

# Package ‘SSP’

March 28, 2020

**Title** Simulated Sampling Procedure for Community Ecology

**Version** 1.0.1

**Maintainer** Edlin Guerra-Castro <edlinguerra@gmail.com>

**Description** Simulation-based sampling protocol (SSP) is an R package design to estimate sampling effort in studies of ecological communities based on the definition of pseudo-multivariate standard error (MultSE) (Anderson & Santana-Garcon, 2015) <doi:10.1111/ele.12385> and simulation of ecological data. The theoretical background is described in Guerra-Castro et al. (2020) <doi:10.1101/2020.03.19.996991>.

**Depends** R (>= 3.5.0)

**License** GPL-2

**Encoding** UTF-8

**LazyData** true

**RoxygenNote** 6.1.1

**Suggests** knitr, rmarkdown, testthat, roxygen2

**VignetteBuilder** knitr

**URL** <https://github.com/edlinguerra/SSP>

**BugReports** <https://github.com/edlinguerra/SSP/issues>

**Imports** vegan, stats, sampling, ggplot2

**NeedsCompilation** no

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**Repository** CRAN

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SSP-package	<i>SSP: Simulated Sampling Procedure for Community Ecology</i>
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### Description

SSP is an R package designed to estimate sampling effort in studies of ecological communities based on the definition of pseudo multivariate standard error (MultSE) (Anderson & Santana-Garcon 2015) and simulation of data (Guerra-Castro et al., 2020).

### Details

The protocol in SSP consists in simulating several extensive data matrices that mimic some of the relevant ecological features of the community of interest using a pilot data set. For each simulated data, several sampling efforts are repeatedly executed and MultSE is calculated to each one. The mean value, 0.025 and 0.975 quantiles of MultSE for each sampling effort across all simulated data are then estimated and plotted. The mean values are standardized in relation to the lowest sampling effort (consequently, the worst precision), and an optimal sampling effort can be identified as that in which the increase in sample size do not improve the precision beyond a threshold value (e.g. 2.5%).

SSP includes seven functions: `assempar` for extrapolation of assemblage parameters using pilot data; `simdata` for simulation of several data sets based on extrapolated parameters; `datquality` for evaluation of plausibility of simulated data; `sampsd` for repeated estimations of MultSE for different sampling designs in simulated data sets; `summary_ssp` for summarizing the behavior of MultSE for each sampling design across all simulated data sets, `ioptimum` for identification of the optimal sampling effort, and `plot_ssp` to plot sampling effort vs MultSE of simulated data.

The SSP package is developed at GitHub (<https://github.com/edlinguerra/SSP/>).

### Author(s)

The SSP development team is Edlin Guerra-Castro, Maite Mascaró, Nuno Simoes, Juan Cruz-Motta and Juan Cajas

## References

-Anderson, M. J., & J. Santana-Garcon. (2015). Measures of precision for dissimilarity-based multivariate analysis of ecological communities. *Ecology Letters* 18:66-73.

-Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaro. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. *bioRxiv:2020.2003.2019.996991*.

## Examples

```
###To speed up the simulation of these examples, the cases, sites and N were set small.
```

```
##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)
```

```
#Estimation of parameters of pilot data
par.mic<-asempar (data = micromollusk,
                 type= "P/A",
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 20 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases= 3, N = 20, sites = 1)
```

```
#Sampling and estimation of MultSE for each sample size (few repetitions
#to speed up the example)
```

```
sam.mic<-samspd(dat.sim = sim.mic,
               Par = par.mic,
               transformation = "P/A",
               method = "jaccard",
               n = 10,
               m = 1,
               k = 3)
```

```
#Summary of MultSE for each sampling effort
summ.mic<-summary_ssp(results = sam.mic, multi.site = FALSE)
```

```
#Cut-off points to identify optimal sampling effort
opt.mic<-ioptimum(xx = summ.mic, multi.site = FALSE)
```

```
#Plot
plot_ssp(xx = summ.mic, opt = opt.mic, multi.site = FALSE)
```

```
##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)
```

```
#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                 type= "counts",
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 10 potential sampling units in 3 sites.
```

```

sim.spo<-simdata(par.spo, cases= 3, N = 10, sites = 3)

#Sampling and estimation of MultSE for each sampling design (few repetitions
#to speed up the example)

sam.spo<-samprsd(dat.sim = sim.spo,
                Par = par.spo,
                transformation = "square root",
                method = "bray",
                n = 10,
                m = 3,
                k = 3)

#Summary of MultSE for each sampling effort
summ.spo<-summary_ssp(results = sam.spo, multi.site = TRUE)

#Cut-off points to identify optimal sampling effort
opt.spo<-ioptimum(xx = summ.spo, multi.site = TRUE)

#Plot
plot_ssp(xx = summ.spo, opt = opt.spo, multi.site = TRUE)

```

---

assempar

*Estimation of Ecological Parameters of the Assemblage*


---

## Description

The function extracts the main parameters of the pilot data using basic R functions as well as functions like [specpool](#) and [dispweight](#)

## Usage

```
assempar(data, type, Sest.method)
```

## Arguments

data	Data frame with species names (columns) and samples (rows) information. The first column should indicate the site to which the sample belongs, regardless of whether a single site has been sampled.
type	Nature of the data to be processed. It may be presence / absence ("P/A"), counts of individuals ("counts"), or coverage ("cover")
Sest.method	Method for estimating species richness. The function <a href="#">specpool</a> is used for this. Available methods are the incidence-based Chao "chao", first order jackknife "jack1", second order jackknife "jack2" and Bootstrap "boot". By default, the "average" of the four estimates is used.

## Details

The expected number of species in the assemblage is estimated using non-parametric methods (Gotelli et al. 2011). Due to the variability in the estimates of each approximation (Reese et al. 2014), we recommend using an average of these. The probability detection of each species is estimated among and within sites. The former is calculated as the frequency of occurrences of each species against the number of sites sampled, the second as the weighted average frequencies in sites where the species were present. Also, the degree of spatial aggregation of species (only for real counts of individuals), is identified with the index of dispersion D (Clarke et al. 2006). The corresponding properties of unseen species are approximated using the information of observed species. Specifically, the probabilities of detection are assumed to be equal to the rarest species in the pilot data. The mean and variance of the abundances are defined using random Poisson values with lambda as the overall mean of species abundances.

## Value

Par                      The function returns an object of class list, to be used by [simdata](#)

## Note

Important: the first column should indicate the site ID of each sample (as character or numeric), even when a single site was sampled.

## Author(s)

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaró (mmm@ciencias.unam.mx).

## References

- Clarke, K. R., Chapman, M. G., Somerfield, P. J., & Needham, H. R. (2006). Dispersion-based weighting of species counts in assemblage analyses. *Journal of Experimental Marine Biology and Ecology*, 320, 11-27.
- Gotelli, N. J., & Colwell, R. K. (2011). Estimating species richness. Pages 39-54, in A. E. Magurran and B. J. McGill (editors). *Biological diversity: frontiers in measurement and assessment*. Oxford University Press, Oxford, UK.
- Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaró. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.2003.2019.996991](https://doi.org/10.1101/2020.2003.2019.996991).
- Reese, G. C., Wilson, K. R., & Flather, C. H. (2014). Performance of species richness estimators across assemblage types and survey parameters. *Global Ecology and Biogeography*, 23(5), 585-594.

## See Also

[dispweight](#), [specpool](#), [simdata](#)

**Examples**

```
##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)
par.mic<-asempar(data = micromollusk,
                 type= "P/A",
                 Sest.method = "average")

par.mic

##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)
par.spo<-asempar(data = sponges,
                 type= "counts",
                 Sest.method = "average")

par.spo
```

---

datquality

*Diversity Metrics of Simulated and Original Data*


---

**Description**

The function estimates the average number of species, and the Simpson diversity index per sampling unit, as well as the total multivariate dispersion of pilot data and simulated data

**Usage**

```
datquality(data, dat.sim, Par, transformation, method)
```

**Arguments**

data	Data frame with species names (columns) and samples (rows) information. The first column should indicate the site to which the sample belongs, regardless of whether a single site has been sampled or not
dat.sim	List of simulated data generated by simdata
Par	List of parameters generated by asempar
transformation	Mathematical function to reduce the weight of dominant species: 'square root', 'fourth root', 'Log (X+1)', 'P/A', 'none'
method	The appropriate distance/dissimilarity metric. The function <code>vegdist</code> is called for that purpose

**Details**

The quality of the simulated data sets is quantified through the statistical similarity with respect to the pilot data using the following estimators: (i) average number of species per sampling unit, (ii) diversity, defined as the average Simpson diversity index per sampling unit, and (iii) the multivariate dispersion (MVD), measured as the average dissimilarity from all sampling units to the main

centroid in the space of the dissimilarity measure used (Anderson 2006). For the simulated data, the overall mean and standard deviation for (i) and (ii) are presented. However, to assess the magnitude of variability in the simulated data, 0.95 quantiles of the MVD for all simulated data sets are also presented.

### Value

`divmetrics` A data frame that includes the mean and standard deviation of richness and diversity per sampling unit, and the MVD for original and 0.95 quantiles of MVD of simulated data.

### Note

It is desirable that the simulated data would be similar to the data observed in terms of species richness and diversity per sampling unit.

### Author(s)

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaro (mmm@ciencias.unam.mx).

### References

Anderson, M.J. (2006) Distance-based tests for homogeneity of multivariate dispersions. *Biometrics*, 62, 245-253

Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaro. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.2003.2019.996991](https://doi.org/10.1101/2020.2003.2019.996991).

### See Also

[vegdist](#), [diversity](#)

### Examples

```
###To speed up the simulation of these examples, the cases, sites and n were set small.

##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)

#Estimation of parameters of pilot data
par.mic<-assemblage (data = micromollusk,
                    type= "P/A",
                    Sest.method = "average")

#Simulation of 3 data sets, each one with 10 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases= 3, N = 10, sites = 1)

#Estimation of diversity metrics of original and simulated data
qua.mic<-datquality(data = micromollusk,
                   dat.sim = sim.mic,
```

```

        Par = par.mic,
        transformation = "none",
        method = "jaccard" )
qua.mic

##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)

#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                type= "counts",
                Sest.method = "average")

#Simulation of 3 data sets, each one with 10 potential sampling units in 3 sites.
sim.spo<-simdata(par.spo, cases= 3, N = 10, sites = 3)

#Estimation of diversity metrics of original and simulated data
qua.spo<-datquality(data = sponges,
                    dat.sim = sim.spo,
                    Par = par.spo,
                    transformation = "square root",
                    method = "bray")
qua.spo

```

---

epibionts

*Epibionts on Caribbean mangrove roots*


---

## Description

Data corresponds to epibenthic organisms in mangrove roots from Laguna de La Restinga National Park, Venezuela (Guerra-Castro et al. 2016).

## Usage

```
data("epibionts")
```

## Format

A data frame with 96 observations on the following 152 variables.

sector a factor with levels E I M

site a numeric vector

Aptos.sp a numeric vector

Acanthophora.spicifera a numeric vector

Acetabularia.crenulata a numeric vector

Aglaothamnion.sp a numeric vector

Amathia.sp a numeric vector



Amorphinopsis.atlantica a numeric vector  
Amphimedon.erina a numeric vector  
Anemonia.sargassensis a numeric vector  
Aplidium.accareense a numeric vector  
Aplysilla.glacialis a numeric vector  
Ascidia.curvata a numeric vector  
Ascidia.sp a numeric vector  
Ascidia.sydneyensis a numeric vector  
Balanus.sp a numeric vector  
Bartholomea.annulata a numeric vector  
Biemna.caribea a numeric vector  
Bostrychia.tenella a numeric vector  
Botrylloides.nigrum a numeric vector  
Botrylloides.sp.1 a numeric vector  
Botrylloides.sp.2 a numeric vector  
Brachidontes.exustus a numeric vector  
Branchiomma.conspersum a numeric vector  
Branchiomma.nigromaculatum a numeric vector  
Bryopsis.sp a numeric vector  
Bugula.neritina a numeric vector  
Bugula.sp a numeric vector  
Calliactis.tricolor a numeric vector  
Callyspongia..Callyspongia..pallida a numeric vector  
Carijoa.riisei a numeric vector  
Caulerpa.racemosa a numeric vector  
Caulerpa.racemosa.var.peltata a numeric vector  
Caulerpa.sertularioides a numeric vector  
Caulerpa.verticillata a numeric vector  
Caulibugula.sp a numeric vector  
Celleporaria.sp a numeric vector  
Ceramium.diaphanum a numeric vector  
Chaetomorpha.sp.1 a numeric vector  
Chaetomorpha.sp.2 a numeric vector  
Chalinula.molitba a numeric vector  
Chelonaplysilla.erecta a numeric vector  
Chondrilla.nucula a numeric vector  
Chthamalus.sp a numeric vector

Clathria..Clathria..microchela a numeric vector  
Clathria.sp a numeric vector  
Clavelina.oblonga a numeric vector  
Clavelina.picta a numeric vector  
Complejo.Cliona.celata a numeric vector  
Crassostrea.rhizophorae a numeric vector  
Dictyota.sp a numeric vector  
Didemnum.cineraceum a numeric vector  
Didemnum.perlucidum a numeric vector  
Didemnum.sp a numeric vector  
Diplosoma.listerianum a numeric vector  
Distaplia.bermudensis a numeric vector  
Distaplia.stylifera a numeric vector  
Dynamena.sp a numeric vector  
Dysidea.etheria a numeric vector  
Dysidea.sp a numeric vector  
Ecteinascidia.sp a numeric vector  
Ecteinascidia.styeloides a numeric vector  
Ecteinascidia.turbinata a numeric vector  
Eudistoma.olivaceum a numeric vector  
Eusynstyela.tincta a numeric vector  
Exaiptasia.pallida a numeric vector  
Ficopomatus.sp a numeric vector  
Geodia.papyracea a numeric vector  
Halichondria..Halichondria..magniconulosa a numeric vector  
Halichondria..Halichondria..melanadocia a numeric vector  
Haliclona..Halichoclona..magnifica a numeric vector  
Haliclona..Reniera..implexiformis a numeric vector  
Haliclona..Reniera..manglaris a numeric vector  
Haliclona..Reniera..ruetzleri a numeric vector  
Haliclona..Reniera..tubifera a numeric vector  
Haliclona..Rhizoniera..curacaoensis a numeric vector  
Haliclona..Soestella..caerulea a numeric vector  
Haliclona..Soestella..smithae a numeric vector  
Haliclona..Soestella..twincayensis a numeric vector  
Halimeda.sp a numeric vector  
Halisarca.sp a numeric vector

Halopteris.sp a numeric vector  
Herdmania.pallida a numeric vector  
Hippopodina.feegeensis a numeric vector  
Hydroides.sp a numeric vector  
Hyrtios.proteus a numeric vector  
Iotrochota.birotulata a numeric vector  
Ircinia.felix a numeric vector  
Ircinia.sp a numeric vector  
Isognomon.alatus a numeric vector  
Kirchenpaueria.sp a numeric vector  
Lissoclinum.sp a numeric vector  
Lissodendoryx..Lissodendoryx..isodictyalis a numeric vector  
Lithophyllum.pustulatum a numeric vector  
Microcosmus.exasperatus a numeric vector  
Molgula occidentalis a numeric vector  
Murrayella.pericladus a numeric vector  
Mycale..Aegogropila..carmigropila a numeric vector  
Mycale..Aegogropila..citrina a numeric vector  
Mycale..Carmia..magnirhaphidifera a numeric vector  
Mycale..Carmia..microsigmatosa a numeric vector  
Mycale..Mycale..laevis a numeric vector  
Mycale..Zygomycala..angulosa a numeric vector  
Mycale.sp a numeric vector  
Nemalecium.sp a numeric vector  
Notaulax.nudicollis a numeric vector  
Obelia.sp a numeric vector  
Oceanapia.nodosa a numeric vector  
Padina.sp a numeric vector  
Perna.viridis a numeric vector  
Perophora.viridis a numeric vector  
Phaeophyceae a numeric vector  
Phallusia.nigra a numeric vector  
Phyllangia.americana a numeric vector  
Pinctada.imbricata a numeric vector  
Plakortis.angulospiculatus a numeric vector  
Polyclinum.constellatum a numeric vector  
Polysiphonia.sp.1 a numeric vector

Polysiphonia.sp.3 a numeric vector  
Polysiphonia.subtilissima a numeric vector  
Pteria.colymbus a numeric vector  
Pyura.sp..1 a numeric vector  
Pyura.sp..2 a numeric vector  
Pyura.vittata a numeric vector  
Rhizoclonium.sp a numeric vector  
Rhodosoma.turcicum a numeric vector  
Sabella.sp a numeric vector  
Sabellastarte.magnifica a numeric vector  
Schizoporella.pungens a numeric vector  
Scopalina.ruetzleri a numeric vector  
Scopalina.sp a numeric vector  
Scrupocellaria.sp a numeric vector  
Sphacelaria.rigidula a numeric vector  
Spongia..Spongia..pertusa a numeric vector  
Spongia..Spongia..tubulifera a numeric vector  
Sporolithon.episporum a numeric vector  
Spyridia.hypnoides a numeric vector  
Styela.canopus a numeric vector  
Styela.sp.1 a numeric vector  
Styela.sp.2 a numeric vector  
Suberites.aurantiacus a numeric vector  
Symplegma.brakenhielmi a numeric vector  
Symplegma.rubra a numeric vector  
Synnotum.circinatum a numeric vector  
Tedania..Tedania..ignis a numeric vector  
Terpios.manglaris a numeric vector  
Tethya.actinia a numeric vector  
Tethya.sp a numeric vector  
Trididemnum.orbiculatum a numeric vector  
Ulva.sp a numeric vector  
Viatrix.globulifera a numeric vector  
Zoobotryon.verticillatum a numeric vector

**Details**

Data consists of the coverage (by point-intercept) of 110 taxa identified in 240 mangrove roots, sampled under a hierarchically nested spatial design that included four random sites within each of three sectors of the lagoon system corresponding to a strong environmental gradient: external (E), intermediate (M), and internal (I). The abundance of epibenthic organisms of 8 roots were described within each site, producing a total of 32 roots in each sector. This spatial protocol was repeated five times over a period of 14 months. For demonstrative purpose, data from the 4th sampling period was randomly chosen as data for this package.

**Source**

<https://doi.org/10.3354/meps11693>

**References**

Guerra-Castro, E. J., J. E. Conde, and J. J. Cruz-Motta. (2016). Scales of spatial variation in tropical benthic assemblages and their ecological relevance: epibionts on Caribbean mangrove roots as a model system. *Marine Ecology Progress Series* 548:97-110.

**Examples**

```
data(epibionts)
str(epibionts)
```

---

 ioptimum

---

*Identification of the Optimal Sampling Effort*


---

**Description**

The function estimates the sampling effort in which the rate of change for each additional sampling unit can be considered optimal.

**Usage**

```
ioptimum(xx, multi.site = TRUE, c1 = 10, c2 = 5, c3 = 2.5)
```

**Arguments**

xx	A data frame generated by <a href="#">summary_ssp</a>
multi.site	Logical argument indicating if several sites were simulated
c1	First cut. By default 10% improvement for each sample with respect to the highest MultSE.
c2	Second cut. By default 5% improvement for each sample with respect to the highest MultSE.
c3	Third cut. By default 2.5% improvement for each sample with respect to the highest MultSE.

**Details**

Sampling efforts between the minimum (i.e. 2) and  $c_1$ , can be considered the necessary efforts to improve the precision. The number of samples between  $c_1$  and  $c_2$  reflects the sub-optimal sampling efforts. The number of samples between  $c_2$  and  $c_3$  indicate the optimal sampling effort. A cost / benefit criterion (e.g. Underwood, 1990) can be used to set the final sample size within this range. The sampling effort beyond  $c_3$  would imply a marginal improvement of the MultSE for each increase in sample size, which would result in an unnecessary sampling effort due to redundancy. The relationship between MultSe, sampling effort, and optimal sampling can be visualized with [plot\\_ssp](#)

**Value**

`sample.cut`      A vector or matrix with the sampling size for each cut point

**Note**

The cuts that define the sampling effort as necessary, sub-optimal, optimal or redundant are arbitrary and can be modified according to each research problem. In particular, it is possible that  $c_3$  as 2.5% is not generated because this would be achieved with a sample size larger than the maximum simulated. In this case, the maximum effort generated with [samprsd](#) will be returned with a warning message.

**Author(s)**

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaró (mmm@ciencias.unam.mx).

**References**

Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaró. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.2003.2019.996991](#).

Underwood, A. J. (1990). Experiments in ecology and management: Their logics, functions and interpretations. *Australian Journal of Ecology*, 15, 365-389.

**See Also**

[samprsd](#)

**Examples**

```
###To speed up the simulation of these examples, the cases, sites and N were set small.

##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)

#Estimation of parameters of pilot data
par.mic<-assempr (data = micromollusk,
                  type= "P/A",
                  Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 20 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases= 3, N = 20, sites = 1)

#Sampling and estimation of MultSE for each sample size (few repetitions
#to speed up the example)

sam.mic<-sampsd(dat.sim = sim.mic,
               Par = par.mic,
               transformation = "P/A",
               method = "jaccard",
               n = 10,
               m = 1,
               k = 3)

#Summary of MultSE for each sampling effort
summ.mic<-summary_ssp(results = sam.mic, multi.site = FALSE)

#Cut-off points to identify optimal sampling effort
opt.mic<-ioptimum(xx = summ.mic, multi.site = FALSE)

##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)

#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                 type= "counts",
                 Sest.method = "average")

#Simulation of 3 data sets, each one with 20 potential sampling units in 3 sites.
sim.spo<-simdata(par.spo, cases= 3, N = 10, sites = 3)

#Sampling and estimation of MultSE for each sampling design (few repetitions
#to speed up the example)

sam.spo<-sampsd(dat.sim = sim.spo,
               Par = par.spo,
               transformation = "square root",
               method = "bray",
               n = 10,
               m = 3,
               k = 3)

#Summary of MultSE for each sampling effort
summ.spo<-summary_ssp(results = sam.spo, multi.site = TRUE)

#Cut-off points to identify optimal sampling effort
opt.spo<-ioptimum(xx = summ.spo, multi.site = TRUE)
```

---

micromollusk

*Micromollusks of marine shallow sandy bottoms around Cayo Nuevo, Gulf of Mexico, Mexico***Description**

Presence/absence of 68 species registered in six cores of 4 cm diameter and 10 cm depth taken in sandy bottoms around Cayo Nuevo, Gulf of Mexico, Mexico

**Usage**

```
data("micromollusk")
```

**Format**

A data frame with 6 observations on the following 69 variables.

site a numeric vector

Leptochiton.sp. a numeric vector

Ischnochiton..Ischnochiton..erythronotus a numeric vector

Arcidae.sp. a numeric vector

Arca.imbricata a numeric vector

Barbatia.domingensis a numeric vector

Bentharca.sp. a numeric vector

Arcopsis.adamsi a numeric vector

Crenella.sp. a numeric vector

Anomia.sp.. a numeric vector

Carditopsis.smithii a numeric vector

Lucinidae.. a numeric vector

Chama.sinuosa a numeric vector

Chama.sp. a numeric vector

Galeommatidae.sp. a numeric vector

Chione.elevata a numeric vector

Semele.bellastrata a numeric vector

Gastropoda.sp..1.. a numeric vector

Gastropoda.sp..2.. a numeric vector

Gastropoda.sp..3.. a numeric vector

Diodora.minuta a numeric vector

Diodora.sp... a numeric vector

Scissurella.redferni a numeric vector

Synaptocochlea.picta a numeric vector



Lodderena.ornata a numeric vector  
Cerithium.sp... a numeric vector  
Sansonia.tuberculata a numeric vector  
Iniforis.turrithomae a numeric vector  
Metaxia.rugulosa a numeric vector  
Cerithiopsis.cf..iuxtafuniculata a numeric vector  
Cerithiopsis.sp. a numeric vector  
Vermetidae.incertae.sedis.irregularis a numeric vector  
Dendropoma.corrodens a numeric vector  
Vermetid.sp..C a numeric vector  
Petalocochnus.mcginnyi a numeric vector  
Thylacodes.sp. a numeric vector  
Alvania.auberiana a numeric vector  
Alvania.colombiana a numeric vector  
Alvania.sp. a numeric vector  
Simulamereleina.caribaea a numeric vector  
Schwartziella.fischeri a numeric vector  
Zebina.browniana a numeric vector  
Zebina.sp. a numeric vector  
Caecum.circumvolutum a numeric vector  
Caecum.donmoorei a numeric vector  
Caecum.floridanum a numeric vector  
Caecum.johnsoni a numeric vector  
Caecum.pulchellum a numeric vector  
Caecum.textile a numeric vector  
Caecum.sp..B a numeric vector  
Meioceras.nitidum a numeric vector  
Cochliolepis.striata a numeric vector  
Parviturboides.interruptus a numeric vector  
Vitrinella.sp. a numeric vector  
Gibberula.lavalleeana a numeric vector  
Prunum.apicinum a numeric vector  
Volvarina.avena a numeric vector  
Astyris.lunata a numeric vector  
Phrontis.albus a numeric vector  
Phrontis.sp. a numeric vector  
Trachypollia.sp... a numeric vector

Turridae.sp..1 a numeric vector  
Turridae.sp..2.. a numeric vector  
Turridae.sp..3.. a numeric vector  
Ammonicera.lineofuscata a numeric vector  
Ammonicera.minortalis a numeric vector  
Rissoella.galba a numeric vector  
Pyramidellidae.sp. a numeric vector  
Pseudoscilla.babylonia a numeric vector

### Details

Cayo Nuevo is a small reef cay located 240 km off the North-Western coast of Yucatan. Data correspond to a study about the biodiversity of marine benthic reef habitats off the Yucatan shelf (Ortigosa, Suarez-Mozo, Barrera et al. 2018).

### Source

<https://doi.org/10.3897/zookeys.779.24562>

### References

Ortigosa, D., Suarez-Mozo, N. Y., Barrera, N. C., & Simoes, N. (2018). First survey of Interstitial molluscs from Cayo Nuevo, Campeche Bank, Gulf of Mexico. *Zookeys*, 779. doi:10.3897/zookeys.779.24562

### Examples

```
data(micromollusk)
```

---

pilot

*Epibionts on Caribbean mangrove roots: pilot data*

---

### Description

Data corresponds to a pilot study about epibenthic organisms in mangrove roots from Laguna de La Restinga National Park, Venezuela (Guerra-Castro et al. 2011).

### Usage

```
data("pilot")
```

**Format**

A data frame with 180 observations on the following 118 variables.

Sector a factor with levels E I M

Site a numeric vector

sp1 a numeric vector

sp2 a numeric vector

sp3 a numeric vector

sp4 a numeric vector

sp5 a numeric vector

sp6 a numeric vector

sp7 a numeric vector

sp8 a numeric vector

sp9 a numeric vector

sp10 a numeric vector

sp11 a numeric vector

sp12 a numeric vector

sp13 a numeric vector

sp14 a numeric vector

sp15 a numeric vector

sp16 a numeric vector

sp17 a numeric vector

sp18 a numeric vector

sp19 a numeric vector

sp20 a numeric vector

sp21 a numeric vector

sp22 a numeric vector

sp23 a numeric vector

sp24 a numeric vector

sp25 a numeric vector

sp26 a numeric vector

sp27 a numeric vector

sp28 a numeric vector

sp29 a numeric vector

sp30 a numeric vector

sp31 a numeric vector

sp32 a numeric vector

sp33 a numeric vector

sp34 a numeric vector  
sp35 a numeric vector  
sp36 a numeric vector  
sp37 a numeric vector  
sp38 a numeric vector  
sp39 a numeric vector  
sp40 a numeric vector  
sp41 a numeric vector  
sp42 a numeric vector  
sp43 a numeric vector  
sp44 a numeric vector  
sp45 a numeric vector  
sp46 a numeric vector  
sp47 a numeric vector  
sp48 a numeric vector  
sp49 a numeric vector  
sp50 a numeric vector  
sp51 a numeric vector  
sp52 a numeric vector  
sp53 a numeric vector  
sp54 a numeric vector  
sp55 a numeric vector  
sp56 a numeric vector  
sp57 a numeric vector  
sp58 a numeric vector  
sp59 a numeric vector  
sp60 a numeric vector  
sp61 a numeric vector  
sp62 a numeric vector  
sp63 a numeric vector  
sp64 a numeric vector  
sp65 a numeric vector  
sp66 a numeric vector  
sp67 a numeric vector  
sp68 a numeric vector  
sp69 a numeric vector  
sp70 a numeric vector

sp71 a numeric vector  
sp72 a numeric vector  
sp73 a numeric vector  
sp74 a numeric vector  
sp75 a numeric vector  
sp76 a numeric vector  
sp77 a numeric vector  
sp78 a numeric vector  
sp79 a numeric vector  
sp80 a numeric vector  
sp81 a numeric vector  
sp82 a numeric vector  
sp83 a numeric vector  
sp84 a numeric vector  
sp85 a numeric vector  
sp86 a numeric vector  
sp87 a numeric vector  
sp88 a numeric vector  
sp89 a numeric vector  
sp90 a numeric vector  
sp91 a numeric vector  
sp92 a numeric vector  
sp93 a numeric vector  
sp94 a numeric vector  
sp95 a numeric vector  
sp96 a numeric vector  
sp97 a numeric vector  
sp98 a numeric vector  
sp99 a numeric vector  
sp100 a numeric vector  
sp101 a numeric vector  
sp102 a numeric vector  
sp103 a numeric vector  
sp104 a numeric vector  
sp105 a numeric vector  
sp106 a numeric vector  
sp107 a numeric vector

sp108 a numeric vector  
sp109 a numeric vector  
sp110 a numeric vector  
sp111 a numeric vector  
sp112 a numeric vector  
sp113 a numeric vector  
sp114 a numeric vector  
sp115 a numeric vector  
sp116 a numeric vector

### Details

Data consists of the coverage (by point-intercept) of 116 taxa identified in 180 mangrove roots, sampled under a hierarchically nested spatial design that included six random sites within each of three sectors of the lagoon system corresponding to a strong environmental gradient: external (E), intermediate (M), and internal (I). The abundance of epibenthic organisms of 10 roots were described within each site, producing a total of 60 roots in each sector. The analysis of these pilot data defined the sampling design used by Guerra-Castro et al. (2016).

### Source

<https://www.interciencia.net/wp-content/uploads/2018/01/923-GUERRA-8.pdf>

### References

Guerra-Castro, E., J. J. Cruz-Motta, and J. E. Conde. 2011. Cuantificación de la diversidad de especies incrustantes asociadas a las raíces de *Rhizophora mangle* L. en el Parque Nacional Laguna de La Restinga. *Interciencia* 36:923-930.

Guerra-Castro, E. J., J. E. Conde, and J. J. Cruz-Motta. (2016). Scales of spatial variation in tropical benthic assemblages and their ecological relevance: epibionts on Caribbean mangrove roots as a model system. *Marine Ecology Progress Series* 548:97-110.

### Examples

```
data(pilot)  
str(pilot)
```

---

plot_ssp	<i>SSP plot</i>
----------	-----------------

---

### Description

Plotting MultSE and sampling effort relationships of simulated data

### Usage

```
plot_ssp(xx, opt, multi.site)
```

### Arguments

xx	A data frame generated by <a href="#">summary_ssp</a>
opt	A vector or data matrix generated by <a href="#">ioptimum</a>
multi.site	Logical argument indicating whether several sites were simulated

### Details

This function allows to visualize the behavior of the MultSE as sampling effort increases. When the simulation involves two sampling scales, a graph for samples and one for sites will be generated. Above the MultSE~Sampling effort projection, two shaded areas are drawn, highlighting: sub-optimal improvement (light grey), and optimal improvement (dark gray). Both reflect the sampling effort that improves the precision at acceptable (light gray) or desirable levels (dark gray), but beyond the later, any gain could be considered unnecessary. In addition, for each sampling effort, the relativized improvement (in relation to the MultSE estimated with the lower sampling effort) is presented cumulatively (as percentages). This is very useful because it indicates exactly how much the precision is improved for each sampling effort. The plot is generated using [ggplot2](#).

### Value

A [ggplot2](#) object

### Note

This is an exploratory plot that can be edited using [ggplot2](#) functions.

### Author(s)

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaró (mmm@ciencias.unam.mx)

### References

Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaró. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.2003.2019.996991](#).

Wickham, H. 2016. [ggplot2: elegant graphics for data analysis](#). Springer.

**See Also**[ggplot2](#)**Examples**

```

###To speed up the simulation of these examples, the cases, sites and N were set small.

##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)

#Estimation of parameters of pilot data
par.mic<-asempar (data = micromollusk,
                  type= "P/A",
                  Sest.method = "average")

#Simulation of 3 data sets, each one with 20 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases= 3, N = 20, sites = 1)

#Sampling and estimation of MultSE for each sample size (few repetitions
#to speed up the example)

sam.mic<-samspd(dat.sim = sim.mic,
                Par = par.mic,
                transformation = "P/A",
                method = "jaccard",
                n = 10,
                m = 1,
                k = 3)

#Summary of MultSE for each sampling effort
summ.mic<-summary_ssp(results = sam.mic, multi.site = FALSE)

#Cut-off points to identify optimal sampling effort
opt.mic<-ioptimum(xx = summ.mic, multi.site = FALSE)

#Plot
plot_ssp(xx = summ.mic, opt = opt.mic, multi.site = FALSE)

##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)

#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                 type= "counts",
                 Sest.method = "average")

#Simulation of 3 data sets, each one with 10 potential sampling units in 3 sites.
sim.spo<-simdata(par.spo, cases= 3, N = 10, sites = 3)

#Sampling and estimation of MultSE for each sampling design (few repetitions
#to speed up the example)

```



```

sam.spo<-sampsd(dat.sim = sim.spo,
                Par = par.spo,
                transformation = "square root",
                method = "bray",
                n = 10,
                m = 3,
                k = 3)

#Summary of MultSE for each sampling effort
summ.spo<-summary_ssp(results = sam.spo, multi.site = TRUE)

#Cut-off points to identify optimal sampling effort
opt.spo<-ioptimum(xx = summ.spo, multi.site = TRUE)

#Plot
plot_ssp(xx = summ.spo, opt = opt.spo, multi.site = TRUE)

```

---

sampsd	<i>Sampling Simulated Data and Estimates of Multivariate Standard Errors</i>
--------	--

---

## Description

Each set of simulated data is sampled many times for each sampling effort, from 2 replicates to those defined as an argument in the function. Then, distance-based multivariate standard errors are estimated using pseudo-variance (for single site evaluation) or Mean Squares Estimates in a linear model (for multisite evaluation).

## Usage

```
sampsd(dat.sim, Par, transformation, method, n, m, k)
```

## Arguments

dat.sim	A list of data sets generated by <a href="#">simdata</a>
Par	A list of parameters estimated by <a href="#">assempar</a>
transformation	Mathematical function to reduce the weight of very dominant species: 'square root', 'fourth root', 'Log (X+1)', 'P/A', 'none'
method	The appropriate distance/dissimilarity metric (e.g. Gower, Bray–Curtis, Jaccard, etc). The function <a href="#">vegdist</a> is called for that purpose.
n	Maximum number of samples to take at each site. Can be equal or less than N
m	Maximum number of sites to sample at each data set. Can be equal or less than sites
k	Number of repetitions of each sampling effort (samples and sites) for each data set

## Details

If several virtual sites have been generated, subsets of sites of size 2 to  $m$  are sampled, followed by the selection of sampling units (from 2 to  $n$ ) using inclusion probabilities and self-weighted two-stage sampling (Tille, 2006). Each combination of sampling effort (number of sample units and sites), are repeated several times (e.g.  $k = 100$ ) for all simulated matrices. If simulated data correspond to a single site, sampling without replacement is performed several times (e.g.  $k = 100$ ) for each sample size (from 2 to  $n$ ) within each simulated matrix. This approach is computationally intensive, especially when  $k$  is high ( $> 10$ ). Keep this in mind as it will affect the time to get results. For each sample, suitable pre-treatments are applied and distance/similarity matrices constructed using the appropriate coefficient. When simulations are done for a single site, the MultSE is estimated as  $\sqrt{(V/n)}$ , being  $V$  the pseudo variance measured at each sample of size  $n$  (Anderson & Santana-Garcon, 2015). When several sites were generated, MultSE are estimated using the residual mean squares and the sites mean squares from a PERMANOVA model (Anderson & Santana-Garcon, 2015).

## Value

`mse.results` A matrix including all estimated MultSE for each simulated data, combination of sample replicates and sites for each  $k$  repetition. This matrix will be used by [summary\\_ssp](#)

## Note

For quick exploratory analyzes, keep the number of repetitions small. Once you have explored the behavior of the MultSE, you can repeat the process keeping  $k$ -values large (e.g. 100). This process will take some time and it will depend on the power of your computer.

## Author(s)

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaro (mmm@ciencias.unam.mx).

## References

- Anderson, M.J. & Santana-Garcon, J. (2015) Measures of precision for dissimilarity-based multivariate analysis of ecological communities. *Ecology Letters*, 18, 66-73
- Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaro. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.2003.2019.996991](https://doi.org/10.1101/2020.2003.2019.996991).
- Tillé, Y. (2006). *Sampling algorithms*. Springer, New York, NY.

## See Also

[assempar](#), [simdata](#), [summary\\_ssp](#), [vegdist](#)

## Examples

```
###To speed up the simulation of these examples, the cases, sites and n were set small.

##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)

#Estimation of parameters of pilot data
par.mic<-asempar (data = micromollusk,
                  type= "P/A",
                  Sest.method = "average")

#Simulation of 3 data sets, each one with 20 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases = 3, N = 20, sites = 1)

#Sampling and estimation of MultSE for each sample size (few repetitions to speed up the example)
sam.mic<-samprsd(dat.sim = sim.mic,
                 Par = par.mic,
                 transformation = "P/A",
                 method = "jaccard",
                 n = 10,
                 m = 1,
                 k = 3)

##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)

#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                 type= "counts",
                 Sest.method = "average")

#Simulation of 3 data sets, each one with 20 potential sampling units in 3 sites.
sim.spo<-simdata(par.spo, cases = 3, N = 20, sites = 3)

#Sampling and estimation of MultSE for each sampling design (few
#repetitions to speed up the example)

sam.spo<-samprsd(dat.sim = sim.spo,
                 Par = par.spo,
                 transformation = "square root",
                 method = "bray",
                 n = 10,
                 m = 3,
                 k = 3)
```

## Description

The function simulates data sets (as many as requested) using estimated parameters from the list generated by [assemblpar](#). The function returns an object of class `list` that includes all the simulated data to be used by [datquality](#) and [samprsd](#).

## Usage

```
simdata(Par, cases, N, sites)
```

## Arguments

Par	A list of parameters estimated by <a href="#">assemblpar</a>
cases	Number of data sets to be simulated
N	Total number of samples to be simulated in each site
sites	Total number of sites to be simulated in each data set

## Details

The presence/absence of each species at each site are simulated with Bernoulli trials and probability of success equals to the empirical frequency of occurrence of each species among sites in the pilot data. For sites with the presence of a particular species, Bernoulli trials are used (with a probability of success equal to the estimated empirical frequency within the sites where it appears), to simulate the distribution of the species at that site. Once created, the P/A matrices are converted to matrices of abundances replacing presences by random values from an adequate statistical distribution and parameters equal to those estimated in the pilot data. Simulations of counts of individuals are generated using Poisson or negative binomial distributions, depending on the degree of aggregation of each species in the pilot data (McArdle & Anderson 2004; Anderson & Walsh 2013). Simulations of continuous variables (i.e. coverage, biomass), are generated using the log-normal distribution. The simulation procedure is repeated to generate as many simulated data matrices as needed.

## Value

`simulated.data` The function returns an object of class `List`, that includes all simulated data. This object will be used by [samprsd](#) and [datquality](#)

## Note

This approach is not free from assumptions. Simulations do not consider any environmental constraint, neither co-occurrence structure of species. It is assumed that potential differences in species composition/abundance among samples and sites are mainly due to spatial aggregation of species, as estimated from the pilot data. Hence, any ecological property of the assemblage that was not captured by the pilot data, will not be reflected in the simulated data. Associations among species can be modeled using copulas, as suggested by Anderson et al (2019), which could be included in an upcoming version of SSP.

## Author(s)

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaró (mmm@ciencias.unam.mx).

## References

Anderson, M. J., & Walsh, D. C. I. (2013). PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: What null hypothesis are you testing? *Ecological Monographs*, 83(4), 557-574.

Anderson, M. J., P. de Valpine, A. Punnett, & Miller, A. E. (2019). A pathway for multivariate analysis of ecological communities using copulas. *Ecology and Evolution* 9:3276-3294.

Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaro. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. *bioRxiv:2020.2003.2019.996991*.

McArdle, B. H., & Anderson, M. J. (2004). Variance heterogeneity, transformations, and models of species abundance: a cautionary tale. *Canadian Journal of Fisheries and Aquatic Sciences*, 61, 1294-1302.

## See Also

[samprsd, datquality](#)

## Examples

```
###To speed up the simulation of these examples, the cases, sites and N were set small.
```

```
##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)  
data(micromollusk)
```

```
#Estimation of parameters of pilot data  
par.mic<-asempar(data = micromollusk,  
                 type= "P/A",  
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 10 potential sampling units from a single site  
sim.mic<-simdata(par.mic, cases = 3, N = 10, sites = 1)
```

```
##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).  
data(sponges)
```

```
#Estimation of parameters of pilot data  
par.spo<-asempar (data = sponges,  
                 type= "counts",  
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 10 potential sampling units in 3 sites.  
sim.spo<-simdata(par.spo, cases = 3, N = 10, sites = 3)
```

---

sponges	<i>Sponges in Alacranes Reef National Park (ARNP), Gulf of Mexico, Mexico</i>
---------	---

---

**Description**

Counts of 41 species of sponges in 36 transects of 20 m \* 1 m across 8 sites around ARNP

**Usage**

```
data("sponges")
```

**Format**

A data frame with 36 observations on the following 42 variables.

site Factor w/ 6 levels

Agelas.clathrodes a numeric vector

Agelas.dispar a numeric vector

Agelas.tubulata a numeric vector

Agelas.wiedenmayeri a numeric vector

Aiolocroia.crassa a numeric vector

Amphimedon.copressa a numeric vector

Aplysina.archeri a numeric vector

Aplysina.cauliformis a numeric vector

Aplysina.fistularis a numeric vector

Aplysina.fulva a numeric vector

Aplysina.insularis a numeric vector

Aplysina.lacunosa a numeric vector

Callyspongia.plicifera a numeric vector

Callyspongia.vaginalis a numeric vector

Callispongia.fallax a numeric vector

Callispongia.armigera a numeric vector

Cliona.delitrix a numeric vector

Cliona.varians a numeric vector

Cribochalina.vascolum a numeric vector

Drarmacidon.sp. a numeric vector

Dysidea.variabilis a numeric vector

Ectyoplasia.ferox a numeric vector

Geodia.neptuni a numeric vector

Hymeniacidon.caerulea a numeric vector  
Iotrochota.birotulata a numeric vector  
Igernella.notabilis a numeric vector  
Ircinia.felix a numeric vector  
Ircinia.strobilina a numeric vector  
Monanchora.arbuscula a numeric vector  
Mycale.laxissima a numeric vector  
Mycale.laevis a numeric vector  
Nipahtes.amorpha a numeric vector  
Niphates.erecta a numeric vector  
Niphathes.digitalis a numeric vector  
Phorbas.amaranthus a numeric vector  
Scopalina.rutzleri a numeric vector  
Svenezzea.flava a numeric vector  
Spirastrella.coccinea a numeric vector  
Verongula.reswigi a numeric vector  
Verongula.rigida a numeric vector  
Xestospongia.muta a numeric vector

### Details

This data corresponds to a pilot study about sponge biodiversity in reef habitats in the Yucatán shelf (Ugalde et al., 2015)

### Source

<https://biotaxa.org/Zootaxa/article/view/zootaxa.3911.2.1>

### References

Ugalde, D., Gomez, P., & Simoes, N. (2015). Marine sponges (Porifera: Demospongiae) from the Gulf of Mexico, new records and redescription of *Erylus trisphaerus* (de Laubenfels, 1953). *Zootaxa*, 3911(2), 151-183.

### Examples

```
data(sponges)  
str(sponges)
```

---

`summary_ssp`*Summary of MultSE for Each Sampling Effort in Simulated Data Sets*

---

**Description**

For each simulated data set, averages of MultSE are estimated for each sampling size. Then an overall mean, as well as lower and upper intervals of means for each sample size are tabulated. A relativization to the maximum is applied to the average MultSE and a numerical derivative, using a forward finite difference, of the resulting quantity is obtained.

**Usage**

```
summary_ssp(results, multi.site)
```

**Arguments**

<code>results</code>	A matrix generated by <code>sampsd</code>
<code>multi.site</code>	Logical argument indicating whether several sites were simulated

**Details**

For each set of simulated data, the average of the MultSE in each sampling effort is estimated (Anderson & Santana-Garcon 2015). Then, an overall mean, lower and upper quantiles of means are tabulated for each sampling effort among all simulated data. In order to have a general and comparable criteria to evaluate the rate of change of the average MultSE with respect to the sampling effort, a relativization to the maximum MultSE (obtained with the lower sampling effort) is calculated; then, a standard forward finite derivation is calculated.

**Value**

<code>mse.results</code>	A data frame including the summary of multivariate standard error for each sampling effort.
--------------------------	---

**Note**

This data frame can then be used to plot MultSE with respect to the sampling effort

**Author(s)**

Edlin Guerra-Castro (edlinguerra@gmail.com), Juan Carlos Cajas, Juan Jose Cruz-Motta, Nuno Simoes and Maite Mascaró (mmm@ciencias.unam.mx).

**References**

Anderson, M.J. & Santana-Garcon, J. (2015) Measures of precision for dissimilarity-based multivariate analysis of ecological communities. *Ecology Letters*, 18, 66-73

Guerra-Castro, E. J., J. C. Cajas, F. N. Dias Marques Simoes, J. J. Cruz-Motta, and M. Mascaró. (2020). SSP: An R package to estimate sampling effort in studies of ecological communities. [bioRxiv:2020.03.20.1996991](https://doi.org/10.1101/2020.03.20.1996991).



**See Also**

[sampsd](#), [ioptimum](#)

**Examples**

```
###To speed up the simulation of these examples, the cases, sites and n were set small.
```

```
##Single site: micromollusk from Cayo Nuevo (Yucatan, Mexico)
data(micromollusk)
```

```
#Estimation of parameters of pilot data
par.mic<-asempar (data = micromollusk,
                 type= "P/A",
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 20 potential sampling units from a single site
sim.mic<-simdata(par.mic, cases= 3, N = 10, sites = 1)
```

```
#Sampling and estimation of MultSE for each sample size (few repetitions
#to speed up the example)
```

```
sam.mic<-sampsd(dat.sim = sim.mic,
               Par = par.mic,
               transformation = "P/A",
               method = "jaccard",
               n = 10,
               m = 1,
               k = 3)
```

```
#Summary of MultSE for each sampling effort
summ.mic<-summary_ssp(results = sam.mic, multi.site = FALSE)
```

```
##Multiple sites: Sponges from Alacranes National Park (Yucatan, Mexico).
data(sponges)
```

```
#Estimation of parameters of pilot data
par.spo<-asempar(data = sponges,
                 type = "counts",
                 Sest.method = "average")
```

```
#Simulation of 3 data sets, each one with 20 potential sampling units in 3 sites.
sim.spo<-simdata(par.spo, cases= 3, N = 20, sites = 3)
```

```
#Sampling and estimation of MultSE for each sampling design (few repetitions
#to speed up the example)
```

```
sam.spo<-sampsd(dat.sim = sim.spo,
               Par = par.spo,
               transformation = "square root",
               method = "bray",
               n = 10,
               m = 3,
```

```
      k = 3)  
  
#Summary of MultSE for each sampling effort  
summ.spo<-summary_ssp(results = sam.spo, multi.site = TRUE)
```

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