel

*Gadget3 surplus production model*


---

## Description

A simple production model can be used in place of a set of gadget stock dynamics actions.

## Usage

```

g3a_spmodel_logistic(
  r = g3_parameterized("spm_r", lower = 0.01, upper = 1, value = 0.5,
    by_stock = by_stock),
  p = g3_parameterized("spm_p", lower = 0.01, upper = 10, value = 1,
    by_stock = by_stock),
  K = g3_parameterized("spm_K", lower = 100, upper = 1e6, value = 1000,
    by_stock = by_stock),
  by_stock = TRUE)

```

```

g3a_spmodel(
  stock,
  spm_num = g3a_spmodel_logistic(),
  spm_num_init = g3_parameterized("spm_n0", by_stock = TRUE),
  spm_wgt = 1,
  run_f = TRUE,
  run_at = g3_action_order$initial)

```

### Arguments

<code>r, p, K</code>	Parameters for the logistic model, see value section.
<code>by_stock</code>	Change the default parameterisation (e.g. to be by 'species'), see <a href="#">g3_parameterized</a> .
<code>stock</code>	<a href="#">g3_stock</a> object to apply the simple production model to.
<code>spm_num</code>	<a href="#">formula</a> to calculate the relative change in abundance, one of the <code>g3a_spmodel_*</code> functions.
<code>spm_num_init</code>	Starting point for stock abundance.
<code>spm_wgt</code>	<a href="#">formula</a> to calculate the mean weight, if "1", then abundance in numbers == total biomass.
<code>run_f</code>	<a href="#">formula</a> specifying a condition for running this action, default always runs.
<code>run_at</code>	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

The actions will define the following variables in your model, which could be reported with [g3a\\_report\\_history](#):

**(stock)\_renewalnum** Numbers added to the abundance of *stock*

Note that the input stock should not have [g3s\\_age](#), if the stock was broken up by age the model would quickly not make sense.

### Value

**g3a\_spmodel\_logistic:** Returns a [formula](#) for use as `spm_num`:

$$rs(1 - (\frac{s}{K})^p)$$

*s*

*r* *r* argument, by default the `(stock)_spm_r` model parameter

*p* *p* argument, by default the `(stock)_spm_p` model parameter

*K* *K* argument, by default the `(stock)_spm_K` model parameter

**g3a\_spmodel:** G3 action that maintains stock abundance / mean weight according to simple production model

### See Also

[g3\\_stock](#)

**Examples**

```

# NB: Stock only has one length group, 30:40. So the stocks midlen is 35
stock_a <- g3_stock(c("stock", "a"), c(30, 40), open_ended = FALSE)
stocks <- list(stock_a)
fleet_a <- g3_fleet(c('fleet', "a"))

actions <- list(
  g3a_time(2000, 2010, step_lengths = c(6,6), project_years = 0),

  g3a_spmode(
    stock_a ),
  g3a_predate(
    fleet_a,
    stocks,
    suitabilityes = 1,
    catchability_f = g3a_predate_catchability_linearfleet(
      g3_parameterized("effort", value = 1e-1, by_predator = TRUE) )),

  # NB: Dummy parameter so model will compile in TMB
  ~{nll <- nll + g3_param("x", value = 0, optimise = TRUE)} )
actions <- c(actions, list(
  # NB: Late reporting for abundance
  g3a_report_history(actions, "__num$|__wgt$", out_prefix="dend_"),
  g3a_report_detail(actions) ))
model_fn <- g3_to_r(actions)

attr(model_fn, 'parameter_template') |>
# Surplus production model parameters
g3_init_val("*.spm_n0", 1e4) |>
g3_init_val("*.spm_r", 0.1) |>
g3_init_val("*.spm_p", 0.01) |>
g3_init_val("*.spm_K", 1e8, lower = 0, upper = 1e20) |>

identity() -> params.in
r <- attributes(model_fn(params.in))

barplot(r$dend_stock_a__num, las = 2)
barplot(r$detail_stock_a__renewalnum, las = 2)

```

---

action\_tagging

*Gadget3 tag-release action*


---

**Description**

Add tag-release to a g3 model

**Usage**

```
g3a_predate_tagrelease(
```

```
fleet_stock, prey_stocks, suitabilities, catchability_f,
output_tag_f, mortality_f = 0, run_f = ~TRUE,
run_at = g3_action_order$predate, ...)
```

```
g3a_tag_shedding(stocks, tagshed_f, run_f = ~TRUE,
run_at = g3_action_order$straying)
```

### Arguments

fleet_stock	Tagging fleet, see <a href="#">g3a_predate_fleet</a>
prey_stocks	Stocks fleet harvests, see <a href="#">g3a_predate_fleet</a>
suitabilities	See <a href="#">g3a_predate_fleet</a>
catchability_f	See <a href="#">g3a_predate_fleet</a>
output_tag_f	<a href="#">formula</a> specifying which numeric tag (see <a href="#">g3s_tag</a> ) stock will be released into. Implemented with a <a href="#">g3_timeareadata</a> table, e.g.
mortality_f	<a href="#">formula</a> generated by one of the <a href="#">g3_suitability_*</a> functions, describing the proportion of tagged stock that will die during tagging.
stocks	Stocks that will shed tags
tagshed_f	<a href="#">formula</a> for proportion that will shed tags at this point
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that spawning actions will be run within model, see <a href="#">g3_action_order</a> .
...	Any further options for <a href="#">g3a_predate_fleet</a>

### Value

**g3a\_predate\_tagrelease:** An action (i.e. list of formula objects) that will...

1. Harvest as-per [g3a\\_predate\\_fleet](#)
2. Use *mortality\_f* to apply tagging mortality to harvested stock
3. Use *output\_tag\_f* to decide what tag should be applied to harvested stock
4. Put harvested stock back into general circulation

**g3a\_tag\_shedding:** An action (i.e. list of formula objects) that will...

1. For each *stock*, move the proportion *tagshed\_f* back to the "untagged" tag

### See Also

[g3a\\_predate\\_fleet](#), [g3s\\_tag](#)

### Examples

```
tags <- c('H1-00', 'H1-01')
tags <- structure(seq_along(tags), names = tags)

prey_a <- g3_stock('prey_a', seq(1, 10)) %>% g3s_tag(tags)
fleet_a <- g3_fleet('fleet_a')
```

```

actions <- list(
  # NB: If g3_tag() is used in the stock, initialconditions/renewal
  # will only renew into tag == 0 (i.e. untagged)
  g3a_predate_tagrelease(
    # Setup as-per g3a_predate_fleet
    fleet_a,
    list(pre_y_a),
    suitability_f = list(pre_y_a = 1),
    catchability_f = g3a_predate_catchability_numberfleet(~100),

    # Optional tag mortality suitability
    mortality_f = g3_suitability_straightline(
      g3_parameterized('mort_alpha'),
      g3_parameterized('mort_beta')),

    # Formula to decide which tag to output into, generate table
    # with one tag per year
    output_tag_f = g3_timeareadata('fleet_a_tags', data.frame(
      year = 2000:2001,
      tag = tags[c('H1-00', 'H1-01')],
      stringsAsFactors = FALSE), value_field = "tag"),

    # Experiment only happens in spring
    run_f = ~cur_step == 2),

  g3a_tag_shedding(
    list(pre_y_a),
    # i.e. 0.125 will lose their tag each step
    tagshed_f = log(8))

```

---

action\_time

*Gadget3 timekeeping actions*

---

### Description

Add timekeeping to a g3 model

### Usage

```

g3a_time(
  start_year,
  end_year,
  step_lengths = c(12),
  final_year_steps = quote( length(step_lengths) ),
  project_years = g3_parameterized("project_years", value = 0, optimise = FALSE),
  retro_years = g3_parameterized("retro_years", value = 0, optimise = FALSE),
  run_at = g3_action_order$initial,
  run_stop_at = g3_action_order$time)

```

## Arguments

<code>start_year</code>	Year model run will start.
<code>end_year</code>	After this year, model run will stop.
<code>step_lengths</code>	Either an MFDB time grouping, e.g. <code>mfdm::mfdm_timestep_quarterly</code> , or a vector of step lengths which should sum to 12, for example, <code>c(3, 3, 3, 3)</code> for quarterly steps within a year.
<code>final_year_steps</code>	Number of steps of final year to include. Either as an integer or quoted code, in which case it will be calculated when the model runs. For example: <code>0</code> Model stops before the start of <code>end_year</code> (it is exclusive) <code>length(step_lengths)</code> Model stops at the end of <code>end_year</code> (it is inclusive) <code>2</code> Model stops at the second step of <code>end_year</code> , mid-year if <code>step_lengths</code> is quarterly
<code>project_years</code>	Number of years to continue running after the "end" of the model. Must be $\geq 0$ . Defaults to an unoptimized <code>project_years</code> parameter, set to 0 (i.e. no projection). Generally, you would change this parameter in the parameter template, rather than changing here.
<code>retro_years</code>	Adjust <code>end_year</code> to finish model early. Must be $\geq 0$ . Can be used in conjunction with <code>project_years</code> to project instead. The true end year of the model will be <code>end_year - retro_years + project_years</code> . Defaults to an unoptimized <code>retro_years</code> parameter, set to 0. Generally, you would change this parameter in the parameter template, rather than changing here.
<code>run_at, run_stop_at</code>	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> . <code>run_at</code> does year variable accounting, <code>run_stop_at</code> is when the model will finish if past the final step in the model.

## Details

The actions will define the following variables in your model:

<code>cur_time</code>	Current iteration of model, starts at 0 and increments until finished
<code>cur_step</code>	Current step within individual year
<code>cur_step_size</code>	Proportion of year this step contains, e.g. quarterly = 3/12
<code>cur_year</code>	Current year
<code>cur_step_final</code>	TRUE iff this is the final step of the year
<code>cur_year_projection</code>	TRUE iff we are currently projecting past <code>end_year</code>
<code>total_steps</code>	Total # of iterations (including projection) before model stops
<code>total_years</code>	Total # of years (including projection) before model stops

## Value

**g3a\_time:** An action (i.e. list of formula objects) that will...

1. Define `cur_*` variables listed above
2. If we've reached the end of the model, return `nil`

**Examples**

```
# Run model 2000..2004, in quarterly steps
time_action <- g3a_time(
  start_year = 2000,
  end_year = 2004,
  c(3, 3, 3, 3))
```

---

action_weightloss	<i>Gadget3 weightloss action</i>
-------------------	----------------------------------

---

**Description**

Add weight loss events to a g3 model

**Usage**

```
g3a_weightloss(
  stock,
  rel_loss = NULL,
  abs_loss = NULL,
  min_weight = 1e-7,
  apply_to_pop = quote( stock__num ),
  run_f = TRUE,
  run_step = NULL,
  run_at = g3_action_order$naturalmortality )
```

**Arguments**

stock	The <a href="#">g3_stock</a> that will lose weight in this action.
rel_loss	Fractional weight loss, 0.1 will result in the stock having 90% weight. NULL means no fractional weight loss will be applied.
abs_loss	Absolute weight loss, applied after <i>rel_loss</i> . NULL means no absolute weight loss will be applied.
min_weight	Minimum weight below which weight cannot fall further. Should be more than zero to avoid models returning NaN.
apply_to_pop	Stock instance weightloss applies to, by default applies to whole stock. Used by <a href="#">g3a_spawn</a> to apply to subset that spawned.
run_step	Which step to perform renewal in, or NULL for continuous spawning. Adds <code>cur_step == (run_step)</code> into default <i>run_f</i> .
run_f	<a href="#">formula</a> specifying a condition for running this action, default always runs.
run_at	Integer order that spawning actions will be run within model, see <a href="#">g3_action_order</a> .

**Value**

**g3a\_weightloss:** An action (i.e. list of formula objects) that will, for the given *stock*...

1. Apply *rel\_loss* and *abs\_loss* to the parent *stock*

**See Also**

[g3a\\_naturalmortality](#), [g3a\\_spawn](#), [g3\\_stock](#)

**Examples**

```
st <- g3_stock('st', 10:20) |> g3s_age(3, 5)

actions <- list(
  g3a_time(2000, 2005, step_lengths = c(3, 3, 3, 3)),
  g3a_initialconditions(st,
    # Set initial abundance & weight based on age
    ~1e5 + 0 * st__midlen,
    ~1000 * age + 0 * st__midlen ),
  g3a_age(st),

  g3a_weightloss(st,
    # 20% of body weight should be shed in autumn
    rel_loss = g3_parameterized("rel_loss_autumn", by_stock = TRUE, value = 0.2),
    run_step = 4 ),

  g3a_weightloss(st,
    # Remove "10" from body weight, with a minimum based on length
    abs_loss = g3_parameterized("absloss_length_mw", by_stock = TRUE, value = 10),
    min_weight = g3_formula(
      wmin.a * st__midlen^wmin.b,
      wmin.a = g3_parameterized("wmin.a", by_stock = TRUE, value = 10),
      wmin.b = g3_parameterized("wmin.a", by_stock = TRUE, value = 2) )),
  NULL)

model_fn <- g3_to_r(c(actions, g3a_report_detail(actions)))
r <- model_fn(attr(model_fn, 'parameter_template'))
g3_array_agg(attr(r, "dstart_st_wgt"), c("age", "time"))

## See g3a_spawn for an example of weightloss in spawning
```

---

array\_utils

*Gadget3 array-handling utilities*

---

**Description**

Tools to make munging array reports easier

**Usage**

```
g3_array_agg(
  ar,
  margins = NULL,
  agg = c(
    "sum",
```

```

        "length_mean", "length_sd",
        "predator_length_mean", "predator_length_sd" ),
    opt_time_split = !("time" %in% margins || "time" %in% ...names()),
    opt_length_midlen = FALSE,
    ... )

g3_array_combine(
  arrays,
  agg = sum,
  init_val = 0 )

g3_array_plot(
  ar,
  legend = "topright" )

```

### Arguments

ar	Input array, e.g. <code>dstart_fish__num</code> from a model report
arrays	List of input arrays, can be a nested list as generated by <code>cons</code> in <code>g3_quota_assess</code>
margins	dimension names to include in the final array, e.g. <code>c("age", "year")</code> to generate a report by-year & age. If <code>NULL</code> , no aggregation is done
agg	Function or character. Function to use when aggregating, or name of one of the built-in functions
init_val	The initial value to use when combining arrays
opt_time_split	Boolean, should we split up "time" into separate "year" & "step" dimensions?
opt_length_midlen	Boolean, should we convert "length"
legend	Location of legend, passed to <code>legend</code> 's <code>x</code> parameter
...	Filters to apply to any dimension, including "year" / "step" if <code>opt_time_split</code> is <code>TRUE</code> . e.g. <code>length = 40, age = 5, step = 1</code>

### Details

`g3_array_agg` allows you to both filter & aggregate an array at the same time.

Specifying a filter in ... is simplified in comparison to a regular R subset:

1. You can give the dimensions in any order
2. Values are always interpreted, `age = 3` will be interpreted as "age3", not the third age.

For particular dimensions we have extra helpers:

**age** Numeric ages e.g. `age = 5` are converted to "age5", as generated by `gadget3`

**length** Numeric lengths will pick a value within groups, e.g. with lengths "10:20", "20:30", `length = 15` will pick the smaller lengthgroup

`g3_array_combine` generates the union of 2 disjoint arrays, so you can combine aggregated output from an immature and mature stock for example.

`g3_array_plot` will plot the contents of an array, for arrays with 2 dimensions or less.

**Value**

An array, filtered by ... and aggregated by *margins*

**Examples**

```
# Generate an array to test with
dn <- list(
  length = c("50:60", "60:70", "70:Inf"),
  age = paste0("age", 0:5),
  time = paste0(rep(1990:1996, each = 2), c("-01", "-02")) )
ar <- array(
  seq_len(prod(sapply(dn, length))),
  dim = sapply(dn, length),
  dimnames = dn)
ar[,,"1994-02", drop = FALSE]
g3_array_plot(ar[,,"1994-02"])
g3_array_plot(ar["50:60","age3",])

# Generate by-year report for ages 2..4
g3_array_agg(ar, c('age', 'year'), age = 2:4)

# ...for only step 1
g3_array_agg(ar, c('age', 'year'), age = 2:4, step = 1)

# Report on smallest length group, for each timestep
g3_array_agg(ar, c('length', 'time'), length = 55)
# Use midlen as the dimension name
g3_array_agg(ar, c('length', 'time'), length = 55, opt_length_midlen = TRUE)

# Combine 2 arrays with disjoint age ranges into one list
g3_array_combine(list(
  g3_array_agg(ar, c('age', 'year'), age = 2:4),
  g3_array_agg(ar / 1000, c('age', 'year'), age = 3:5) ))
```

---

env\_dif

*g3 env: differentiable functions*


---

**Description**

Differentiable helper functions available to any gadget3 model

**Details**

These functions are part of `g3_env` is the top-level [environment](#) that any gadget3 model uses.

**dif\_pmax**

```
dif_pmax(a, b, scale)
```

Returns the maximum of  $a$  &  $b$ . If  $a$  is a vector/array, then all members of  $a$  are compared against  $b$ . If  $b$  is also a vector, then all members of  $a$  are compared against the matching member of  $b$  (repeating  $b$  if necessary).

$scale$  influences the sharpness of inflection points, should be about  $1e5$ , depending on ranges of input values.

**dif\_pmin**

```
dif_pmin(a, b, scale)
```

Returns the minimum of  $a$  &  $b$ , otherwise works like `dif_pmax`.

$scale$  influences the sharpness of inflection points, should be about  $1e5$ , depending on ranges of input values.

**dif\_pminmax**

```
dif_pminmax(a, lower, upper, scale)
```

Returns values of  $a$  bounded between  $lower$  &  $upper$ .

$scale$  influences the sharpness of inflection points at  $lower$  &  $upper$ , should be about  $1e5$ , depending on ranges of input values.

**Examples**

```
## dif_pmax
g3_eval(quote( dif_pmax(1:10, 5, 1e5) ))
g3_eval(quote( dif_pmax(1:10, c(4, 7), 1e5) ))
g3_eval(quote( dif_pmax(array(1:9, dim = c(3,3)), c(3,6,8), 1e5) ))

## dif_pmin
g3_eval(quote( dif_pmin(1:10, 5, 1e5) ))
g3_eval(quote( dif_pmin(1:10, c(4, 7), 1e5) ))

## dif_pminmax
g3_eval(quote( dif_pminmax(1:10, 3, 6, 1e5) ))
```

**Description**

Evaluate G3 formulas / code outside a model

**Usage**

```
g3_eval(f, ...)
```

**Arguments**

<code>f</code>	A <a href="#">formula</a> object or <a href="#">quoted</a> code to be evaluated
<code>...</code>	Named items to add to the formula's environment, or a single list / environment to use.

**Details**

Allows snippets of gadget3 code to be run outside a model. This could be done with regular [eval](#), however, `g3_eval` does a number of things first:

1. The global [g3\\_env](#) is in the environment, so functions such as [avoid\\_zero](#) can be used
2. If substituting a [g3\\_stock](#), all definitions such as `stock__minlen` will also be substituted
3. `g3_param('x')` will pull `param.x` from the environment

**Value**

Result of evaluating `f`.

**Examples**

```
# Evaluate suitability function for given stocks
g3_eval(
  g3_suitability_andersen(0,1,2,3,4),
  predator_length = 100,
  stock = g3_stock('prey', 1:10))

# Parameters can be filled in with "param." items in environment
g3_eval(quote( g3_param('x') ), param.x = 88)
g3_eval(
  g3_parameterized('lln.alpha', by_stock = TRUE, value = 99),
  stock = g3_stock("fish", 1:10),
  param.fish.lln.alpha = 123)

# Graph gadget3's built-in logspace_add()
if (interactive()) {
  curve(g3_eval(quote( logspace_add(a, 10) ), a = x), 0, 50)
}
```

## Description

Tools to create R formulas

## Usage

```
g3_formula(code, ...)
```

## Arguments

code	Unevaluated code to be turned into a formula
...	Named items to add to the formula's environment, or a single list / environment to use.

## Details

When using `~`, the local environment is attached to the code. This can leak unwanted variables into a model. This allows you to avoid the problem without resorting to [local](#).

## Value

A [formula](#) object, with environment created from .... Can then be used anywhere in `gadget3` that accepts a [formula](#).

## Examples

```
# g3_formula is identical to defining a formula within local():
stopifnot(all.equal(
  g3_formula(x + 1, z = 44),
  local({ z = 44; ~x + 1 })
))
```

```
# If the code is destined for CRAN, you need to quote() to avoid check errors:
stopifnot(all.equal(
  g3_formula(quote( x + 1 ), z = 44),
  local({ z = 44; ~x + 1 })
))
```

---

init\_val                      *Gadget3 parameter value setter*

---

## Description

Helper for setting initial parameter value

## Usage

```
g3_init_val(
  param_template,
  name_spec,
  value = NULL,
  spread = NULL,
  lower = if (!is.null(spread)) min(value * (1-spread), value * (1+spread)),
  upper = if (!is.null(spread)) max(value * (1-spread), value * (1+spread)),
  optimise = !is.null(lower) & !is.null(upper),
  parscale = if (is.null(lower) || is.null(upper)) NULL else 'auto',
  random = NULL,
  auto_exponentiate = TRUE)
```

## Arguments

param_template	A parameter template generated by <a href="#">g3_to_r</a> or <a href="#">g3_to_tmb</a>
name_spec	A glob-like string to match parameter names, see <a href="#">Details</a>
value	Numeric value / vector of values to set for value / 'value' column in template. Original value left if NULL
spread	Shortcut for setting <i>lower</i> & <i>upper</i> .
lower	Numeric value / vector of values to set for 'lower' column in template. Original value left if NULL
upper	Numeric value / vector of values to set for 'upper' column in template. Original value left if NULL
optimise	Boolean value to set for 'optimise' column in template. Default is true iff both lower and upper are non-NULL. Original value left if NULL
parscale	Numeric value / vector of values to set for 'parscale' column in template. Default (auto) is difference between lower & upper (or NULL if they're not set). Original value left if NULL
random	Boolean value to set for 'random' column in template. Original value left if NULL
auto_exponentiate	If TRUE, will implicitly match parameters ending with "_exp", and if this is the case log all <i>value/lower/upper</i> values

## Details

*name\_spec* is a glob (or wildcard) matching parameters. It is a string separated by ., where each part can be:

1. A wildcard matching anything (\*), or a matching anything with a prefix, e.g. m\*
2. A wildcard matching any number (#), or a matching a number with a prefix, e.g. age\*
3. A range of numbers, e.g. [1979-1984]
4. A choice of options can be separated with |, e.g. init|rec or [1979-1984]|[2000-2003]

## Value

A new parameter template list/table containing modifications

## See Also

[g3\\_parameterized](#)

## Examples

```
# A parameter template, would already be got via. attr(g3_to_tmb(...), "parameter_template")
pt <- data.frame(
  switch = c(
    paste0('fish.init.', 1:9),
    paste0('fish.rec.', 1990:2000),
    'fish.M'),
  value = NA,
  lower = NA,
  upper = NA,
  parscale = NA,
  optimise = FALSE,
  random = FALSE)

# Set all fish.init.# parameters to optimise
pt <- g3_init_val(pt, 'fish.init.#', 4, spread = 8)

# Set a fixed value for any .M
pt <- g3_init_val(pt, '*.M', value = 0.3, optimise = FALSE)

# Set a fixed value for a range of recruitment years, optimise the rest
pt |>
  g3_init_val('*.rec.#', value = 4, lower = 0, upper = 10) |>
  g3_init_val('*.rec.[1993-1996]', value = 0, optimise = FALSE) |>
  identity() -> pt

pt
```

**Description**

Additional meta-functions available for use in G3 formula.

**Details**

Whilst used as functions, these functions alter the code output of the model, rather than appearing directly.

**g3\_idx**

Adds a - 1 to the supplied expression, but only in C++ (which has 0-based indexes). Under R the expression is passed through unchanged.

*Note:* This is generally for internal use, as `[[` will do this automatically for you.

For example, `g3_idx(a)` will be replaced with `a` in R output and `a - 1` in C++ output.

**g3\_param**

Reference a scalar parameter by name. Arguments:

**name** Variable name for parameter. Required

**value** Initial value in model parameter\_template. Default 0

**optimise** Initial optimise setting in parameter\_template. Default TRUE

**random** Initial random setting in parameter\_template. Default FALSE

**lower** Initial lower setting in parameter\_template. Default NA

**upper** Initial upper setting in parameter\_template. Default NA

For example, `g3_param("ling.Linf")` will register a scalar parameter called *ling.Linf*, available in the model parameter template, and be replaced by a reference to that parameter.

`g3_param("ling.Linf")` can be used multiple times, to refer to the same value.

**g3\_param\_vector**

Reference a vector parameter by name. Arguments:

**name** Variable name for parameter. Required

**value** Initial value for use in model parameter\_template. Default 0

Same as `g3_param`, but the parameter will be expected to be a vector. You can then dereference with `[[`.

For example, `g3_param_vector("lingimm.M")[[age - 3 + 1]]`.

**g3\_param\_table**

Reference a lookup-table of parameters.

**name** Variable name for parameter. Required

**table** A data.frame, one column for each variable to check, one row for possible values. Required

**value** Initial value(s) for use in model parameter\_template. Default 0

**optimise** Initial optimise setting in parameter\_template. Default TRUE

**random** Initial random setting in parameter\_template. Default FALSE

**lower** Initial lower setting(s) in parameter\_template. Default NA

**upper** Initial upper setting(s) in parameter\_template. Default NA

**ifmissing** Value to return when outside of table bounds. Default NaN with warning if a value is missing

This is similar to providing a vector, but can use values in the model to provide bounds-checking.

The function takes 2 arguments, a prefix for the generated parameters, and a data.frame of variables to possible values. `expand.grid` can be used to produce a cross product of all provided variables.

`value`, `lower`, `upper` can be vectors, in which case it is split up with one per parameter.

*Note:* The variables referenced will need to be integer variables, most likely iteration variables such as `cur_year`, `age`, `area`...

For example, the following: `g3_param_table('lingimm.M', expand.grid(age = seq(ling_imm__minage, ling_imm__maxage)))` will generate parameters `lingimm.M.3..lingimm.M.10`, assuming that `ling_imm` has ages 3..10.

The call to `g3_param_table` will be replaced with `param[[paste("lingimm.M", age, sep = ".")]]`, or equivalent code in C++.

**g3\_with**

`g3_with(var1 := val1, var2 := val2, { x <- val1 * val2 })` is equivalent to `local({var1 <- val1, var2 <- val2, { x <<- val1 * val2 } })`

However, we don't make a new environment for the code block in R, only in C++.

---

likelihood\_bounds\_penalty

*Gadget3 likelihood bounds\_penalty action*

---

**Description**

Add a likelihood penalty for parameters leaving the bounds set in `parameter_template`

**Usage**

```
g3l_bounds_penalty(
  actions_or_parameter_template,
  weight = 1,
  run_at = g3_action_order$likelihood)
```

**Arguments**

actions_or_parameter_template	Either: A list of actions, to extract parameters from and to add bounds to. A parameter template generated by <code>g3_to_tmb</code> , with <i>optimise</i> , <i>lower</i> , <i>upper</i> populated, bounds for the parameters will be hard-coded.
weight	Weighting applied to this likelihood component.
run_at	Integer order that actions will be run within model, see <code>g3_action_order</code> .

**Details**

Whilst *lower/upper* can be passed to `optim`, not all methods can use them. Adding `g3l_bounds_penalty` OTOH can be used with any method.

**Value**

**g3l\_bounds\_penalty:** An action (i.e. list of formula objects) that will... If a *actions* list is supplied, add a large number to likelihood when any parameter is outside bounds. Bounds are updated whenever `g3_tmb_adfun` is run.

If a *parameter\_template* is supplied, add a large number to likelihood when outside the bounds in the template. The bounds are baked into the model at this point.

**Examples**

```

anch <- g3_stock('anch', seq(20, 156, 4)) %>% g3s_age(3, 10)
actions <- list(
  g3a_time(1990, 1994),
  g3a_growmature(anch, g3a_grow_impl_bbinom(
    maxlengthgroupgrowth = 38L)),
  g3a_naturalmortality(anch),
  g3a_initialconditions_normalparam(anch),
  g3a_renewal_normalparam(anch,
    run_step = NULL),
  g3a_age(anch),
  NULL)

# Generate code with bounds added
model_code <- g3_to_tmb(c(actions, list(g3l_bounds_penalty(actions))))

attr(model_code, "parameter_template") %>%
  # Set lower / upper bounds for initial conditions
  g3_init_val("*.init.#", 10, lower = 0.001, upper = 200) %>%
  identity() -> params.in

# The objective function produced by g3_tmb_adfun() will honour the bounds
# above, without having to pass them to stats::optim()

```

---

```
likelihood_catchdistribution
      Gadget3 likelihood actions
```

---

**Description**

Gather nll in a g3 model

**Usage**

```
g3l_distribution_sumofsquares(
  over = c('area', 'predator', 'predator_tag', 'predator_age', 'predator_length'))

g3l_distribution_multinomial(epsilon = 10)

g3l_distribution_multivariate(rho_f, sigma_f, over = c("area"))

g3l_distribution_surveyindices_log(alpha = NULL, beta = 1)

g3l_distribution_surveyindices_linear(alpha = NULL, beta = 1)

g3l_distribution_sumofsquaredlogratios(epsilon = 10)

g3l_abundancedistribution(
  nll_name,
  obs_data,
  fleets = list(),
  stocks,
  function_f,
  predators = list(),
  transform_fs = list(),
  missing_val = 0,
  area_group = NULL,
  report = FALSE,
  nll_breakdown = FALSE,
  weight = g3_parameterized(paste0(nll_name, "_weight"),
    optimise = FALSE, value = 1),
  run_at = g3_action_order$likelihood)

g3l_catchdistribution(
  nll_name,
  obs_data,
  fleets = list(),
  stocks,
  function_f,
  predators = list(),
  transform_fs = list(),
```

```

missing_val = 0,
area_group = NULL,
report = FALSE,
nll_breakdown = FALSE,
weight = g3_parameterized(paste0(nll_name, "_weight"),
  optimise = FALSE, value = 1),
run_at = g3_action_order$likelihood)

g3_distribution_preview(
  obs_data,
  predators = list(),
  fleets = list(),
  stocks = list(),
  area_group = NULL)

```

### Arguments

over	When comparing proportions of lengthgroups, specifies the dimensions that define the total. For example the default "area" means the proportion of the current lengthgroup to all individuals in that area. <code>c('area', 'predator_tag', 'predator_age', 'predator_length')</code> will compare the current lengthgroup to all individuals consumed by that predator. Note that any unknown dimensions will be ignored; for example a fleet does not have a tag/age/length, so only area will have an effect here.
rho_f, sigma_f	<a href="#">formula</a> substituted into multivariate calculations, see below.
epsilon	Value to be used whenever the calculated probability is very unlikely. Default 10.
alpha	<a href="#">formula</a> substituted into surveyindices calculations to fix intercept of linear regression, or NULL if not fixed. See below.
beta	<a href="#">formula</a> substituted into surveyindices calculations to fix slope of linear regression, or NULL if not fixed. See below.
nll_name	Character string, used to define the variable name for <i>obsstock</i> and <i>modelstock</i> .
obs_data	Data.frame of observation data, for example the results of <code>mfdb_sample_count</code> . Should at least have a year column, and a length or weight column. For more information, see "obs_data and data aggregation" below.
fleets, predators	A list of <a href="#">g3_stock</a> objects to collect catch data for. If empty, will collect abundance data for <i>stocks</i> instead.
stocks	A list of <a href="#">g3_stock</a> objects to collect catch or abundance data for, depending if <i>stocks</i> were provided.
function_f	A <a href="#">formula</a> to compare <i>obsstock__x</i> to <i>modelstock__x</i> and generate nll, defined by one of the <code>g3l_distribution_*</code> functions. This will be adapted to compare either number ( <i>modelstock__num</i> ) or weight ( <i>modelstock__wgt</i> ) depending on what columns <i>obs_data</i> has.
transform_fs	A list of dimension names to either formula objects or list of stock names to formula objects (where the transform differs between stocks). See examples.

missing_val	Where there are missing values in the incoming data, value to replace them with.
area_group	<a href="#">mfdb_group</a> or list mapping area names used in <i>obs_data</i> to integer model areas, see "obs_data and data aggregation" below.
report	If TRUE, add model and observation arrays to the model report, called <code>cdist_nll_name_model__num/wgt</code> and <code>cdist_nll_name_obs__num/wgt</code> respectively
nll_breakdown	Should the nll report be broken down by time? TRUE / FALSE
weight	Weighting applied to this likelihood component. Default is a <code>g3_param</code> that defaults to 1, allowing weights to be altered without recompiling.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

## Details

The actions will define the following variables in your model:

`obsstock__num/wgt` A [g3\\_stock](#) instance that contains all observations in an array

`modelstock__num/wgt` A [g3\\_stock](#) instance that groups in an identical fashion to `obsstock`, that will be filled with the model's predicted values

The model report will contain `nll_cdist_nll_name__num` and/or `nll_cdist_nll_name__wgt`, depending on the columns in *obs\_data* (a number column will compare by individuals, and produce a corresponding num report). If `nll_breakdown` is TRUE, this will be an array with one entry per timestep.

[g3l\\_abundancedistribution](#) compares abundance of stocks, [g3l\\_catchdistribution](#) compares fleet catch. Thus providing fleets is mandatory for [g3l\\_catchdistribution](#), and an error for [g3l\\_abundancedistribution](#).

**obs\_data and data aggregation:** The *obs\_data* data.frame, as well as providing the observation data to compare the model data against, controls the grouping of model data to compare to the observation data, by inspecting the MFDB column attributes produced by e.g. [mfdb\\_sample\\_count](#). Metadata columns describe the observation datapoint in that row. The columns should be from this list:

**year** Required. Year for the data point. Gaps in years will result in no comparison for that year

**step** Optional. If there is no step column, then the data is assumed to be yearly, and the model data for all timesteps will be summed before comparing.

Model timestep for the data point. Gaps in steps will result in no comparison for that year/step.

**length** Optional. If missing all lengthgroups in the model will be summed to compare to the data.

The column can be a factor, as generated by [cut\(\)](#), e.g `cut(raw_length, c(seq(0, 50, by = 10), Inf), right = FALSE)` for an open-ended upper group.

The column can be character strings also formatted as factors as above. The column entries are assumed to be sorted in order and converted back to a factor.

If `open_ended = c('lower', 'upper')` was used when querying MFDB for the data, then the bottom/top length groups will be modified to start from zero or be infinite respectively.

Any missing lengthgroups (when there is otherwise data for that year/step) will be compared to zero.

**age** Optional. If missing all age-groups (if any) in the model will be summed to compare to the data.

Model ages will be grouped by the same groupings as MFDB used, thus if the data was formed with a query `age = mfdb_group(young = 1:3, old = 4:5)`, then the model data will similarly have 2 groups in it.

Any missing ages (when there is otherwise data for that year/step) will be compared to zero.

**predator\_length / predator\_age / predator\_tag** Optional.

Values are the same as with length/age/tag respectively, but group by the predator rather than the prey.

**stock** Optional. If missing all stocks in *stocks* will be summed to compare to the data.

The values in the stocks column should match the names of the stocks given in the *stocks* parameter. This column can be factor or character.

The values can also be some of the stock name parts, e.g. "st\_f" or "f" which would then aggregate "st\_imm\_f", "st\_mat\_f" together.

However, note that a stock can only be included in one grouping, so given columns "f" & "imm", "st\_imm\_f" would only be included in the former group. If you want to do something along these lines, 2 separate likelihood actions would be more appropriate.

Any missing stocks (when there is otherwise data for that year/step) will be compared to zero.

**stock\_re** Optional. If this and stock are missing all stocks in *stocks* will be summed to compare to the data.

The values in the stocks column will be used as regular expressions to match the names of the stocks given in the *stocks* parameter. For example, '\_mat\_' will match both 'ghd\_mat\_f' and 'ghd\_mat\_m' and will be compared against the sum of the 2 stocks.

Any missing stocks (when there is otherwise data for that year/step) will be compared to zero.

**fleet** Optional. If this and fleet\_re are missing all fleets in *fleets* will be summed to compare to the data.

The values in the fleets column should match the names of the fleets given in the *fleets* parameter. This column can be factor or character.

Any missing fleets (when there is otherwise data for that year/step) will be compared to zero.

**fleet\_re** Optional. If this and fleet are missing all fleets in *fleets* will be summed to compare to the data.

The values in the fleets column will be used as regular expressions to match the names of the fleets given in the *fleets* parameter. For example, '\_trawl\_' will match both 'fleet\_trawl\_is' and 'fleet\_trawl\_no' and will be compared against the sum of the 2 fleets.

Any missing fleets (when there is otherwise data for that year/step) will be compared to zero.

**area** Optional. If missing all areas in the model will be summed to compare to the data.

Unlike other columns, the MFDB grouping here is ignored (the areas it is grouping over aren't integer model areas). Instead, the *area\_group* parameter should describe how to map from the area names used in the table to integer model areas.

For example, if `area_group = list(north=1:2, south=3:5)`, then the area column of *obs\_data* should contain either "north" or "south", and corresponding model data will be summed from integer model areas 1,2 and 3,4,5 respectively.

If *area\_group* is not supplied, then we assume that *obs\_data* area column will contain model area integers.

Any missing areas (when there is otherwise data for that year/step) will be compared to zero.

Data columns contain the observation data to compare. There should be at least one of:

**number** If a number column appears in *obs\_data*, then the stock abundance by individuals will be aggregated and compared to the *obs\_data* number column.

**weight** If a weight column appears in *obs\_data*, then the total biomass of the stock will be aggregated and compared to the *obs\_data* number column.

You can use `g3_distribution_preview` to see how your observation data will be converted into an array.

## Value

**g3\_distribution\_sumofsquares:** Returns a [formula](#) for use as *function\_f*:

$$\sum_{lengths} \left( \frac{N_{tral}}{N_{tr}} - \frac{\nu_{tral}}{\nu_{tr}} \right)^2$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$N_{tr}$  Total observation sample size for current time/area (or dimensions set in *over*)

$\nu_{tr}$  Total model sample size for current time/area (or dimensions set in *over*)

**g3\_distribution\_multinomial:** Returns a [formula](#) for use as *function\_f*:

$$2 \left( \sum_{lengths} \log N_{tral}! - \log \left( \sum_{lengths} N_{tral} \right)! - \sum_{lengths} \left( N_{tral} \log \min \left( \frac{\nu_{tral}}{\sum_{lengths} \nu_{tral}}, \frac{1}{l\epsilon} \right) \right) \right)$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$l$  Number of lengthgroups in sample

$\epsilon$  *epsilon* parameter

**g3\_distribution\_multivariate:** Returns a [formula](#) for use as *function\_f*, which calls TMB's `SCALE(AR1(rho), sigma)(x)`, where *rho* and *sigma* are parameters, and *x* is defined as:

$$\frac{N_{tral}}{N_{tr}} - \frac{\nu_{tral}}{\nu_{tr}}$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$N_{tr}$  Total observation sample size for current time/area (or dimensions set in *over*)

$\nu_{tr}$  Total model sample size for current time/area (or dimensions set in *over*)

For more information, see [Autoregressive processes](#) in the TMB book.

**g3\_distribution\_surveyindices\_log:** Returns a [formula](#) for use as *function\_f*:

$$\sum_{time} (\alpha + \beta \log N_{tral} - \log \nu_{tral})^2$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$\alpha$  *alpha* parameter

$\beta$  *beta* parameter

If *alpha* or *beta* is not provided, then linear regression is performed on  $N, \nu$  over time for each area/age/length combination. The used values will be stored in a `cdist_nll_name_model__param` array and reported after model run, whether calculated or hard-coded.

**g3l\_distribution\_surveyindices\_linear:** Returns a [formula](#) for use as *function\_f*:

$$\sum_{lengths} (\alpha + \beta N_{tral} - \nu_{tral})^2$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$\alpha$  *alpha* parameter

$\beta$  *beta* parameter

If *alpha* or *beta* is not provided, then linear regression is performed on  $N, \nu$  over time for each area/age/length combination. The used values will be stored in a `cdist_nll_name_model__param` array and reported after model run, whether calculated or hard-coded.

**g3l\_distribution\_sumofsquaredlogratios:** The equivalent of gadget2's `catchinkilos`.

Returns a [formula](#) for use as *function\_f*:

$$\sum_{lengths} (\log(N_{tral} + \epsilon) - \log(\nu_{tral} + \epsilon))^2$$

$N_{tral}$  Observation sample size for current time/area/age/length combination

$\nu_{tral}$  Model sample size for current time/area/age/length combination

$\epsilon$  *epsilon* parameter

**g3l\_abundancedistribution:** An action (i.e. list of formula objects) that will...

1. For all *stocks*, collect catch data into `modelstock__num` or `modelstock__wgt`, depending on the columns provided in `obs_data`
2. Compare `modelstock__num/wgt` with `obsstock__num/wgt`, using *function\_f*

The output of *function\_f* is summed over all stock dimensions (age/area) and time and added to `nll`.

**g3l\_catchdistribution:** An action (i.e. list of formula objects) that will...

1. For all *fleets* and *stocks* combinations, collect catch data into `modelstock__num` or `modelstock__wgt`, depending on the columns provided in `obs_data`
2. Compare `modelstock__num/wgt` with `obsstock__num/wgt`, using *function\_f*

The output of *function\_f* is summed over all stock dimensions (age/area) and time and added to `nll`.

**g3\_distribution\_preview:** The input `obs_data` formatted as an array, applying the same rules that `g3l_*distribution` will.

#### See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-like.html>, [g3\\_stock](#)

**Examples**

```

ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock('ling_mat', seq(20, 156, 4)) %>% g3s_age(5, 15)
lln <- g3_fleet('lln')

# Invent a ldist.lln table for our tests
ldist.lln.raw <- data.frame(
  year = c(1999, 2000),
  age = sample(5:9, 100, replace = TRUE),
  length = sample(10:70, 100, replace = TRUE),
  number = 1,
  stringsAsFactors = FALSE)

# Group length into 10-long bins
# NB: The last 2 bins will be empty, but gadget3 will use the factor levels, include them as zero
# NB: Generally one would use mfdb::mfdb_sample_count() source and group data for you
ldist.lln.raw |> dplyr::group_by(
  year = year, age = age,
  length = cut(length, breaks = seq(10, 100, by = 10), right = FALSE)
) |> dplyr::summarise(number = sum(number), .groups = 'keep') -> ldist.lln

# Turn age into a factor, indicating all ages we should be interested in
ldist.lln$age <- factor(ldist.lln$age, levels = 5:15)

# We can see the results of this being turned into an array:
g3_distribution_preview(ldist.lln)

likelihood_actions <- list(
  g3l_catchdistribution(
    'ldist_lln',
    ldist.lln,
    fleets = list(lln),
    stocks = list(ling_imm, ling_mat),
    g3l_distribution_sumofsquares())

# Make an (incomplete) model using the action, extract the observation array
fn <- suppressWarnings(g3_to_r(likelihood_actions))
environment(fn)$cdist_sumofsquares_ldist_lln_obs__num

# Apply age-reading error matrix to model data
more_likelihood_actions <- list(
  g3l_catchdistribution(
    'ldist_lln_readerror',
    ldist.lln,
    fleets = list(lln),
    stocks = list(ling_imm, ling_mat),
    transform_fs = list(age = g3_formula(
      g3_param_array('reader1matrix', value = diag(5))[g3_idx(preage), g3_idx(age)]
    )),
    g3l_distribution_sumofsquares())

# Apply per-stock age-reading error matrix to model data

```

```

more_likelihood_actions <- list(
  g3l_catchdistribution(
    'ldist_lln_readerror',
    ldist.lln,
    fleets = list(lln),
    stocks = list(ling_imm, ling_mat),
    transform_fs = list(age = list(
      ling_imm = quote( g3_param_array('imm_readermatrix',
        value = diag(ling_imm__maxage - ling_imm__minage + 1)
      )[ling_imm__preage_idx, ling_imm__age_idx] ),
      ling_mat = quote( g3_param_array('mat_readermatrix',
        value = diag(ling_mat__maxage - ling_mat__minage + 1)
      )[ling_mat__preage_idx, ling_mat__age_idx] ),
      unused = 0)),
    g3l_distribution_sumofsquares())

## Stomach content: predator-prey species preference
prey_a <- g3_stock('prey_a', seq(1, 10)) |> g3s_age(1,3)
prey_b <- g3_stock('prey_b', seq(1, 10)) |> g3s_age(1,3)
pred_a <- g3_stock('pred_a', seq(50, 80, by = 10)) |> g3s_age(0, 10)
otherfood <- g3_stock('otherfood', 0)

# Produce data.frame with columns:
# * predator_length or predator_age
# * stock
# * number or weight
pred_a_preypref_obs <- expand.grid(
  year = 2000:2005,
  predator_length = c(50,70),
  stock = c('prey_a', 'prey_b', 'otherfood'),
  number = 0 )

# Create catchdistribution likelihood component
actions <- list(
  g3l_catchdistribution(
    'pred_a_preypref',
    pred_a_preypref_obs,
    fleets = list(pred_a),
    stocks = list(pre_y_a, prey_b, otherfood),
    g3l_distribution_sumofsquares(),
    nll_breakdown = TRUE,
    report = TRUE ),
  NULL)

## Stomach content: predator-prey size preference
# Produce data.frame with columns:
# * predator_length or predator_age
# * (prey) length
# * number or weight
pred_a_sizepref_obs <- expand.grid(
  year = 2000:2005,
  predator_length = c(50,70),
  length = seq(1, 10),

```

```

number = 0 )

# Create catchdistribution likelihood component
actions <- list(
  g3l_catchdistribution(
    'pred_a_sizepref',
    pred_a_sizepref_obs,
    predators = list(pred_a),
    # NB: Only referencing stocks included in observation data
    stocks = list(pre_y_a),
    function_f = g3l_distribution_sumofsquares(),
    # Use transform_fs to apply digestioncoefficients
    transform_fs = list(length = list(pre_y_a = g3_formula(
      quote( diag(d0 + d1 * pre_y_a_midlen^d2) ),
      d0 = g3_parameterized('d0', by_stock = TRUE),
      d1 = g3_parameterized('d1', by_stock = TRUE),
      d2 = g3_parameterized('d2', by_stock = TRUE) ))) ,
    nll_breakdown = TRUE,
    report = TRUE ),
  NULL)

```

---

likelihood\_random

*Gadget3 random effects likelihood actions*


---

## Description

Add likelihood components for random effects

## Usage

```

g3l_random_dnorm(
  nll_name,
  param_f,
  mean_f = 0,
  sigma_f = 1,
  log_f = TRUE,
  period = 'auto',
  nll_breakdown = FALSE,
  weight = g3_parameterized(paste0(nll_name, "_weight"),
    optimise = FALSE, value = 1),
  run_at = g3_action_order$likelihood)

g3l_random_walk(
  nll_name,
  param_f,
  sigma_f = 1,
  log_f = TRUE,
  period = 'auto',
  nll_breakdown = FALSE,

```

```
weight = g3_parameterized(paste0(nll_name, "_weight"),
  optimise = FALSE, value = 1),
run_at = g3_action_order$likelihood)
```

### Arguments

param_f	A <a href="#">formula</a> representing the value to apply <a href="#">dnorm</a> to. Invariably a <a href="#">g3_param</a> for <a href="#">g3l_random_dnorm</a> , a <a href="#">g3_param_table</a> with <code>cur_year</code> for <a href="#">g3l_random_walk</a> .
mean_f	A <a href="#">formula</a> representing <i>mean</i> in <a href="#">dnorm</a> .
sigma_f	A <a href="#">formula</a> representing <i>sigma</i> in <a href="#">dnorm</a> .
log_f	A <a href="#">formula</a> representing <i>log</i> in <a href="#">dnorm</a> .
period	When <a href="#">dnorm</a> should be recalculated. Once per year every step, or single for once. The default, <code>auto</code> , will assume the input is generated by <a href="#">g3_parameterized</a> and will derive the most appropriate option.
nll_name	Character string, used to define the variable name for <a href="#">dnorm</a> output.
nll_breakdown	Should the nll report be broken down by time? TRUE / FALSE
weight	Weighting applied to this likelihood component.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

The model report will contain `nll_random_dnorm_dnorm_lin__dnorm`, the results of applying [dnorm](#). If `nll_breakdown` is TRUE, this will be an array with one entry per timestep.

### Value

**g3l\_random\_dnorm:** An action (i.e. list of formula objects) that will...

1. On the final model step, calculate `dnorm(param_f, mean_f, sigma_f)` & add to nll

**g3l\_random\_walk:** An action (i.e. list of formula objects) that will...

1. Calculate `dnorm(param_f, previous param_f, sigma_f)` (at final year if `period = year`)
2. Add to nll.

### Examples

```
likelihood_actions <- list(
  # Calculate dnorm() for the dnorm_log parameter
  g3l_random_dnorm('dnorm_log',
    g3_parameterized('dnorm_log', value = 0, random = TRUE),
    mean_f = 0),

  # Treat the walk_year.xxxx parameters as a random walk
  g3l_random_walk('walk_year',
    g3_parameterized('walk_year', by_year = TRUE, value = 0, random = TRUE))
)
```

---

likelihood\_sparsesample

*Gadget3 likelihood actions for sparse data*


---

### Description

Compare model predictions against a set of sparse data points

### Usage

```
g3l_sparsesample_linreg(
  fit = c('log', 'linear'),
  slope = 1,
  intercept = NULL )

g3l_sparsesample_sumsquares(
  weighting = "model_stddev" )

g3l_sparsesample(
  nll_name,
  obs_df,
  stocks,
  measurement_f = quote( wgt ),
  function_f = g3l_sparsesample_linreg(),
  predstocks = list(),
  area_group = NULL,
  weight = g3_parameterized(paste(
    if (length(predstocks) > 0) "csparse" else "asparsed",
    function_f_name,
    nll_name,
    "weight",
    sep = "_"), optimise = FALSE, value = 1),
  run_at = g3_action_order$likelihood )
```

### Arguments

slope, intercept	<a href="#">formula</a> substituted into surveyindices calculations to fix slope/intercept of linear regression, or NULL if not fixed. See below.
fit	Is the fit 'log' or 'linear'? See below.
weighting	Weighting applied to sum-of-squares. One of "model_stddev", "obs_stddev" or a <a href="#">formula</a> .
nll_name	Character string, used to define the variable name for <i>obsstock</i> and <i>modelstock</i> . By default set to (asparsed csparsed)_(name_of_function_f)_(nll_name)_weight.
obs_df	Data.frame of observation data. See details.

stocks	A list of <a href="#">g3_stock</a> objects to collect sparsesample data for, depending if <i>stocks</i> were provided.
measurement_f	<a href="#">formula</a> to derive the model's equivalent predicted value for a data point. You can use <i>wgt</i> to refer to weight of matching individuals, <i>length</i> to refer to length of matching individuals.
function_f	A <a href="#">formula</a> to compare <i>obs_df</i> to predicted values generated via <i>transform_f</i> and generate <i>nll</i> , defined by one of the <i>g3l_sparsesample_*</i> functions.
predstocks	A list of <a href="#">g3_stock</a> predator or fleet objects. If present, we will compare against the model predicted catch. Without (the default), we compare against overall abundance.
area_group	List mapping area names used in <i>obs_df</i> to integer model areas, most likely generated by <a href="#">g3_areas</a> .
weight	Weighting applied to this likelihood component. Default is a <i>g3_param</i> that defaults to 1, allowing weights to be altered without recompiling.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

The actions will define the following variables in your model, which could be reported with [g3a\\_report\\_history](#):

- nll\_sp(abundlcatch)\_name\_\_obs\_mean** Observation mean, the *mean* column from *obs\_df*
- nll\_sp(abundlcatch)\_name\_\_obs\_stddev** Observation standard deviation, the *stddev* column from *obs\_df*
- nll\_sp(abundlcatch)\_name\_\_obs\_n** Observation number, the *number* column from *obs\_df*
- nll\_sp(abundlcatch)\_name\_\_model\_sum** The corresponding model prediction vector, total datapoints. *\_\_model\_sum* / *\_\_model\_n* for the mean
- nll\_sp(abundlcatch)\_name\_\_model\_sqsum** The corresponding model prediction vector, squared-sum datapoints.
- nll\_sp(abundlcatch)\_name\_\_model\_n** The number of data points at each point in the model prediction vector, if *predstocks* set this is the number of individuals caught matching the datapoint (*length/age/...*), otherwise abundance of individuals matching the datapoint.

**obs\_df format:** *data.frame* of observation data. Unlike [g3l\\_abundancedistribution](#), gaps and sparse data is accepted, and gaps will not be filled with zero.

For each row in the table, all matching predictions are aggregated. Aggregation columns include:

- year** Required. The year the sample is from
- step** Optional. The timestep/season the sample is from
- area** Optional. Only aggregate predicted values from given area
- age** Optional. Only aggregate predicted values with given age
- length** Optional. Only aggregate predicted values with given length (matches nearest length-group)

So, a row with "year=1998,age=4" will be compared against age 4 individuals of all lengths in 1998, step 1 & 2. A row with "year=2004,step=1,age=2,length=19" will be compared against individuals of age 4, length 10..20, in winter 2004.

The observation data is provided in the following columns:

**mean** Required. Mean value at this data point  
**number** Optional. Number of data points, defaults to 1  
**stddev** Optional. Observed standard deviation (only required if `weighting = "obs_stddev"`)

### Value

**g3l\_sparsesample\_linreg:** Returns a [formula](#) for use as `function_f`:

If `fit = "log"`:

$$\sum_i^{rows} (\alpha + \beta \log N_i - \log \frac{\nu_i}{P_i})^2$$

If `fit = "linear"`:

$$\sum_i^{rows} (\alpha + \beta N_i - \frac{\nu_i}{P_i})^2$$

$N_i$  "mean" column from `obs_df`

$\nu_i$  Total predicted values for all data points, i.e. `nll_spabund_name__model_sum`

$P_i$  Number of data points, i.e. `nll_spabund_name__model_n`

$\alpha$  *intercept* parameter, defaults to 1, i.e. fixed slope

$\beta$  *slope* parameter, defaults to NULL, i.e. linear regression performed to find optimal value

If either *alpha* or *beta* is not provided, then linear regression is performed on  $N$  vs  $\nu$  for each value in table, and the optimal value used for each.

**g3l\_sparsesample\_sumsquares:** Returns a [formula](#) for use as `function_f`:

$$\sum_i^{rows} w(\frac{\nu_i}{P_i} - N_i)^2$$

$N_i$  "mean" column from `obs_df`

$\nu_i$  Total predicted values, i.e. `nll_spabund_name__model_sum`

$P_i$  Number of data points, i.e. `nll_spabund_name__model_n`

$w$  *weighting* parameter, either:

1.  $1/\sigma^2$ , using stddev of model predicted values if `weighting = "model_stddev"`
2.  $1/\sigma^2$ , using stddev column from `obs_df` if `weighting = "obs_stddev"`
3. A custom formula provided for *weighting*

### See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-like.html>, [g3l\\_catchdistribution](#)  
[g3\\_stock](#)

### Examples

```
st <- g3_stock("fish", c(10, 20, 30)) %>% g3s_age(3,5)

# Generate some random sparsesample samples
obs_df <- data.frame(
  # NB: No 1993, we don't have any samples for that year
```

```

    year = rep(c(1990, 1991, 1992, 1994), each = 2),
    step = 1:2 )
obs_df$age = floor(runif(nrow(obs_df), min = 3, max = 5.1))
obs_df$length = floor(runif(nrow(obs_df), min = 10, max = 50))
obs_df$mean = runif(nrow(obs_df), min = 10, max = 1000)

actions <- list(
  g3a_time(1990, 1994, c(6,6)),
  # Use otherfood to populate abundance / mean weight
  g3a_otherfood(st,
    quote( age * 100 + stock__minlen ),
    quote( cur_year * 1e5 + cur_step * 1e4 + 0 * stock__minlen ) ),
  g3l_sparsesample(
    "bt",
    obs_df,
    list(st),
    measurement_f = g3_formula(
      # Derive blubber thickness from length/weight
      ((wgt/(wmax.a * length^wmax.b) - 0.5) * 100 - 4.44) / (5693 * (length/wgt)^0.5),
      wmax.a = g3_parameterized("wmax.a", by_stock = TRUE),
      wmax.b = g3_parameterized("wmax.b", by_stock = TRUE),
      end = NULL ),
    function_f = g3l_sparsesample_linreg(fit = "linear") ),
  NULL )

model_fn <- g3_to_r(c(actions, list(
  g3a_report_detail(actions), # TODO: Not reporting anything useful
  NULL )))
r <- attributes(model_fn())
colSums(r$dstart_fish_num) # TODO: Report something related

```

---

likelihood\_tagging\_ckmr

*Gadget3 CKMR likelihood*

---

## Description

\*Experimental\* CKMR tagging likelihood

## Usage

```

g3l_tagging_ckmr(
  nll_name,
  obs_data,
  fleets,
  parent_stocks,
  offspring_stocks,
  weight = g3_parameterized(paste0(nll_name, "_weight"),
    optimise = FALSE, value = 1),
  run_at = g3_action_order$likelihood)

```

**Arguments**

nll_name	Character string, used to define the variable name for <i>obsstock</i> and <i>modelstock</i> .
obs_data	Data.frame of observed mother-offspring pairs with columns year / parent_age / offspring_age / mo_pairs
fleets	A list of <a href="#">g3_stock</a> objects to collect catch data for.
parent_stocks	A list of <a href="#">g3_stock</a> objects that are parents in a <a href="#">g3a_spawn</a> action
offspring_stocks	A list of <a href="#">g3_stock</a> objects that are output_stocks in a <a href="#">g3a_spawn</a> action
weight	Weighting applied to this likelihood component. Default is a <a href="#">g3_param</a> that defaults to 1, allowing weights to be altered without recompiling.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

**Details**

Implementation of CKMR based on *Bravington, M.V., Skaug, H.J., & Anderson, E.C. (2016). Close-Kin Mark-Recapture. Statistical Science, 31, 259-274.*

Only one kinship probability is implemented, mother-offspring with lethal sampling, i.e. (3.2) in the paper. This is then used as a pseudo-likelihood as per (4.1).

**obs\_data:** The *obs\_data* data.frame provides observed pairs. Unlike other likelihood methods, it has a fixed structure:

**year** Year of observation for the data point.

**parent\_age** Age of the parent in an observed parent-offspring pair.

**offspring\_age** Age of the offspring in an observed parent-offspring pair.

**mo\_pairs** Number of pairs observed with these ages.

**Value**

**g3l\_tagging\_ckmr:** An action (i.e. list of formula objects) that will...

1. For all *parent\_stocks* and *offspring\_stocks*, collect spawning rate into *modelhist\_\_spawning* and *modelhist\_\_spawned*, total number of parents and total number of spawned offspring respectively
2. For all *fleets*, collect catch data into *modelhist\_\_catch*
3. For any observed pairs that year, include the probability of that event happening into nll

**See Also**

*Bravington, M.V., Skaug, H.J., & Anderson, E.C. (2016). Close-Kin Mark-Recapture. Statistical Science, 31, 259-274.* [g3\\_stock](#)

---

likelihood\_understocking

*Gadget3 likelihood understocking action*


---

## Description

Add rates of understocking in a g3 model to nll

## Usage

```
g3l_understocking(
  prey_stocks,
  power_f = ~2,
  nll_breakdown = FALSE,
  weight = 1e+08,
  run_at = g3_action_order$likelihood)
```

## Arguments

prey_stocks	A list of <a href="#">g3_stock</a> objects to collect catch data for
power_f	A <a href="#">formula</a> representing power coefficient $p$ to use.
nll_breakdown	Should the nll report be broken down by time? TRUE / FALSE
weight	Weighting applied to this likelihood component.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

## Details

The model report will contain `nll_understocking__wgt`, the results of the formula below. If `nll_breakdown` is TRUE, this will be an array with one entry per timestep.

## Value

**g3l\_distribution\_understocking:** An action (i.e. list of formula objects) that will...

1. Sum the total biomass adjustment due to overstocking for each prey according to the formula

$$\ell = \sum_{time} \sum_{areas} \left( \sum_{prey\_stocks} U_{trs} \right)^p$$

Where  $p$  is the power coefficient from `power_f`,  $U_{trs}$  is the total biomass adjustment to predator consumption due to overconsumption.

**Examples**

```

ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock('ling_mat', seq(20, 156, 4)) %>% g3s_age(5, 15)
lln <- g3_fleet('lln')

likelihood_actions <- list(
  g3l_understocking(list(ling_imm, ling_mat)))

```

params

*Gadget3 parameter helpers***Description**

Shortcuts to parameterise a model with `g3_param`

**Usage**

```

g3_parameterized(
  name,
  by_stock = FALSE,
  by_predator = FALSE,
  by_year = FALSE,
  by_step = FALSE,
  by_age = FALSE,
  by_area = FALSE,
  prepend_extra = list(),
  exponentiate = FALSE,
  avoid_zero = FALSE,
  scale = 1,
  offset = 0,
  ifmissing = NULL,
  ...)

```

**Arguments**

name	Suffix for parameter name.
by_stock	Should there be individual parameters per-stock? <b>FALSE</b> No <b>TRUE</b> Produce a "stock_name.name" parameter <b>character vector</b> Select the stock name_part(s) to use, e.g. to produce "stock_species.name" parameter with "species" <b>List of g3_stock objects</b> Produce a parameter that applies to all given stocks
by_predator	Should there be individual parameters per-predator (read: per-fleet) stock? <b>FALSE</b> No <b>TRUE</b> Produce a "fleet_stock_name.name" parameter

	<b>character vector</b> Select the stock name_part(s) to use, e.g. to produce "fleet_country.name" parameter with "country"
	<b>List of g3_stock objects</b> Produce a parameter that applies to all given stocks
by_year	Should there be individual parameters per model year? <b>FALSE</b> No <b>TRUE</b> Produce a "name.1998" parameter for each year the model runs <b>1998:2099</b> Override the year range, so when projecting there will be sufficient parameters available.
by_step	Should there be individual parameters per step within years? <b>FALSE</b> No <b>TRUE</b> Produce a "name.1" seasonal parameter for each step, or "name.1998.1" for every timestep in the model if combined with <i>by_year</i> .
by_age	Should there be individual parameters per stock age? <b>FALSE</b> No <b>TRUE</b> Produce a "name.4" parameter for each age of the stock(s) in <i>by_stock</i>
by_area	Should there be individual parameters per stock area? <b>FALSE</b> No <b>TRUE</b> Produce a "name.area" parameter for each area of the stock(s) in <i>by_stock</i>
prepend_extra	List of extra things to prepend to the parameter name. Can be a string, or a stock object. See <a href="#">stock_prepend</a> , which <i>prepend_extra</i> is passed to
ifmissing	Value to use for when there is no valid parameter (read: year when <i>by_year</i> = TRUE) Either a numeric constant or character. If character, add another parameter for ifmissing, using the same <i>by_stock</i> value.
exponentiate	Use $\exp(\text{value})$ instead of the raw parameter value. Will add "_exp" to the parameter name.
avoid_zero	If TRUE, wrap parameter with <i>avoid_zero</i>
scale	Use $\text{scale} * \text{value}$ instead of the raw parameter value. Either a numeric constant or character. If character, add another parameter for scale, using the same <i>by_stock</i> value.
offset	Use $\text{value} + \text{offset}$ instead of the raw parameter value Either a numeric constant or character. If character, add another parameter for offset, using the same <i>by_stock</i> value.
...	Additional parameters passed through to <a href="#">g3_param</a> , e.g. <i>optimise</i> , <i>random</i> , ...

### Details

The function provides shortcuts to common formulas used when parameterising a model.

### Value

A [formula](#) object defining the given parameters

### See Also

[g3\\_param](#), [g3\\_param\\_table](#), [stock\\_prepend](#)

**Examples**

```

stock_imm <- g3_stock(c(species = 'stock', 'imm'), seq(10, 35, 5)) %>% g3s_age(1, 4)
stock_mat <- g3_stock(c(species = 'stock', 'mat'), seq(10, 35, 5)) %>% g3s_age(3, 6)

# Helper function that shows the parameter template for the given parameter
param_template_for <- function (g3_param) {
  model_code <- g3_to_tmb(list(
    # g3a_naturalmortality() isn't important, it is a place to add our parameter
    g3a_naturalmortality(stock_imm, g3_param),
    # We also need stock_mat in the model at least once
    g3a_naturalmortality(stock_mat, 0),

    # Set a year range to use for parameters where relevant
    g3a_time(1990, 1994) ))

  # Extract template, throw away default parameters from g3a_time()
  params <- attr(model_code, "parameter_template")
  params <- params[!(rownames(params) %in% c('retro_years', 'project_years')),]
  return(params)
}

# Not 'by' anything, so we add a single parameter value
param_template_for( g3_parameterized('K') )

# Can set defaults for the parameter template when defining a parameter
param_template_for( g3_parameterized('K', value = 5, lower = 2,
  upper = 8, optimise = FALSE) )

# by_stock, so the parameters will have the stock name prepended
param_template_for( g3_parameterized('K', by_stock = TRUE) )

# Similarly, we can prepend year & age
param_template_for( g3_parameterized('K', by_stock = TRUE, by_year = TRUE, by_age = TRUE) )

# You can specify the name part to use,
# e.g. if a parameter should be shared between mature and immature:
param_template_for( g3_parameterized('K', by_stock = 'species', by_year = TRUE) )

# Can give a list of stocks, in which case it works out name parts for you
param_template_for( g3_parameterized('K', by_stock = list(stock_imm, stock_mat)) )
param_template_for( g3_parameterized('K', by_stock = list(stock_imm, stock_mat), by_age = TRUE) )

# If there are no shared name parts, then all names will be added
param_template_for( g3_parameterized(
  'btrigger',
  by_stock = list(g3_fleet("surv"), g3_fleet("comm"))) )

# You can set fixed scale/offset for the parameter
g3_parameterized('K', scale = 5, offset = 9)

# ...or give names and they will also be parameters, sharing the by_stock setting
param_template_for( g3_parameterized('K', by_stock = TRUE, scale = "sc", offset = "offs") )

```

---

param_project	<i>Gadget3 projected parameters</i>
---------------	-------------------------------------

---

### Description

Add time-based random deviates / projections

### Usage

```

g3_param_project_dlnorm(
  lmean_f = g3_parameterized("proj.dlnorm.lmean",
    value = 0, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  lstddev_f = g3_parameterized("proj.dlnorm.lstddev",
    value = 1e5, optimise = FALSE,
    prepend_extra = quote(param_name) ))

g3_param_project_dnorm(
  mean_f = g3_parameterized("proj.dnorm.mean",
    value = 0, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  stddev_f = g3_parameterized("proj.dnorm.stddev",
    value = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ))

g3_param_project_rwalk(
  mean_f = g3_parameterized("proj.rwalk.mean",
    value = 0, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  stddev_f = g3_parameterized("proj.rwalk.stddev",
    value = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ))

g3_param_project_ar1(
  phi_f = g3_parameterized(
    "proj.ar1.phi",
    value = 0.8, lower = 0, upper = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  stddev_f = g3_parameterized(
    "proj.ar1.stddev",
    value = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  level_f = g3_parameterized(
    "proj.ar1.level",
    value = -1, optimise = FALSE,

```

```

prepend_extra = quote(param_name) ))

g3_param_project_logar1(
  logphi_f = g3_parameterized(
    "proj.logar1.logphi",
    value = 0.8, lower = 0, upper = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  lstddev_f = g3_parameterized(
    "proj.logar1.lstddev",
    value = 1, optimise = FALSE,
    prepend_extra = quote(param_name) ),
  loglevel_f = g3_parameterized(
    "proj.logar1.loglevel",
    value = -1, optimise = FALSE,
    prepend_extra = quote(param_name) ))

g3_param_project(
  param_name,
  project_fs = g3_param_project_rwalk(),
  by_step = TRUE,
  by_stock = FALSE,
  weight = g3_parameterized(
    paste("proj", project_fs$name, param_name, "weight", sep = "_"),
    optimise = FALSE, value = 1),
  scale = 1,
  offset = 0,
  random = TRUE )

```

## Arguments

mean_f, stddev_f, phi_f, lmean_f, lstddev_f, logphi_f	mean / stddev in normal / logspace used for both the likelihood of deviates & to project future values. Defaults to parameters with names (by_stock).(param_name).proj.(mean stddev)
level_f, loglevel_f	(logspace) level (or offset) applied on top of ar1/logar1 regression. If negative, use the mean of the last (x) non-projection values as (log)level. Defaults to parameter with name (by_stock).(param_name).proj.(level loglevel), which itself defaults to -1 (i.e. use the last non-projection value)
param_name	Character string used to name the parameters.
project_fs	Results of either <a href="#">g3_param_project_dnorm</a> , <a href="#">g3_param_project_rwalk</a> .
by_step	Boolean, generate per-step or per-year values.
by_stock	Prepend stock name to the projection variable, i.e. <i>param_name</i> . Unlike <a href="#">g3_parameterized</a> , can only be FALSE or <a href="#">g3_stock</a> objects, TRUE or "species" isn't supported.
weight	A weighting to give to the likelihood when generating total nll.
scale, offset	Number, formula or string. Scale / offset to add to parameter values. If string, then the scale/offset will also be a parameter, equivalent to setting scale = <code>g3_parameterized(c(param_name, "proj", "scale"))</code> .

**random** Boolean, tell TMB to treat the deviates as random variables by default. Can be changed in the parameter template.

### Details

The actions will define the following variables in your model, which could be reported with [g3a\\_report\\_history](#):

**proj\_(dnorm|rwalk)\_(param\_name)\_\_var** Vector of all values, both parameters & projected, by time

**proj\_(dnorm|rwalk)\_(param\_name)\_\_nll** Likelihood of each value

### Value

**g3\_param\_project\_dlnorm:** Returns a "nll" & "project" [formula](#) objects for use as *project\_fs*. The functions compare / generate normally-distributed deviates around a mean, i.e:

$$V_t = \epsilon_{M - \frac{\epsilon^{2 \cdot \Sigma}}{2}, \Sigma}$$

$$v = \exp(V)$$

*M* *lmean\_f* / (by\_stock) . (param\_name) . proj . lmean parameter

*Σ* *lstddev\_f* / (by\_stock) . (param\_name) . proj . lstddev parameter

$\epsilon_{\mu, \sigma}$  Normally distributed noise generated using [rnorm](#)

*v* Output time series

**nll** Compare values against `dnorm(x, mean_f, stddev_f)`

**proj** Generate new values with `rnorm(mean_f, stddev_f)`

**g3\_param\_project\_dnorm:** Returns a "nll" & "project" [formula](#) objects for use as *project\_fs*. The functions compare / generate log-normal deviates around a mean, i.e:

$$v_t = \epsilon_{\mu, \sigma}$$

$\mu$  *mean\_f* / (by\_stock) . (param\_name) . proj . mean parameter

$\sigma$  *stddev\_f* / (by\_stock) . (param\_name) . proj . stddev parameter

$\epsilon_{\mu, \sigma}$  Normally distributed noise generated using [rnorm](#)

*v* Output time series

**nll** Compare values against `dnorm(x, mean_f, stddev_f)`

**proj** Generate new values with `rnorm(mean_f, stddev_f)`

**g3\_param\_project\_rwalk:** Returns a "nll" & "project" [formula](#) objects for use as *project\_fs*. The functions compare / generate to a random walk, i.e:

$$v_t = v_{t-1} + \epsilon_{\mu, \sigma}$$

$\mu$  *mean\_f* / (by\_stock) . (param\_name) . proj . mean parameter

$\sigma$  *stddev\_f* / (by\_stock) . (param\_name) . proj . stddev parameter

$\epsilon_{\mu, \sigma}$  Normally distributed noise generated using [rnorm](#)

*v* Output time series

**nll** Compare difference between values  $dnorm(x, mean\_f, stddev\_f)$

**proj** Generate new values with a delta of  $rnorm(mean\_f, stddev\_f)$

**g3\_param\_project\_ar1:** Returns a "nll" & "project" [formula](#) objects for use as *project\_fs*.

The functions compare / generate a AR1 process projecting from any existing values, i.e:

$$v_t = \phi v_{t-1} + (1 - \phi)\theta + \epsilon_{0,\sigma}$$

$\phi$  *phi\_f* / (by\_stock). (param\_name).proj.phi parameter

$\theta$  *level\_f* / (by\_stock). (param\_name).proj.level parameter

$\sigma$  *stddev\_f* / (by\_stock). (param\_name).proj.stddev parameter

$\epsilon_{\mu,\sigma}$  Normally distributed noise generated using [rnorm](#)

*v* Output time series

**g3\_param\_project\_logar1:** Returns a "nll" & "project" [formula](#) objects for use as *project\_fs*.

The functions compare / generate a log-AR1 process projecting from any existing values, i.e:

$$V_t = \Phi V_{t-1} + (1 - \Phi)\Theta + \epsilon_{0 - \frac{\epsilon^2 * \Sigma}{2}, \Sigma}$$

$$v = exp(V)$$

$\Phi$  *logphi\_f* / (by\_stock). (param\_name).proj.logphi parameter

$\Theta$  *loglevel\_f* / (by\_stock). (param\_name).proj.loglevel parameter

$\Sigma$  *lstddev\_f* / (by\_stock). (param\_name).proj.lstddev parameter

$\epsilon_{\mu,\sigma}$  Normally distributed noise generated using [rnorm](#)

*v* Output time series

**g3\_param\_project:** Returns a [formula](#) to choose the current value from the `__var` vector.

An extra G3 action will:

1. Populate the array with random deviates from parameters (see examples)
2. Project for any projection years (see [g3a\\_time](#))
3. Add likelihood comparing random deviates to expected values

**g3l\_sparsesample\_sumsquares:** Returns a [formula](#) for use as *function\_f*:

$$\sum_i^{rows} w \left( \frac{\nu_i}{P_i} - N_i \right)^2$$

$N_i$  "mean" column from *obs\_df*

$\nu_i$  Total predicted values, i.e. *nll\_spabund\_name\_\_model\_sum*

$P_i$  Number of data points, i.e. *nll\_spabund\_name\_\_model\_n*

*w* *weighting* parameter, either:

1.  $1/\sigma^2$ , using stddev of model predicted values if *weighting* = "model\_stddev"
2.  $1/\sigma^2$ , using stddev column from *obs\_df* if *weighting* = "obs\_stddev"
3. A custom formula provided for *weighting*

## See Also

[g3a\\_time](#) [g3\\_parameterized](#)

**Examples**

```

st <- list(
  imm = g3_stock(c("fish", maturity = "imm"), c(10, 20, 30)),
  mat = g3_stock(c("fish", maturity = "mat"), c(10, 20, 30)) )
st2 <- g3_stock("other", c(10, 20, 30))

# Set up a projected parameter to share over both stocks
st_Mdn <- g3_param_project(
  "Mdn",
  g3_param_project_dnorm(),
  # Append common part of stock names to parameter name
  by_stock = st )

actions <- list(
  g3a_time(1990, 1994, c(6,6)),
  g3a_initialconditions(st$imm,
    quote( 100 + stock__minlen ),
    quote( 1e4 + 0 * stock__minlen ) ),
  g3a_initialconditions(st$mat,
    quote( 100 + stock__minlen ),
    quote( 1e4 + 0 * stock__minlen ) ),
  g3a_initialconditions(st2,
    quote( 100 + stock__minlen ),
    quote( 1e4 + 0 * stock__minlen ) ),

  # Natural mortality with per-step deviates
  g3a_naturalmortality(st$imm, g3a_naturalmortality_exp(st_Mdn)),
  g3a_naturalmortality(st$mat, g3a_naturalmortality_exp(st_Mdn)),

  # Natural mortality with per-year random walk
  g3a_naturalmortality(st2, g3a_naturalmortality_exp(
    g3_param_project(
      "Mrw",
      g3_param_project_rwalk(),
      # The same value will be used for each step
      by_step = FALSE,
      # by_stock means the stock name will be included in parameter names
      by_stock = st2 ))) ,
  NULL )

model_fn <- g3_to_r(c(actions, list(
  g3a_report_history(actions, 'proj.*', out_prefix = NULL),
  NULL )))

# Mdn has a parameter for each year/step, as well as mean/sd (added above) & likelihood weighting
grep("^fish.Mdn", names(attr(model_fn, 'parameter_template')), value = TRUE)

# Mrw has parameters for each year
grep("^other.Mrw", names(attr(model_fn, 'parameter_template')), value = TRUE)

attr(model_fn, 'parameter_template') |>
  g3_init_val("stst.Mdn.#.#", 0.5, lower = 0.1, upper = 0.9, random = TRUE) |>

```

```

g3_init_val("stst.Mdn.proj.dnorm.lmean", 0.1) |>
g3_init_val("stst.Mdn.proj.dnorm.lstddev", 0.001) |>

g3_init_val("other.Mrw.proj.rwalk.mean", 0) |>
g3_init_val("other.Mrw.proj.rwalk.stddev", 0.001) |>
g3_init_val("other.Mrw.#", 0.5, lower = 0.1, upper = 0.9, random = TRUE) |>

# Project forwards 20 years
g3_init_val("project_years", 20) |>

# Don't include projections in nll calculations:
# allows a stddev to be supplied for projections, but estimated freely
g3_init_val("proj_rwalk_fish_Mrw_weight", 0) |>
g3_init_val("proj_dnorm_fish_Mdn_weight", 0) |>

identity() -> params
r <- attributes(model_fn(params))

# Values used for dnorm
plot(r$proj_dnorm_fish_Mdn__var)

# Values used for random walk
plot(r$proj_rwalk_other_Mrw__var)

### Plot values for an individual projection function

actions <- list( g3a_time(1990, 1991), g3_param_project("M", g3_param_project_dlnorm()) )
model_fn <- g3_to_r(c(actions, list(
  g3a_report_history(actions, 'proj_.*', out_prefix = NULL),
  NULL )))

attr(model_fn, 'parameter_template') |>
g3_init_val("M.proj.dlnorm.lmean", log(20)) |>
g3_init_val("M.proj.dlnorm.lstddev", log(1e-6)) |>
g3_init_val("M.#.#", 20) |>

g3_init_val("project_years", 100) |>

identity() -> params

par(mfrow=c(3, 1))
plot(attr(model_fn(params) |>
  g3_init_val("M.proj.dlnorm.lstddev", log(1.001)) ), "proj_dlnorm_M__var"), ylim = c(15, 25))
plot(attr(model_fn(params) |>
  g3_init_val("M.proj.dlnorm.lstddev", log(1e-1)) ), "proj_dlnorm_M__var"), ylim = c(15, 25))
plot(attr(model_fn(params) |>
  g3_init_val("M.proj.dlnorm.lstddev", log(1e-2)) ), "proj_dlnorm_M__var"), ylim = c(15, 25))

```

## Description

Add projected fishing quotas / MSE

## Usage

```
g3_quota_hockeyfleet(
  predstocks,
  preystocks,
  preyprop_fs = 1,
  btrigger = g3_parameterized("hf.btrigger", by_stock = predstocks),
  harvest_rate = g3_parameterized("hf.harvest_rate", by_stock = predstocks),
  stddev = g3_parameterized("hf.stddev", by_stock = predstocks, value = 0) )
```

```
g3_quota_assess(
  predstocks,
  preystocks,
  assess_f,
  unit = c("biomass-year", "biomass", "harvest-rate", "harvest-rate-year",
           "individuals", "individuals-year"))
```

```
g3_quota(
  function_f,
  quota_name = attr(function_f, 'quota_name'),
  year_length = 1L,
  start_step = 1L,
  interim_value = NULL,
  run_revstep = -1,
  run_f = TRUE,
  run_at = g3_action_order$quota )
```

## Arguments

predstocks, preystocks	Lists of <a href="#">g3_stock</a> objects to represent the predators/fleets and prey when forming the quota.
preyprop_fs	A <a href="#">formula</a> or list of formulas representing the proportion of that prey that makes up the Spawning Stock Biomass (SSB). The proportions do not need to sum to 1, for example you may use <code>preyprop_fs = 0.4</code> to assume that 40% of the spawning stock biomass is made up of that prey. Using a suitability function is also supported, e.g. <a href="#">g3_suitability_exponential150</a> .
btrigger	Trigger biomass, see <a href="#">formula</a>
harvest_rate	Harvest rate, see <a href="#">formula</a>
stddev	If > 0, then apply log-normal noise to the output quota.
assess_f	A <a href="#">formula</a> that runs an assessment model & returns a quota. See vignette <a href="#">TODO</a> :
unit	A single string representing the unit of the value that <code>assess_f</code> returns.
function_f	Output of one of the <code>g3_quota_*</code> functions, responsible for choosing the next quota

quota_name	A name used to refer to the quota internally, by default a combination of the quota function and the stocks used.
year_length	The length of the <i>fishing year</i> , in years, see details.
start_step	The initial step of the <i>fishing year</i> , in model steps, see details. This can be used to offset the fishing year from the calendar year for, if your fishing year should run autumn–autum. It can also offset from the start of the model, if your model starts at 1998 and your fishing year should run 2000–2005.
run_revstep	A negative integer, defining which step in the <i>fishing year</i> an assessment for next year is performed. If NULL, run every step.
run_f	When the quota should be recalculated, in addition to any condition defined by <i>run_revstep</i> .
interim_value	A formula that provides the interim value to bridge the gap between historical landings & projected quota values, see examples.
run_at	Integer order that actions will be run within model, see <a href="#">g3_action_order</a> .

### Details

**Variables defined in your model:** Once added the following variables can be reported:

**quota\_quota\_name\_\_var** A vector of quota values, one per *fishing year* in your model, see [quota\\_hockeyfleet\\_fl\\_\\_var](#) in example below

**Fishing year:** Instead of generating a quota per calendar year or step, as we do with other projections, quotas are per fishing year.

The schedule of the fishing calendar is defined with:

**year\_length** The length of the fishing year, in years. If > 1, the same yearly quota will be used for all years

**start\_step** Offset of the initial fishing year, in model steps. So you can both start your fishing year in autumn, and have a fishing year that is offset against the model start year

**run\_revstep** The step in the fishing year that the quota for the next year should be calculated

In addition, [g3a\\_predate\\_catchability\\_project](#) will allow you to assign proportions of a quota to model steps.

Examples:

year\_length = 2, start\_step = 3, run\_revstep = -2 A 2 year fishing calendar, i.e. a quota will be calculated every other year and the same value used for the next 2 years. Assuming 4 model steps, the quota will be calculated in winter for the next fishing year in summer.

year\_length = 5, start\_step = 4 \* 2 A 5 year fishing calendar, the quota will be recalculated every 5 years in the autumn (the final step before the next fishing year starts). If our model starts at 1998 and have 4 steps, 4 \* 2 means our first full fishing year is 2000–2005.

### Value

**g3\_quota\_hockeyfleet:** A formula for use in [g3\\_quota](#)

$$H\left(\sum_{predators} \sum_{preys} S_{p,p} P_p\right) \min\max\left(\sum_{preys} \frac{B_p}{T}, 0, 1\right)$$

$H$  Harvest rate, provided by *harvest\_rate* argument, by default the `hf.harvest_rate` parameter  
 $T$  Trigger biomass, provided by *btrigger* argument, by default the `hf.btrigger` parameter  
 $P_p$  Prey proportion, provided by *preyprop\_fs* (i.e. the proportion of the prey stock that can be considered part of the spawning stock)  
 $S_{p,p}$  Total suitable biomass for predator/prey combination  
 $B_p$  Total abundance of prey in biomass

**g3\_quota\_assess:** A formula for use in `g3_quota`

**g3\_quota:** A formula for use in `g3a_predate_catchability_project`

### See Also

[g3a\\_predate\\_catchability\\_project](#)

### Examples

```
st <- g3_stock("st", c(10))
fl <- g3_fleet('fl')

# Define quota for the fleet, with an assessment in spring, application in autumn
fl_quota <- g3_quota(
  g3_quota_hockeyfleet(list(fl), list(st), preyprop_fs = 1),
  start_step = 4L,
  run_revstep = -2L )

actions <- list(
  g3a_time(1990, 1995, c(3,3,3,3)),
  # Define st with steadily collapsing stock
  g3a_otherfood(st, num_f = g3_timeareadata('st_abund', data.frame(
    year = 1990:2050,
    abund = 1e6 - 1e4 * seq(0, 2050-1990)), "abund"), wgt_f = 10),
  # Fleet predates stock
  g3a_predate(
    fl,
    list(st),
    suitabilities = 0.8,
    catchability_f = g3a_predate_catchability_project(
      # Use the quota when projecting, otherwise use landings parameters
      fl_quota,
      g3_parameterized("landings", value = 0, by_year = TRUE, by_predator = TRUE) ),
    NULL )
)
model_fn <- g3_to_r(c(actions,
  g3a_report_detail(actions),
  g3a_report_history(actions, "__num$|__wgt$", out_prefix="dend_"), # NB: Late reporting
  g3a_report_history(actions, "quota_", out_prefix = NULL) ))

attr(model_fn, "parameter_template") |>
# Project for 30 years
g3_init_val("project_years", 30) |>
# Fishing generally occurs in spring/summer, none in winter
g3_init_val("fl.quota.step.#", c(0.0, 0.5, 0.4, 0.1)) |>
```

```

# Initial landings fixed
g3_init_val("fl.landings.#", 1e6) |>
# Hockefleet: harvest rate & trigger biomass
g3_init_val("fl.hf.harvest_rate", 0.2) |>
g3_init_val("fl.hf.btrigger", 7.2e6) |>
identity() -> params.in
r <- attributes(model_fn(params.in))

## Total biomass at assessment step, with btrigger marked
barplot(g3_array_agg(r$dend_st__num * r$dend_st__wgt, "year", step = 2), las = 2)
abline(h=7.2e6) ; abline(v=26.5)

## Quota values, inflection once total biomass falls below btrigger
par(mar = c(6, 5, 1, 0)) ; barplot(r$quota_hockeyfleet_fl__var, las = 2) ; abline(v=27.7)

## Consumption by fleet, demonstrating
## (a) fixed landings before projections (fl.landings.#)
## (b) inflection of hitting btrigger
## (c) Uneven spread of fishing effort throughout year (fl.quota.step.#)
barplot(g3_array_agg(r$detail_st_fl__cons, "time"), las = 2)

## Timing of calculations for fishing year
fl_quota <- g3_quota(
  # Our quota values are year/step at the assessment time step
  quote( cur_year * 10 + cur_step ),
  year_length = 1L,
  start_step = 4L,
  interim_value = g3_parameterized("interim_value", value = 99, optimize = FALSE),
  run_revstep = -3L )
yr <- as.integer(format(Sys.Date(), "%Y"))
actions <- list(
  g3a_time(yr - 6, yr - 1, project_years = 10, step_lengths = rep(3L, 4)),
  fl_quota,
  # At each step in the model, print the current year/step, and the quota value that will get used
  # NB: before projection, g3a_predate_catchability_project() will use landings data not the quota
  g3_step(g3_formula(
    writeLines(paste(cur_year, cur_step, if (cur_year_projection) q else "landings")),
    q = fl_quota )),
  NULL)
model_fn <- g3_to_r(c(actions,
  g3a_report_history(actions, "quota_", out_prefix = NULL) ))
attr(model_fn(), "quota__var")

```

---

run\_desc

*Gadget3 actions into R code*


---

## Description

Convert g3 actions into a character vector describing the model

**Usage**

```
g3_to_desc(actions, minor_steps = FALSE)
```

**Arguments**

`actions`            A list of actions (i.e. list of formula objects), as produced by `g3a_*` functions.  
`minor_steps`        Include minor steps (e.g. zeroing cumulative arrays)? TRUE / FALSE

**Value**

Character vector describing each step in the model. An action in a model may have generated multiple steps (e.g. select each prey stock, scale total amount, apply overstocking), and there will be a line in here for each.

**Examples**

```
ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)

initialconditions_action <- g3a_initialconditions_normalparam(
  ling_imm,
  by_age = TRUE)

# Timekeeping action
time_action <- g3a_time(
  start_year = 2000,
  end_year = 2004,
  c(3, 3, 3, 3))

# Generate a list outlining the steps the model uses
as.list(g3_to_desc(list(initialconditions_action, time_action)))
```

---

run\_r

*Gadget3 actions into R code*


---

**Description**

Convert g3 actions into an R function that can then be executed

**Usage**

```
g3_to_r(
  actions,
  work_dir = getOption('gadget3.r.work_dir', default = tempdir()),
  trace = FALSE,
  strict = FALSE,
  cmp_options = list(optimize = 3) )
```

```
## S3 method for class 'g3_r'
print(x, ..., with_environment = FALSE, with_template = FALSE)
```

### Arguments

<code>actions</code>	A list of actions (i.e. list of formula objects), as produced by <code>g3a_*</code> functions.
<code>work_dir</code>	Where to write the temporary R script containing your function
<code>cmp_options</code>	options to pass through to <code>compiler::cmpfun()</code> . If NULL, then don't run the model through the byte-code compiler
<code>trace</code>	If TRUE, turn all comments into print statements.
<code>strict</code>	If TRUE, enable extra sanity checking in actions. Any invalid conditions (e.g. more/less fish after growth) will result in a warning.
<code>x</code>	The <code>g3_to_r</code> -generated function to print
<code>with_environment</code>	If TRUE, list data stored in function environment when printing
<code>with_template</code>	If TRUE, show parameter template when printing
<code>...</code>	Other arguments

### Value

A function that takes a *params* variable, which can be:

1. A list of parameters as defined by `attr(fn, 'parameter_template')`
2. A data.frame of parameters defined by `g3_to_tmb`'s parameter template
3. Not provided, in which case the parameter defaults are used

The function will have the following attributes:

**actions** The original *actions* list given to the function

**parameter\_template** A list of all parameters expected by the model, to fill in

Use e.g. `attr(fn, 'parameter_template')` to retrieve them.

Invariant model data will be stored as a closure, i.e. in `environment(fn)`. This can be fetched with `environment(fn)$cdist_sumofsquares_ldist_gil_obs__num`.

The function will return *nll* produced by the model. You can also use `attributes(nll)` to get any report variables from the model.

### Examples

```
ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4)) %>% g3s_age(3, 10)
```

```
initialconditions_action <- g3a_initialconditions_normalparam(
  ling_imm,
  factor_f = g3a_renewal_initabund(by_stock_f = 'species'),
  by_stock = 'species',
  by_age = TRUE)
```

```

# Timekeeping action
time_action <- g3a_time(
  start_year = 2000,
  end_year = 2004,
  c(3, 3, 3, 3))

# Generate a model from the above 2 actions
# NB: Obviously in reality we'd need more actions
fn <- g3_to_r(list(initialconditions_action, time_action))

if (interactive()) {
  # Edit the resulting function
  fn <- edit(fn)
}

param <- attr(fn, 'parameter_template')
param$project_years <- 0
param$ling.init.F <- 0.4
param$ling.Linf <- 160
param$ling.K <- 90
param$ling.recl <- 12
param$recage <- g3_stock_def(ling_imm, 'minage')
param[grepl('^ling.init.sd.', names(param))] <- 50.527220
param[grepl('^ling_imm.init.\\d+', names(param))] <- 1
param$ling_imm.init.scalar <- 200
param$ling_imm.walpha <- 2.27567436711055e-06
param$ling_imm.wbeta <- 3.20200445996187
param$ling_imm.M <- 0.15

# Run the model with the provided parameters
nll <- fn(param)

# Get the report from the last model run
report <- attributes(nll)

# Fetch a value from the model data
environment(fn)$ling_imm__midlen

```

---

run\_tmb

*Gadget3 actions into TMB code*


---

## Description

Turn g3 actions into CPP code that can be compiled using TMB

## Usage

```
g3_to_tmb(actions, trace = FALSE, strict = FALSE)
```

```

g3_tmb_adfun(
  cpp_code,
  parameters = attr(cpp_code, 'parameter_template'),
  compile_flags = getOption('gadget3.tmb.compile_flags', default =
    if (.Platform$OS.type == "windows") c("-O1", "-march=native")
    else c("-O3", "-flto=auto", "-march=native") ),
  work_dir = getOption('gadget3.tmb.work_dir', default = tempdir()),
  output_script = FALSE,
  compile_args = list(
    framework = getOption("gadget3.tmb.framework", default = "TMBad") ),
  ...)

g3_tmb_par(parameters, include_random = TRUE)

g3_tmb_lower(parameters)

g3_tmb_upper(parameters)

g3_tmb_parscale(parameters)

g3_tmb_relist(parameters, par)

```

## Arguments

actions	A list of actions (i.e. list of formula objects), as produced by <code>g3a_*</code> functions.
trace	If TRUE, turn all comments into print statements.
strict	If TRUE, enable extra sanity checking in actions. Any invalid conditions (e.g. more/less fish after growth) will result in a warning.
cpp_code	<code>cpp_code</code> as produced by <code>g3_to_tmb</code> .
parameters	Parameter table as produced by <code>attr(g3_to_tmb(...), 'parameter_template')</code> , modified to provide initial conditions, etc.
par	Parameter vector, as produced by one of <ol style="list-style-type: none"> <li><code>nlminb(...)\$par</code></li> <li><code>obj.fun\$env\$last.par</code></li> <li><code>g3_tmb_par()</code></li> </ol> The first will not include random parameters by default, the others will.
include_random	Should random parameters assumed to be part of <code>par</code> ? Should be TRUE if using <code>obj.fun\$fn</code> , <code>obj.fun\$report</code> directly, e.g. <code>obj.fun\$fn(g3_tmb_par(param_tbl))</code> . In other cases, FALSE.
compile_flags	List of extra flags to compile with, use e.g. "-g" to enable debugging output. Can be set with an option, e.g. <code>options(gadget3.tmb.compile_flags = c('-O0', '-g'))</code>
compile_args	Any other arguments to pass to <a href="#">TMB::compile</a>

work_dir	Directory to write and compile .cpp files in. Defaults to R's current temporary directory. Set this to preserve compiled output and re-use between R sessions if possible. Can be set with an option, e.g. <code>options(gadget3.tmb.work_dir = fs::path_abs('tmb-workdir'))</code>
output_script	If TRUE, create a temporary R script that runs <code>MakeADFun</code> , and return the location. This can then be directly used with <code>gdbsource</code> or <code>callr::rscript</code> .
...	Any other options handed directly to <code>MakeADFun</code>

### Details

**g3\_tmb\_adfun:** `g3_tmb_adfun` will do both the `compile` and `MakeADFun` steps of making a model. If the code is identical to an already-loaded model then it won't be recompiled, so repeated calls to `g3_tmb_adfun` to change `parameters` are fast.

If `MakeADFun` is crashing your R session, then you can use `output_script` to run in a separate R session. Use this with `gdbsource` to debug your model.

### Value

**g3\_to\_tmb:** A string of C++ code that can be used as an input to `g3_tmb_adfun`, with the following attributes:

**actions** The original `actions` list given to the function

**model\_data** An environment containing data attached to the model

**parameter\_template** A data.frame to be filled in and used as `parameters` in the other `g3_tmb_*` functions

Use e.g. `attr('cpp_code', 'parameter_template')` to retrieve them.

**g3\_tmb\_adfun:** An ADfun as produced by TMB's `MakeADFun`, or location of temporary script if `output_script` is TRUE

**g3\_tmb\_par:** Values extracted from `parameters` table converted into a vector of values for `obj$fn(par)` or `nlminb`

**g3\_tmb\_lower:** Lower bounds extracted from `parameters` table converted into a vector of values for `nlminb`. Random parameters are always excluded

**g3\_tmb\_upper:** Lower bounds extracted from `parameters` table converted into a vector of values for `nlminb`. Random parameters are always excluded

**g3\_tmb\_parscale:** Parscale extracted from `parameters` table, converted into a vector of values for `nlminb`. Random parameters are always excluded

**g3\_tmb\_relist:** The `parameters` table value column, but with optimised values replaced with contents of `par` vector. i.e. the inverse operation to `g3_tmb_par`. `par` can either include or discount random variables.

**Examples**

```

ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4)) %>% g3s_age(3, 10)

initialconditions_action <- g3a_initialconditions_normalparam(
  ling_imm,
  factor_f = g3a_renewal_initabund(by_stock_f = 'species'),
  by_stock = 'species',
  by_age = TRUE)

abundance_action <- g3l_abundancedistribution(
  'abundance',
  data.frame(year = 2000:2004, number = 100),
  stocks = list(ling_imm),
  function_f = g3l_distribution_sumofsquares())

# Timekeeping action
time_action <- g3a_time(
  start_year = 2000,
  end_year = 2004,
  c(3, 3, 3, 3))

# Generate a model from the above 2 actions
# NB: Obviously in reality we'd need more actions
cpp <- g3_to_tmb(list(initialconditions_action, abundance_action, time_action))

if (interactive()) {
  # Edit the resulting code
  cpp <- edit(cpp)
}

# Set initial conditions for parameters
attr(cpp, 'parameter_template') |>
  g3_init_val("project_years", 0) |>
  g3_init_val("ling.init.F", 0.4) |>
  g3_init_val("ling.Linf", 160) |>
  g3_init_val("ling.K", 90) |>
  g3_init_val("ling.t0", 0) |>
  g3_init_val("ling.init.sd.#", 50.527220) |>
  g3_init_val("ling_imm.init.#", 1, lower = 0, upper = 1000) |>
  g3_init_val("ling_imm.init.scalar", 200) |>
  g3_init_val("ling_imm.walpha", 2.275e-06) |>
  g3_init_val("ling_imm.wbeta", 3.2020) |>
  g3_init_val("ling*.M.#", 0.15) |>
  identity() -> tmb_param

if (!(nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # Compile to a TMB ADFun
  tmb <- g3_tmb_adfun(cpp, tmb_param)
}

```

```

# NB: TMB::gdbsource() requires both "R" and "gdb" to be available
# NB: gdbsource hangs on windows - https://github.com/kaskr/adcomp/issues/385
if (all(nzchar(Sys.which(c('gdb', 'R')))) && .Platform$OS.type != "windows") {

  cpp_broken <- g3_to_tmb(list(
    initialconditions_action,
    abundance_action,
    g3_formula(quote( stop("This model is broken") )),
    time_action))

  # Build the model in an isolated R session w/debugger
  writelines(TMB::gdbsource(g3_tmb_adfun(
    cpp_broken,
    compile_flags = "-g",
    output_script = TRUE)))

}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # Perform a single run, using values in table
  result <- tmb$fn(g3_tmb_par(tmb_param))
}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # perform optimisation using upper/lower/parscale from table
  fit <- optim(tmb$par, tmb$fn, tmb$gr,
    method = "L-BFGS-B",
    upper = g3_tmb_upper(tmb_param),
    lower = g3_tmb_lower(tmb_param),
    control = list(maxit=10, parscale=g3_tmb_parscale(tmb_param)))
}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # perform optimisation without bounds
  fit <- optim(tmb$par, tmb$fn, tmb$gr)
}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # Go back to a list of parameters, suitable for the R version
  # NB: This will not set the values for random parameters
  param_list <- g3_tmb_relist(tmb_param, fit$par)
}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # Update parameters with values from last run, *including* random parameters.
  param_list <- g3_tmb_relist(tmb_param, tmb$env$last.par)
}

if (!( nzchar(Sys.getenv('GITHUB_CI')) && .Platform$OS.type == "windows" )) {
  # Rebuild, only including "Fun" (i.e. without auto-differentiation)
  # Result will only work for tmb$report
  tmb <- g3_tmb_adfun(cpp, tmb_param, type = "Fun")
}

```

```

result <- tmb$report(g3_tmb_par(tmb_param, include_random = TRUE))

# We can also use tmb$simulate
result <- tmb$simulate(g3_tmb_par(tmb_param, include_random = TRUE))

# NB: Before running simulations, you should use set.seed() to ensure random output
}

```

---

step

*G3 stock\_\* transformation functions*


---

### Description

Additional meta-functions to help manage writing stock-handling actions.

### Usage

```
g3_step(step_f, recursing = FALSE, orig_env = environment(step_f))
```

### Arguments

step_f	Input <a href="#">formula</a> containing references to functions below
recursing	Only use default value
orig_env	Only use default value

### Details

All action producing functions will run their output through `g3_step`. This means that the functions described here will be available in any `gadget3` code.

They handle translation of stock instance naming, so code can refer to e.g. `stock__num` without having to translate naming to the final stock name, and iterating over stock dimensions.

### Value

**g3\_step:** A [formula](#) object with references to above functions replaced.

### debug\_label

Add a comment to the code to act as a label for that step, when producing an outline of the model. There shouldn't be more than one `debug_label` call in a step.

Models compiled with `trace = TRUE` will print the resultant string to `stdout`.

**Arguments:** Any number of character strings, or [g3\\_stock](#) variables. The latter will be replaced with the final name.

**debug\_trace**

Identical to [debug\\_label](#), but not considered a "label", just a code comment, so any number of calls can be added.

**stock\_assert**

```
stock_assert(expression, message, message/stock-var, ...)
```

Assert that *expression* is true, if not abort with a message.

**stock\_reshape**

```
stock_reshape(dest_stock, expression)
```

Output *expression* with its length structure reshaped to match *dest\_stock*. The source stock is considered to be the first one found in *expression*

How this is achieved depends on the difference. If the source and destination match then this is a no-op. Otherwise a transformation matrix is generated and included into the model.

**stock\_ss**

```
stock_ss(stock_var, [ dimname = override, dimname = override, ... ][, vec = (dimname|full|single)
])
```

Subsets *stock\_var* for the current iteration of [stock\\_iterate\(\)](#).

The *vec* parameter decides the start value for all dimensions. If *full*, no other dimensions are set. If set to a *dimname*, all dimensions after that dimension are set (i.e. a *dimname*-vector will be returned). If *single*, all dimensions are set (i.e. a single value will be returned). The default is *length* if a *length* dimension is present (i.e. a *length* vector will be returned), otherwise *single*.

If *dimnames* are supplied, then the code supplied will override the above. This code can include *default*, which will be substituted for the default subset, or *missing* to represent an empty position in the subset. If a *dimname* is not present in *stock\_var*, it will be ignored.

**stock\_ssinv**

```
stock_ssinv(stock_var, [ dimname, dimname, ... ])
```

like [stock\\_ss\(\)](#), but subset only the mentioned *dimnames*.

**stock\_switch**

```
stock_switch(stock, stock_name1 = expr, stock_name2 = expr, ... [ default ])
```

Switch based on name of *stock*, returning the relevant *expr* or *default*. If no *default* supplied, then an unknown stock is an error.

*expr* is implicitly wrapped with [stock\\_with](#)(*stock*, ...), so any references to the stock variable will work. If only *default* is provided, then this is identical to calling [stock\\_with](#).

**stock\_with**

```
stock_with(stock, expr)
```

Replaced with *expr* but with all stock variables of *stock* renamed with their final name. This is generally needed when not iterating over a stock, but e.g. zeroing or summing the whole thing.

**stock\_iterate**

```
stock_iterate(stock, expr)
```

Wrap *expr* with the code to iterate over vector dimensions in *stock*, accessed using `stock_ss(stock)`.

Which dimensions are iterated over is decided based on the call to `stock_ss(stock)`. By default, `stock_ss` leaves length blank so will iterate over a length vector for each dimension.

You can iterate over each value individually with the following: `stock_iterate(stock, stock_ss(stock, length = default) )`

Current values for each dimension will be available as variables, e.g. *area*, *age*, and can be used in formulae.

**stock\_intersect**

```
stock_intersect(stock, expr)
```

Wrap *expr* with the code to intersect all dimensions with the dimensions of an outer `stock_iterate()`.

**stock\_interact**

```
stock_interact(stock, expr, prefix = prefix)
```

Wrap *expr* with the code to interact with the dimensions of an outer `stock_iterate()`. Interact means to intersect over *area*, but try the combinatorial explosion of all other dimensions, i.e. what would make most sense when 2 stocks interact in a predator-prey relationship.

Additional variables will be prefixed with *prefix*.

**stock\_prepend**

```
stock_prepend(stock, param_call, name_part = NULL)
```

Converts a `g3_param` or `g3_param_table` call, prefixing the parameter name with the stock name, and renaming any references to stock variables. If *name\_part* given, will only add given part(s) of the stock name.

Returns *param\_call* with the additions made.

**Examples**

```
### debug_label
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10)
prey_stock <- g3_stock('herring', 1:3) %>% g3s_age(1,3)
g3_step("debug_trace("Zero ", stock, "-", prey_stock, " biomass-consuming counter"))

### stock_assert
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10)
```

```

g3_step(~stock_assert(stock_with(stock, all(is.finite(stock__num))), stock, "__num became NaN/Inf"))

### stock_reshape
s <- g3_stock('s', seq(3, 21, 3))
s__num <- g3_stock_instance(s, 100)
agg <- g3_stock('agg', c(3, 10, 21), open_ended = FALSE)
g3_eval(~stock_iterate(s, stock_reshape(agg, stock_ss(s__num))))

### stock_ss
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10) %>% g3s_livesonareas(1)
stock__num <- g3_stock_instance(stock)
g3_step(~stock_iterate(stock, { x <- x + stock_ss(stock__num) }))
g3_step(~stock_ss(stock__num, area = 5))
# Lengthgroups for age_idx + 1
g3_step(~stock_ss(stock__num, age = default + 1))
# Vector for the entirety of the "next" area
g3_step(~stock_ss(stock__num, area = default + 1, vec = area))
g3_step(~stock_ss(stock__num, area = , age = j))

### stock_ssinv
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10) %>% g3s_livesonareas(1)
g3_step(~g3_step(~stock_ssinv(stock, 'age')))
g3_step(~g3_step(~stock_ssinv(stock, 'area')))

### stock_switch
stock <- g3_stock('halibut', 1:10) ; fleet_stock <- g3_fleet('igfs')
g3_step(~stock_switch(stock, halibut = 2, herring = 3, -1))
g3_step(~stock_switch(fleet_stock, halibut = 2, herring = 3, -1))
g3_step(~stock_switch(stock, halibut = stock__midlen, -1))

### stock_with
stock <- g3_stock('halibut', 1:10)
g3_step(~stock_with(stock, sum(stock__num)))

### stock_iterate
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10)
g3_step(~stock_iterate(stock, x <- x + stock_ss(stock__num)))

### stock_intersect
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10)
prey_stock <- g3_stock('herring', 1:3) %>% g3s_age(1,3)
g3_step(~stock_iterate(stock, stock_intersect(pre_y_stock, {
  x <- x + stock_ss(stock__num) + stock_ss(pre_y_stock__num)
})))

### stock_interact
stock <- g3_stock('halibut', 1:10) %>% g3s_age(1,10)
prey_stock <- g3_stock('herring', 1:3) %>% g3s_age(1,3)
g3_step(~stock_iterate(stock, stock_interact(pre_y_stock, {
  x <- x + stock_ss(stock__num) + stock_ss(pre_y_stock__num)
}, prefix = "prey" )))

```

---

stock	<i>Gadget3 stock storage</i>
-------	------------------------------

---

### Description

Define multi-dimensional storage for use in models, mostly to contain state about stocks.

### Usage

```
g3_stock(var_name, lengthgroups, open_ended = TRUE)

g3_stock_instance(stock, init_value = NA, desc = "")

g3_fleet(var_name)

g3_stock_def(stock, name)

g3s_clone(inner_stock, var_name)

g3_is_stock(stock)
```

### Arguments

var_name	Prefix used for all instance variables of this stock. Can have multiple parts that will be concatenated together, see example.
lengthgroups	Vector defining length groups, each entry defining the minimum value.
open_ended	If TRUE, final <i>lengthgroups</i> value defines a group $x:Inf$ . If FALSE, final <i>lengthgroups</i> value is the upper bound for the previous group.
inner_stock	A <a href="#">g3_stock</a> or <a href="#">g3_fleet</a> object to clone.
stock	A <a href="#">g3_stock</a> or <a href="#">g3_fleet</a> . For <code>g3_stock_def</code> , can also be a list of stock objects.
init_value	Initially the array will be filled with this constant, e.g. 1, 0 or NaN
desc	Description of the array that will be included in models
name	Name of definition to extract, e.g. "minlen".

### Value

**g3\_stock:** A [g3\\_stock](#) with length groups

**g3\_stock\_instance:** An array with dimensions matching the stock.

**g3\_fleet:** A [g3\\_stock](#) without length groups

**g3\_stock\_def:** The definition of the given variable in the stock. If *stock* is a list, then a list with the definition of each will be returned.

**g3s\_clone:** A [g3\\_stock](#) with identical dimensions to *inner\_stock* but with a new name.

**g3\_is\_stock:** TRUE iff *stock* is a [g3\\_stock](#) object.

**Examples**

```

# Define a stock with 3 lengthgroups
stock <- g3_stock('name', c(1, 10, 100))

# Define a stock with a multi-part name. We can then dig out species name
stock <- g3_stock(c(species = 'ling', 'imm'), c(1, 10, 100))
stopifnot( stock$name == 'ling_imm' )
stopifnot( stock$name_parts[['species']] == 'ling' )

# Use stock_instance define storage for mean weight of stock,
# has dimensions matching what was defined above.
g3_stock_instance(stock, 1, "Mean weight")

# Can get definitions for multiple stocks in one go
stocks <- list(
  imm = g3_stock(c('st', 'imm'), 1:10),
  mat = g3_stock(c('st', 'mat'), 1:10) )
g3_stock_def(stocks, 'minlen')

# Retrieve the upperlen for the stock
g3_stock_def(stock, 'upperlen')

# Define a stock, not-open-ended. Now only 2 groups long
stock <- g3_stock('name', c(1, 10, 100), open_ended = FALSE)

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

# Fleets don't have lengthgroups
stock <- g3_fleet('name') %>% g3s_livesonareas(1)

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

```

---

stock\_age

*Gadget3 stock age dimensions*


---

**Description**

Add age dimensions to g3\_stock classes

**Usage**

```
g3s_age(inner_stock, minage, maxage)
```

```
g3s_agegroup(inner_stock, agegroups)
```

**Arguments**

inner_stock	A <a href="#">g3_stock</a> that we extend with an age dimension
minage	Minimum age to store, integer.
maxage	Maximum age to store, integer.
agegroups	(optionally named) list of vectors of ages, grouping them together.

**Value**

**g3s\_age:** A [g3\\_stock](#) with an additional 'age' dimension.

When iterating over the stock, iterate over each age in turn, *age* will be set to the current integer age.

When intersecting with another stock, only do anything if *age* is between *minage* and *maxage*.

If an age dimension already exists, it is redefined with new parameters.

**g3s\_agegroup:** A [g3\\_stock](#) with an additional 'age' dimension.

When iterating over the stock, iterate over each agegroup in turn, *age* will be set to the first age in the group.

When intersecting with another stock, only do anything if *age* is part of one of the groups.

**Examples**

```
# Define a stock with 3 lengthgroups and 3 ages
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_age(5, 10)

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

# Define a stock that groups age into "young" and "old"
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_agegroup(list(
    young = 5:7,
    old = 8:10))

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)
```

---

stock\_areas

*Gadget3 stock area dimensions*


---

**Description**

Add area dimensions to [g3\\_stock](#) classes

**Usage**

```
g3_areas(area_names)

g3s_livesonareas(inner_stock, areas)

g3s_areagroup(inner_stock, areagroups)
```

**Arguments**

area_names	A character vector of area names to use in the model
inner_stock	A <a href="#">g3_stock</a> that we extend with an area dimension
areas	A vector of numeric areas that the stock is part of
areagroups	A list mapping names to vectors of numeric areas the stock is part of

**Details**

`g3s_livesonareas` breaks up a stock by area. Within a model, areas are only referred to by integer, however if these are named then that name will be used for report output.

Each area will be defined as a variable in your model as `area_x`, allowing you to use names in formulas, e.g. `run_f = quote( area == area_x )`.

`g3_areas` is a helper to map a set of names to an integer

Inside a model each area will only be referred to by integer.

`g3s_areagroup` allows areas to be combined, this is mostly used internally by [g3l\\_catchdistribution](#).

**Value**

**g3\_areas:** A named integer vector, assigning each of `area_names` a number.

**g3s\_livesonareas:** A [g3\\_stock](#) with an additional 'area' dimension.

When iterating over the stock, iterate over each area in turn, `area` will be set to the current integer area.

When intersecting with another stock, only do anything if `area` is also part of our list of areas.

**g3s\_areagroup:** A [g3\\_stock](#) with an additional 'area' dimension.

When iterating over the stock, iterate over each areagroup in turn, `area` will be set to the first area in the group.

When intersecting with another stock, only do anything if `area` is part of one of the groups.

**Examples**

```
# Make a lookup so we can refer to areas by name
area_names <- g3_areas(c('a', 'b', 'c', 'd', 'e'))
stopifnot(area_names == c(a=1, b=2, c=3, d=4, e=5))

# Define a stock with 3 lengthgroups and 3 areas
```

```

stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_livesonareas(area_names[c('a', 'b', 'c')])

# Area variables will be defined, so you can refer to them in formulas:
g3a_migrate(stock, g3_parameterized("migrate_spring"),
  run_f = ~area == area_b && cur_step == 2)

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

# Define a stock that groups areas into "north" and "south"
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_areagroup(list(
    north = area_names[c('a', 'b', 'c')],
    south = area_names[c('d', 'e')]))

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

```

---

stock\_tag

*Gadget3 tag dimension*


---

## Description

Add tag dimensions to `g3_stock` classes

## Usage

```
g3s_tag(inner_stock, tag_ids, force_untagged = TRUE)
```

## Arguments

`inner_stock` A `g3_stock` that we extend with an area dimension

`tag_ids` A vector of numeric tags the stock can have, generated by `seq_along`, e.g. Tag ID 0 is considered to be "untagged".

`force_untagged` If TRUE, if "untagged" tag 0 isn't present it will be added.

## Value

**g3s\_tag:** A `g3_stock` with an additional 'tag' dimension.

When iterating over the stock, iterate over each tag in turn, `tag` will be set to the current integer area.

When interacting with another stock, iterate over each tag in turn, the variable name will depend on the scenario, e.g. `prey_tag`.

## Examples

```
# Make a lookup of text names to integers
tags <- c('H1-00', 'H1-01')
tags <- structure(seq_along(tags), names = tags)

# prey_a can have any of these tags
prey_a <- g3_stock('prey_a', seq(1, 10)) %>% g3s_tag(tags)

# Use stock_instance to see what the array would look like
g3_stock_instance(prex_a)
```

---

stock_time	<i>Gadget3 stock time dimensions</i>
------------	--------------------------------------

---

## Description

Add time dimensions to `g3_stock` classes

## Usage

```
g3s_time_convert(year_or_time, step = NULL)

g3s_time(inner_stock, times, year = NULL, step = NULL)
```

## Arguments

year_or_time	Etiher vector of years, or vector of year & step strings, e.g. "1999-01".
year	Vector of years, used to generate <i>times</i> if provided.
step	Vector of steps, used to generate <i>times</i> if provided.
inner_stock	A <code>g3_stock</code> that we extend with a time dimension
times	A vector of year/step integers as generated by <code>g3s_time_convert</code>

## Value

**g3s\_time\_convert:** A single integer vector representing *year* and *step*.

If *step* is `NULL`, returns *year*, otherwise  $year * 1000 + step$ .

**g3s\_time:** A `g3_stock` with an additional 'time' dimension.

If *year/step* provided, time is defined by those, otherwise *times*.

The `g3_stock` will not support iterating, only intersecting.

When intersecting with another stock, only do anything if *cur\_year* and *cur\_step* matches a time stored in the vector

**Examples**

```

# Define a stock with 3 lengthgroups and 3 years, not continuous
# When used, all steps within a year will be aggregated, year 2002 will be ignored.
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_time(year = c(2000, 2001, 2003))

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

# Define a stock with 3 lengthgroups and 3 years, 2 steps
# The dimension will have 6 entries, 2000.1, 2000.2, 2001.1, 2001.2, 2002.1, 2002.2
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_time(year = c(2000, 2001, 2002), step = 1:2)

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

# g3s_time_convert is best used with a data.frame
data <- read.table(header = TRUE, text = '
year step
2001 1
2001 2
# NB: No "2002 1"
2002 2
')
stock <- g3_stock('name', c(1, 10, 100)) %>%
  g3s_time(times = g3s_time_convert(data$year, data$step))

# Will also parse strings
g3s_time_convert(c("1999-01", "1999-02"))

# Use stock_instance to see what the array would look like
g3_stock_instance(stock)

```

---

suitability

*Gadget3 suitability formulae*


---

**Description**

Formula-returning functions describing length suitability relationships.

**Usage**

```

g3_suitability_exponential150(
  alpha = g3_parameterized("alpha", by_stock = by_stock, by_predator = by_predator),
  l50 = g3_parameterized("l50", by_stock = by_stock, by_predator = by_predator),
  by_stock = TRUE,
  by_predator = TRUE)

```

```

g3_suitability_andersen(p0, p1, p2, p3 = p4, p4, p5 = quote( predator_length ))

g3_suitability_andersenfleet(
  p0 = g3_parameterized('andersen.p0', value = 0, optimise = FALSE,
                        by_stock = by_stock),
  p1 = g3_parameterized('andersen.p1', value = log(2),
                        by_stock = by_stock, by_predator = by_predator),
  p2 = g3_parameterized('andersen.p2', value = 1, optimise = FALSE,
                        by_stock = by_stock),
  p3 = g3_parameterized('andersen.p3', value = 0.1, exponentiate = exponentiate,
                        by_stock = by_stock, by_predator = by_predator),
  p4 = g3_parameterized('andersen.p4', value = 0.1, exponentiate = exponentiate,
                        by_stock = by_stock, by_predator = by_predator),
  p5 = quote( stock__maxmidlen ),
  by_stock = TRUE,
  by_predator = TRUE,
  exponentiate = TRUE)

g3_suitability_gamma(alpha, beta, gamma)

g3_suitability_exponential(alpha, beta, gamma, delta)

g3_suitability_straightline(alpha, beta)

g3_suitability_constant(
  suit = g3_parameterized("suit", by_stock = by_stock, by_predator = by_predator),
  by_stock = TRUE,
  by_predator = TRUE )

g3_suitability_richards(p0, p1, p2, p3, p4)

```

### Arguments

suit, alpha, beta, gamma, delta, l50, p0, p1, p2, p3, p4, p5  
[formula](#) substituted into calculations, see below.

by\_stock      Change the default parameterisation (e.g. to be by 'species'), passed through to default calls to [g3\\_parameterized](#).

by\_predator    Change the default parameterisation (e.g. to be by 'fleet'), passed through to default calls to [g3\\_parameterized](#).

exponentiate   Exponentiate parameters, passed through to default calls to [g3\\_parameterized](#).

### Details

When using these to describe a predator/prey relationship, the stock midlength  $l$  will refer to the prey midlength.

**Value**

All functions return a [formula](#) for use in `g3a_predate_fleet`'s *suitabilities* argument:

**g3\_suitability\_exponential50:** A logarithmic dependence on the length of the prey as given by the following equation (note that the prey length dependence is actually dependant on the difference between the length of the prey and  $l_{50}$ ):

$$\frac{1}{1 + e^{-\alpha(l-l_{50})}}$$

$l$  Vector of stock midlength for each lengthgroup

$l_{50}$  Length of the stock with a 50% probability of predation, from parameter *l50*

**g3\_suitability\_andersen:** This is a more general suitability function that is dependant on the ratio of the predator length to the prey length as given by the following equation:

If  $p_3 = p_4$ :

$$p_0 + p_2 e^{-\frac{(x-p_1)^2}{p_4}}$$

Otherwise:

$$p_0 + p_2 e^{-\frac{(x-p_1)^2}{p_4}} * \min(\max(p_1 - x, 0), 1) + p_2 e^{-\frac{(x-p_1)^2}{p_3}} * \min(\max(x, 0), 1)$$

...i.e if  $\log \frac{L}{l} \leq p_1$  then  $p_3$  used in place of  $p_4$ .

$x \log \frac{p_5}{l}$

$L$  Vector of predator midlength for each lengthgroup

$l$  Vector of stock midlength for each lengthgroup

$p_0 .. p_4$  Function parameter  $p_0 .. p_4$

$p_5$  Function parameter  $p_5$ , if unspecified uses  $L$ , Vector of predator midlength for each lengthgroup.

NB: Specifying  $p_5$  is equivalent to using the `andersenfleet` function in `gadget2`.

**g3\_suitability\_andersenfleet:** A simplified version of `g3_suitability_andersen`, suitable for predation by fleets, as the defaults do not rely on the predator's length.

**g3\_suitability\_gamma:** This is a suitability function that is more suitable for use when considering the predation by a fleet, where the parameter  $\gamma$  would represent the size of the mesh used by the fleet (specified in centimetres).

$$\left(\frac{l}{(\alpha - 1)\beta\gamma}\right)^{(\alpha-1)e^{\alpha-1-\frac{1}{\beta\gamma}}}$$

$l$  Vector of stock midlength for each lengthgroup

$\alpha$  Function parameter *alpha*

$\beta$  Function parameter *beta*

$\gamma$  Function parameter *gamma*

This is a suitability function that is more suitable for use when considering the predation by a fleet, where the parameter  $\gamma$  would represent the size of the mesh used by the fleet (specified in centimetres).

**g3\_suitability\_exponential:** This is a suitability function that has a logarithmic dependence on both the length of the predator and the length of the prey as given by the following equation:

$$\frac{\delta}{1 + e^{-\alpha - \beta l - \gamma L}}$$

$L$  Vector of predator midlength for each lengthgroup

$l$  Vector of stock midlength for each lengthgroup

$\alpha$  Function parameter *alpha*

$\beta$  Function parameter *beta*

$\gamma$  Function parameter *gamma*

$\delta$  Function parameter *delta*

**g3\_suitability\_straightline:** Returns a [formula](#) for use in predation function's *suitabilities* argument:

$$\alpha + \beta l$$

$l$  Vector of stock midlength for each lengthgroup

$\alpha$  Function parameter *alpha*

$\beta$  Function parameter *beta*

**g3\_suitability\_constant:** Returns a [formula](#) for use in predation function's *suitabilities* argument:

$$\alpha$$

$\alpha$  Function parameter *suit*, i.e. the "prey.predator.suit" model parameter by default

**g3\_suitability\_richards:** Returns a [formula](#) for use in predation function's *suitabilities* argument:

$$\left( \frac{p_3}{1 + e^{-p_0 - p_1 l - p_2 L}} \right)^{\frac{1}{p_4}}$$

$L$  Vector of predator midlength for each lengthgroup

$l$  Vector of stock midlength for each lengthgroup

$p_0 .. p_4$  Function parameter  $p_0 .. p_4$

This is an extension to [g3\\_suitability\\_exponential](#).

### See Also

<https://gadget-framework.github.io/gadget2/userguide/chap-stock.html#sec-suitability>,

**Examples**

```

ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock(c(species = 'ling', 'mat'), seq(20, 156, 4)) %>% g3s_age(5, 15)
igfs <- g3_fleet('igfs')

igfs_landings <-
  structure(expand.grid(year=1990:1994, step=2, area=1, total_weight=1),
            area_group = list(`1` = 1))

# Generate a fleet predation action using g3_suitability_exponential150
predate_action <- g3a_predate_fleet(
  igfs,
  list(ling_imm, ling_mat),
  suitabilities = list(
    ling_imm = g3_suitability_exponential150(
      g3_parameterized('lln.alpha', by_stock = 'species'),
      g3_parameterized('lln.l50', by_stock = 'species')),
    ling_mat = g3_suitability_exponential150(
      g3_parameterized('lln.alpha', by_stock = 'species'),
      g3_parameterized('lln.l50', by_stock = 'species'))),
  catchability = g3a_predate_catchability_totalfleet(
    g3_timeareadata('igfs_landings', igfs_landings)))

# You can use g3_eval to directly calculate values for a stock:
g3_eval(
  g3_suitability_exponential150(alpha = 0.2, l50 = 60),
  stock = g3_stock('x', seq(0, 100, 10)) )

## Plots
suit_plot <- function (
  suit_f,
  stock = g3_stock('x', seq(0, 100, 5)),
  predator_length = 140,
  cols = rainbow(5) ) {
  par(mar = c(2,2,2,2), cex.main = 1)

  for (a in seq_along(cols)) curve(
    g3_eval(
      suit_f,
      a = a,
      stock = stock,
      predator_length = predator_length )[x %/% g3_stock_def(stock, 'dl')[[1]] + 1],
    from = min(g3_stock_def(stock, 'minlen')),
    to = max(g3_stock_def(stock, 'minlen')),

    col = cols[[a]],
    main = deparse1(sys.call()[[2]]), xlab = "", ylab = "",
    add = (a != 1) )
  }

suit_plot(g3_suitability_exponential150(alpha = ~a * 0.1, l50 = 50))
suit_plot(g3_suitability_andersen(0, log(2), 1, p3 = ~a * 0.1, 0.1, 140))

```

```

suit_plot(g3_suitability_andersen(0, log(2), 1, 0.1, p4 = ~a * 0.1, 140))
suit_plot(g3_suitability_gamma(alpha = ~2 + a * 0.1, beta = 1, gamma = 40))
suit_plot(g3_suitability_exponential(0, ~0.01 * a, 0, 1))
suit_plot(g3_suitability_straightline(alpha = 0.1, beta = ~0.01 * a))
suit_plot(g3_suitability_constant(~a * 0.1))
suit_plot(g3_suitability_richards(0, 0.05, 0, 1, ~0.1 * a))

```

---

timedata

*Gadget3 time-based data*


---

### Description

Convert time-based data into a formula to lookup values

### Usage

```
g3_timeareadata(lookup_name, df, value_field = "total_weight", areas = NULL)
```

### Arguments

`lookup_name` A unique name for this lookup, e.g. "igfs\_landings".

`df` A [data.frame](#) with any of columns out of age, area, year and step, finally *value\_field*.

`value_field` Column name that contains output value.

`areas` Named integer vector of area names to integer values. See [g3s\\_livesonareas](#).

### Value

A [formula](#) object that looks up *value\_field* for the current values of age, area, cur\_year and cur\_step, depending on the columns in *df*. If there's no match, return 0.

### Examples

```

ling_imm <- g3_stock(c(species = 'ling', 'imm'), seq(20, 156, 4)) %>% g3s_age(3, 10)
ling_mat <- g3_stock(c(species = 'ling', 'mat'), seq(20, 156, 4)) %>% g3s_age(5, 15)
igfs <- g3_fleet('igfs')

igfs_landings <-
  structure(expand.grid(year=1990:1994, step=2, area=1, total_weight=1),
            area_group = list(`1` = 1))

# Generate a fleet predation action, use g3_timeareadata to supply landings
# NB: Since igfs_landings only contains values for step=2, there will be no
#     predation on other steps (since g3_timeareadata will return 0).
predate_action <- g3a_predate_fleet(
  igfs,
  list(ling_imm, ling_mat),

```

```
suitabilities = list(
  ling_imm = g3_suitability_exponential150(
    g3_parameterized('ln.alpha', by_stock = 'species'),
    g3_parameterized('ln.150', by_stock = 'species')),
  ling_mat = g3_suitability_exponential150(
    g3_parameterized('ln.alpha', by_stock = 'species'),
    g3_parameterized('ln.150', by_stock = 'species')),
  catchability = g3a_predate_catchability_totalfleet(
    g3_timeareadata('igfs_landings', igfs_landings)))
```

---

timevariable

*Gadget3 time-based formulas*


---

## Description

Switch formula based on current time step

## Usage

```
g3_timevariable(lookup_name, fs)
```

## Arguments

lookup_name	A unique name for this lookup, e.g. "igfs_landings".
fs	A list of <a href="#">formula</a> objects, named with either "init", "(year)" or "(year)-(step)". When the matching time step is reached, the value of the lookup will be changed.

## Details

This is mostly for backwards compatibility with gadget2, before using this, consider other simpler options, e.g. [g3\\_timeareadata](#) or the *by\_year* option in [g3\\_parameterized](#).

## Value

A [formula](#) object that will switch values at the given time points.

## Examples

```
ling_imm <- g3_stock('ling_imm', seq(20, 156, 4)) %>% g3s_age(3, 10)

naturalmortality_action <- g3a_naturalmortality(ling_imm,
  g3a_naturalmortality_exp( g3_timevariable("lingimm.M", list(
    # Start off using lingimm.M.early
    "init" = g3_parameterized("lingimm.M.early"),
    # At 2005 step 2, switch to lingimm.M.mid
    "2005-02" = g3_parameterized("lingimm.M.mid"),
    # At 2010 step 1, switch to lingimm.M.late
    "2010" = g3_parameterized("lingimm.M.late")))))
```

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