Package ‘extr’

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Title Extinction Risk Estimation

Version 1.0.0

Description Estimates extinction risk from population time series under a drifted Wiener process using the w-z method for accurate confidence intervals.

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Encoding UTF-8

Language en-US

RoxygenNote 7.3.2

NeedsCompilation no

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Contents

`ext_di` *Extinction Risk Estimation for a Density-Independent Model*

Description

Estimates demographic parameters and extinction probability under a density-independent (drifted Wiener) model. From a time series of population sizes, it computes MLEs of growth rate and environmental variance, then evaluates extinction risk over a horizon t^*. Confidence intervals are constructed by the w-z method, which achieve near-nominal coverage across the full parameter space.

Usage

```
ext_di(
  dat,
  ne = 1,
  th = 100,
  alpha = 0.05,
  unit = "years",
  qq_plot = FALSE,
  formatted = TRUE,
  digits = getOption("extr.digits", 5L)
)
```

Arguments

`dat`	Data frame with two numeric columns: time (strictly increasing) and population size. Column names are not restricted.
`ne`	Numeric. Extinction threshold $n_e \geq 1$. Default is 1.
`th`	Numeric. Time horizon $t^* > 0$. Default is 100.
`alpha`	Numeric. Significance level $\alpha \in (0, 1)$. Default is 0.05.
`unit`	Character. Unit of time (e.g., "years", "days", "generations"). Default is "years".
`qq_plot`	Logical. If `TRUE`, draws a QQ-plot of standardized increments to check model assumptions. Default is `FALSE`.
`formatted`	Logical. If `TRUE`, returns an `"ext_di"` object; otherwise returns a raw list. Default is `TRUE`.
`digits`	Integer. Preferred significant digits for printing. Affects display only. Default is `getOption("extr.digits", 5)`.

Details

Population dynamics follow

$$dX = \mu\, dt + \sigma\, dW,$$

where $X(t) = \log N(t)$, μ is the growth rate, σ^2 the environmental variance, and W a Wiener process. Extinction risk is

$$G = \Pr[T \leq t^* \mid N(0) = n_0, n_e, \mu, \sigma],$$

the probability the population falls below n_e within t^*. Irregular intervals are allowed.

The function:

1. estimates μ and σ^2 (Dennis et al., 1991),
2. computes extinction probability $G(w, z)$ (Lande and Orzack, 1988),
3. constructs confidence intervals for G using the w-z method (Hakoyama, 2025).

Numerical range. Probabilities are evaluated on G, $\log G$, and $\log(1 - G)$ scales. The log-scale removes the $\approx 4.94 \times 10^{-324}$ lower bound of linear doubles and extends the safe range down to `exp(-DBL_MAX)` (kept symbolically), avoiding underflow/cancellation.

Value

A list (class "ext_di" if formatted=TRUE) with:

- Growth.rate, Variance, Unbiased.variance;
- AIC;
- Extinction.probability with confidence limits;
- data summary (nq, xd, sample.size);
- input parameters (unit, ne, th, alpha).

Author(s)

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References

Lande, R. and Orzack, S.H. (1988) Extinction dynamics of age-structured populations in a fluctuating environment. *Proceedings of the National Academy of Sciences*, 85(19), 7418–7421.

Dennis, B., Munholland, P.L., and Scott, J.M. (1991) Estimation of growth and extinction parameters for endangered species. *Ecological Monographs*, 61, 115–143.

Hakoyama, H. (2025) Confidence intervals for extinction risk: validating population viability analysis with limited data. Preprint, doi:10.48550/arXiv.2509.09965

See Also

statistics_di, extinction_probability_di, confidence_interval_wz_di, print.ext_di

Examples

```
# Example from Dennis et al. (1991), Yellowstone grizzly bears
dat <- data.frame(Time = 1959:1987,
Population = c(44, 47, 46, 44, 46, 45, 46, 40, 39, 39, 42, 44, 41, 40,
33, 36, 34, 39, 35, 34, 38, 36, 37, 41, 39, 51, 47, 57, 47))

# Probability of decline to 1 individual within 100 years
ext_di(dat, th = 100)

# Probability of decline to 10 individuals within 100 years
ext_di(dat, th = 100, ne = 10)

# With QQ-plot
ext_di(dat, th = 100, qq_plot = TRUE)

# Change digits
ext_di(dat, th = 100, ne = 10, digits = 9)
```

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