

# Package ‘alien’

May 7, 2026

**Title** Estimate Invasive and Alien Species (IAS) Introduction Rates

**Version** 1.0.2

**Description** Easily estimate the introduction rates of alien species given first records data. It specializes in addressing the role of sampling on the pattern of discoveries, thus providing better estimates than using Generalized Linear Models which assume perfect immediate detection of newly introduced species.

**License** MIT + file LICENSE

**Encoding** UTF-8

**RoxygenNote** 7.2.3

**Imports** cli, dplyr, ggplot2, HelpersMG, rlang, stats, tidyr

**Depends** R (>= 3.4.0)

**LazyData** true

**Suggests** BH, knitr, purrr, Rcpp, RcppEigen, RcppParallel, rmarkdown, rstan, testthat (>= 3.0.0), tibble

**Config/testthat/edition** 3

**VignetteBuilder** knitr

**NeedsCompilation** no

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likelihood_map	<i>Plot log-likelihood space</i>
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### Description

Plot a filled-contour heatmap displaying the log-likelihood space calculated using `likelihood_space`.

### Usage

```
likelihood_map(likelihood_space, x, y, delta = 10)
```

### Arguments

<code>likelihood_space</code>	a data frame resulting from a call to <code>likelihood_space</code> , where columns represent parameter values and an extra column <code>log_likelihoods</code> with the corresponding log-likelihood for each parameter value combination.
<code>x</code>	a string specifying the parameter to be plotted on the x-axis.
<code>y</code>	a string specifying the parameter to be plotted on the y-axis.
<code>delta</code>	the range of log-likelihood values of which different color codes will be plotted. Defaults to 10.

### Value

#' A ggplot plot with the corresponding type of plot.

### Examples

```
if (FALSE){ # takes a while to finish
  example_model <- snc(sfestuary)
  estimates <- example_model$coefficients$Estimate

  likelihood_space <- likelihood_space(y = sfestuary, centers = estimates,
                                       ranges = 1.5, steps_from_center = 10,
                                       calculate = TRUE)

  likelihood_map(likelihood_space, "beta0", "beta1", 10)
}
```

likelihood\_space

*Calculate log-likelihood space for a given time series and data***Description**

This function allows to calculate the log-likelihood values for a given set of parameter values. It can be used for diagnostics of the likelihood space and check - among others - for parameter contribution to log-likelihood. passing FALSE for the calculate argument allows to experiment with different parameter values sets before calculating their log-likelihoods. Please note: This functions may take a lot of time, depending on the number of parameters, and steps!

**Usage**

```
likelihood_space(
  y,
  mu = NULL,
  pi = NULL,
  data = NULL,
  growth = TRUE,
  type = "exponential",
  centers,
  ranges,
  steps_from_centers,
  calculate = TRUE
)
```

**Arguments**

y	either a vector describing the number of discovered alien and invasive species (IAS) over a given time period, or the name (quoted or unquoted) of the corresponding column in the provided data.
mu	a formula defining the predictors for $\mu_t$ , the annual introduction rate. Formulas should be provided in the syntax $\sim x_1 + x_2 + \dots + x_n$ . Use $\sim 1$ for an intercept only model.
pi	a formula defining the predictors for $\Pi_{st}$ , the annual probability of detection. Formulas should be provided in the syntax $\sim x_1 + x_2 + \dots + x_n$ . Use $\sim 1$ for an intercept only model.
data	a data frame containing the variables in the model(s).
growth	logical. Should the population growth parameter $\gamma_2$ be included in the model for $\Pi_{st}$ ? Note that values for <code>init</code> , if provided, need to include an initial value for the growth parameter, when <code>growth = TRUE</code> .
type	Define whether the mu function should be on "linear" or "exponential" scale. Defaults to "exponential".
centers	the values used as the center-points for the parameter values. Usually the maximum likelihood estimation from a call to <code>snc</code> . Length should be either 1 or correspond to number of parameters (including the growth parameter).

ranges	the range of the parameter values in term of the center. The values will be withing center - (center * range) and center + (center * range). Length should be either 1 or correspond to number of parameters (including the growth parameter).
steps_from_centers	How many values in the range between center and center + (center * range) should be included in the set. Length should be either 1 or correspond to number of parameters (including the growth parameter).
calculate	Whether to calculate the log-likelihoods (TRUE) or just view the parameter values (FALSE).

### Value

A data frame containing the parameter values, and if calculate = TRUE including the log-likelihood values for each parameter combination.

### Examples

```
if (FALSE){ # this takes a while...
example_model <- snc(sfestuary)
estimates <- example_model$coefficients$Estimate

likelihood_space <- likelihood_space(y = sfestuary, centers = estimates,
                                     ranges = 1.5, steps_from_center = 10,
                                     calculate = TRUE)

# with specified formula:
example_buba <- snc(y = aliens, pi = ~ natives, data = medfish)
estimates <- example_buba$coefficients$Estimate

likelihood_space <- likelihood_space(y = aliens, pi = ~ natives,
                                     data = medfish, centers = estimates,
                                     ranges = 1.5, steps_from_center = 10,
                                     calculate = TRUE)
}
```

---

medfish

*Discoveries Of Native And Alien Fish Species In The Eastern Mediterranean Sea*

---

### Description

The updated data used in Belmaker et al (2009) describing discoveries of native and alien species in the Mediterranean Sea between the years 1927–2017. The original data is described in full in Golani (2005); see also Golani (2021) for the updated version used here.

**Usage**

```
medfish
```

**Format**

A data frame with 60 rows and 4 columns:

**year** Year of record

**time** Time since the first record in the records data

**natives** Number of newly recorded native species in corresponding year

**aliens** Number of newly recorded alien species in corresponding year

**Source**

<https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/07-1904.1>

<https://www.mapress.com/zt/article/view/zootaxa.4956.1.1>

**References**

Golani, D. 2005. Checklist of the Mediterranean Fishes of Israel. *Zootaxa*, 947, 1-90. <https://mapress.com/zt/article/view/zootaxa.4956.1.1>

Belmaker, J., Brokovich, E., China, V., Golani, D., and Kiflawi, M. 2009. Estimating the rate of biological introductions: Lessepsian fishes in the Mediterranean. *Ecology*, 90(4), 1134–1141. <https://esajournals.onlinelibrary.wiley.com/doi/10.1890/07-1904.1>

Golani, D. 2021. An updated Checklist of the Mediterranean fishes of Israel, with illustrations of recently recorded species and delineation of Lessepsian migrants. *Zootaxa*, 4956, 1-108. <https://www.mapress.com/zt/article/view/zootaxa.4956.1.1>

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plot\_snc

*Plot an introduction record and the fitted model values*

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**Description**

Plot an introduction record and the fitted model values

**Usage**

```
plot_snc(object, cumulative = FALSE)
```

**Arguments**

**object** an object of class "snc", usually a result of a call to snc

**cumulative** logical - should plot be annual or cumulative number of IAS.

**Value**

A ggplot plot with the corresponding type of plot.

## Examples

```
data(sfestuary)
example_model <- snc(sfestuary)
plot_snc(example_model, cumulative = TRUE)
```

---

sfestuary	<i>Discoveries Of Introduced Species In The San Francisco Estuary (California, USA)</i>
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---

## Description

The data provided by Solow and Costello (2004) describing discoveries of introduced species in the San Francisco estuary (California, USA) between the years 1850–1995. These data were compiled by Cohen and Carlton (1995); see also Cohen and Carlton (1998).

The original data in PDF format is described in full in Cohen and Carlton (1995) and can be viewed here: <https://repository.library.noaa.gov/view/noaa/40918>

## Usage

```
sfestuary
```

## Format

An object of class integer of length 145.

## Source

<https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/03-3102>

<https://repository.library.noaa.gov/view/noaa/40918>

## References

Cohen, A. N., and J. T. Carlton. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service, Washington, D.C., USA. <https://repository.library.noaa.gov/view/noaa/40918>

Cohen, A. N., and J. T. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. *Science* 279: 555–558. <https://www.science.org/doi/10.1126/science.279.5350.555>

Solow, A. R., and Costello, C. J. 2004. Estimating the rate of species introductions from the discovery record. *Ecology*, 85(7), 1822–1825. <https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/03-3102>

snc

*Fit a model to discovery records***Description**

Fit a model to a time series describing first records of alien species. If no external data is provided, the function fits the model described in Solow and Costello (2004). When external data on either  $\mu_t$  or  $\Pi_{st}$  is provided, the function fits the modified model (sampling-proxy model in the case of  $\Pi_{st}$ ) as described in Buba et al (2024).

**Usage**

```
snc(
  y,
  mu = NULL,
  pi = NULL,
  data = NULL,
  init = NULL,
  growth = TRUE,
  type = "exponential",
  ...
)
```

**Arguments**

y	either a vector describing the number of discovered alien and invasive species (IAS) over a given time period, or the name (quoted or unquoted) of the corresponding column in the provided data.
mu	a formula defining the predictors for $\mu_t$ , the annual introduction rate. Formulas should be provided in the syntax $\sim x_1 + x_2 + \dots + x_n$ . Use $\sim 1$ for an intercept only model.
pi	a formula defining the predictors for $\Pi_{st}$ , the annual probability of detection. Formulas should be provided in the syntax $\sim x_1 + x_2 + \dots + x_n$ . Use $\sim 1$ for an intercept only model.
data	a data frame containing the variables in the model(s).
init	Optional. Initial values supplied to <code>optim</code> . Must be same length as the total number of parameters.
growth	logical. Should the population growth parameter $\gamma_2$ be included in the model for $\Pi_{st}$ ? Note that values for <code>init</code> , if provided, need to include an initial value for the growth parameter, when <code>growth = TRUE</code> .
type	Define whether the mu function should be on "linear" or "exponential" scale. Defaults to "exponential".
...	Further arguments passed to <code>optim</code> .

## Details

This function expands on the model described in Solow and Costello (2004) by facilitating the inclusion of external data to describe either introduction rate  $\mu_t$  or detection probability  $\Pi_{st}$ . The model with external data for detection probability (sampling-proxy model) is described fully in Buba et al (2024). The use of external data to describe the introduction rate has not been thoroughly evaluated. When no formula is defined for either, the function automatically fits the original Solow and Costello (2004) model using the length of the vector data as the independent variable  $t$ . All models return estimated parameters for both the introduction rate and the detection probability, with the parameter of interest usually being the change of introduction rate -  $\beta_1$ . For more details see the Basic Usage vignette: `vignette("basic_usage", package = "alien")`

## Value

snc returns an object of class "snc" containing:

records	the supplied first records data
convergence	the optim convergence code.
log-likelihood	the maximum log-likelihood.
coefficients	a named vector of the ML estimates of the coefficients.
fitted.values	the fitted mean $\lambda$ values.
predict	a data frame containing the estimated mean +- Standard error $\mu$ values.

## References

Solow, A. R., & Costello, C. J. (2004). Estimating the rate of species introductions from the discovery record. *Ecology*, 85(7), 1822–1825. <https://doi.org/10.1890/03-3102>

Buba, Y., Kiflwai, M., McGeoch, M. A., Belmaker, J. (2024) Evaluating models for estimating introduction rates of alien species from discovery records. <https://doi.org/10.1111/geb.13859>

## Examples

```
# Solow and Costello (2004) model:
data(sfestuary)
example_model <- snc(sfestuary)
print(example_model)

# Buba et al (2024) sampling-proxy model:
data(medfish)
example_buba <- snc(y = aliens, pi = ~ natives, data = medfish)
print(example_buba)
```

---

`summary_snc`*Summarize a Solow and Costello Model Fit*

---

**Description**

Summarize a Solow and Costello Model Fit

**Usage**

```
summary_snc(object)
```

**Arguments**

`object` an object of class "snc", usually a result of a call to `snc`

**Value**

A data.frame containing the model estimates, standard error, and the probability of the true value being 0 under the given estimates and errors.

**Examples**

```
data(sfestuary)
example_model <- snc(sfestuary)
summary(example_model)
```

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