## Appendix 1: Data on papers using SES

The aim of the review was to illustrate that most authors that use SES are not aware that SES assumes symmetry of null-distributions. To this purpose, I collected ecological papers that use SES. I searched Scopus for papers citing Gotelli and MacCabe (2002). I found 143 such papers published in 2015 or later. Three of them could not be accessed and two of them were not written in English. All 138 papers were downloaded and I have read their Methods sections to determine if they used SES or not. Note that Gotelli and MacCabe (2002) is not a methodological paper, its main purpose was testing Diamond's hypothesis that species co-occurrence pattern is non-random. More than half of the downloaded papers cite their biological result (i.e. often there are less co-occurrences than expected in random assembly), and only 63 of 138 papers used SES.

I also checked if each manuscript used SES to estimate p-values. Note that if SES was used for estimating p-values, normality of the null-distribution has to be assumed, not only symmetry. If there was any ambiguity (i.e. the methods section was not detailed enough), I categorized the paper as "not use". I also analyzed if the manuscript checked/assumed normality or symmetry.

The results of this review are summarized in the following table:

| | **Paper** | **Did it use SES for estimating p-value?** | **Did it check/assume symmetry or normality?** |
|---|---|---|---|
| 1 | Šímová I., Violle C., Kraft N.J.B., Storch D., Svenning J.-C., Boyle B., Donoghue J.C., Jørgensen P., McGill B.J., Morueta-Holme N., Piel W.H., Peet R.K., Regetz J., Schildhauer M., Spencer N., Thiers B., Wiser S., Enquist B.J. 2015. Shifts in trait means and variances in North American tree assemblages: Species richness patterns are loosely related to the functional space. *Ecography* **38**:649-658 | Y | checked (normality) |
| 2 | Lavender T.M., Schamp B.S., Lamb E.G. 2016. The influence of matrix size on statistical properties of co-occurrence and limiting similarity null models. *PLoS ONE* **11**:e151146 | Y | assumed (normality) |
| 3 | Long W., Xiong M., Zang R., Schamp B.S., Yang X., Ding Y., Huang Y., Xiang Y. 2015. Changes in Patterns of Species Co-occurrence across Two Tropical Cloud Forests Differing in Soil Nutrients and Air Temperature. *Biotropica* **47**:416-423 | Y | assumed (normality) |
| 4 | Ulrich W., Jabot F., Gotelli N.J. 2017. Competitive interactions change the pattern of species co-occurrences under neutral dispersal. *Oikos* **126**:91-100 | Y | assumed (normality) |
| 5 | Gao M., Liu D., Lin L., Wu D. 2016. The small-scale structure of a soil mite metacommunityEuropean. *Journal of Soil Biology* **74**:69-75 | Y | assumed (normality) |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| 6 | Spickett A., Junker K., Krasnov B.R., Haukisalmi V., Matthee S 2017. Community structure of helminth parasites in two closely related South African rodents differing in sociality and spatial behaviour. *Parasitology Research* **116**:2299-2312 | N | assumed (normality) |
| 7 | Breton E., Christaki U., Bonato S., Didry M., Artigas L.F. 2017. Functional trait variation and nitrogen use efficiency in temperate coastal phytoplankton. *Marine Ecology Progress Series* **563**:35-49 | N | assumed (normality) |
| 8 | Polly P.D., Fuentes-Gonzalez J., Lawing A.M., Bormet A.K., Dundas R.G. 2017. Clade sorting has a greater effect than local adaptation on ecometric patterns in Carnivora. *Evolutionary Ecology Research* **18**:61-95 | N (because worrying in normality) | N |
| 9 | Kwon T.-S. 2018. High competition between ant species at intermediate temperatures. *Journal of Thermal Biology* **72**:59-66 | Y | N |
| 10 | Marteinsdóttir B., Svavarsdóttir K., Thórhallsdóttir T.E. 2018. Multiple mechanisms of early plant community assembly with stochasticity driving the process. *Ecology* **99**: 91-102 | Y | N |
| 11 | Henriques D.S.G., Rigal F., Borges P.A.V., Ah-Peng C., Gabriel R. 2017. Functional diversity and composition of bryophyte water-related traits in Azorean native vegetation. *Plant Ecology and Diversity* **10**:127-137 | Y | N |
| 12 | Aiello-Lammens M.E., Slingsby J.A., Merow C., Mollmann H.K., Euston-Brown D., Jones C.S., Silander J.A., Jr. 2017. Processes of community assembly in an environmentally heterogeneous, high biodiversity region. *Ecography* **40**:561-576 | Y | N |
| 13 | Echevarría G.E., González N. 2017. Co-occurrence patterns of fish communities in littorals of three floodplain lakes of the Orinoco River, Venezuela. *Journal of Threatened Taxa* **9**:10249-10260 | Y | N |
| 14 | Hoppeler F., Tachamo Shah R.D., Shah D.N., Jähnig S.C., Tonkin J.D., Sharma S., Pauls S.U. 2016. Environmental and spatial characterisation of an unknown fauna using DNA sequencing – an example with Himalayan Hydropsychidae (Insecta: Trichoptera). *Freshwater Biology* **61**:1905-1920 | Y | N |
| 15 | Castelin M., Van Steenkiste N., Pante E., Harbo R., Lowe G., Gilmore S.R., Therriault T.W., Abbott C.L. 2016. A new | Y | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| | integrative framework for large-scale assessments of biodiversity and community dynamics, using littoral gastropods and crabs of British Columbia, Canada. *Molecular Ecology Resources* **16**:1322-1339 | | |
| 16 | Jeanbille M., Gury J., Duran R., Tronczynski J., Agogué H., Saïd O.B., Ghiglione J.-F., Auguet J.-C. 2016. Response of core microbial consortia to chronic hydrocarbon contaminations in coastal sediment habitats. *Frontiers in Microbiology* **7**:1637 | Y | N |
| 17 | Bringloe T.T., Adamowicz S.J., Harvey V.F.I., Jackson J.K., Cottenie K. 2016. Detecting signatures of competition from observational data: A combined approach using DNA barcoding, diversity partitioning and checkerboards at small spatial scales. *Freshwater Biology* **61**:646-657 | Y | N |
| 18 | Briscoe Runquist R., Grossenbacher D., Porter S., Kay K., Smith J. 2016. Pollinator-mediated assemblage processes in California wildflowers. *Journal of Evolutionary Biology* **29**:1045-1058 | Y | N |
| 19 | Dambros C.S., Morais J.W., Vasconcellos A., Souza J.L.P., Franklin E., Gotelli N.J. 2016. Association of Ant Predators and Edaphic Conditions with Termite Diversity in an Amazonian Rain Forest. *Biotropica* **48**: 237-245 | Y | N |
| 20 | Mudrák O., Janeček S., Götzenberger L., Mason N.W.H., Horník J., de Castro I., Doležal J., Klimešová J., de Bello F. 2016. Fine-scale coexistence patterns along a productivity gradient in wet meadows: Shifts from trait convergence to divergence. *Ecography* **39**:338-348 | Y | N |
| 21 | Fillol M., Auguet J.-C., Casamayor E.O., Borrego C.M. 2016. Insights in the ecology and evolutionary history of the Miscellaneous Crenarchaeotic Group lineage. *ISME Journal* **10**:665-677 | Y | N |
| 22 | Barnard K., Krasnov B.R., Goff L., Matthee S. 2015. Infracommunity dynamics of chiggers (Trombiculidae) parasitic on a rodent. *Parasitology* **142**:1605-1611 | Y | N |
| 23 | Satdichanh M., Millet J., Heinimann A., Nanthavong K., Harrison R.D. 2015. Using plant functional traits and phylogenies to understand patterns of plant community assembly in a seasonal tropical forest in Lao PDR. *PLoS ONE* | Y | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| | **10**:e0130151 | | |
| 24 | Heino J., Soininen J., Alahuhta J., Lappalainen J., Virtanen R. 2015. A comparative analysis of metacommunity types in the freshwater realm. *Ecology and Evolution* **5**:1525-1537 | Y | N |
| 25 | Jung T.S., Hegel T.M., Stotyn S.A., Czetwertynski S.M. 2015. Co-occurrence of reintroduced and resident ungulates on a shared winter range in northwestern Canada. *Ecoscience* **22**:7-16 | Y | N |
| 26 | Mahaut L., Fried G., Gaba S. 2018. Patch dynamics and temporal dispersal partly shape annual plant communities in ephemeral habitat patches. *Oikos* **127**:147-159 | N | N |
| 27 | Hu A., Ju F., Hou L., Li J., Yang X., Wang H., Mulla S.I., Sun Q., Bürgmann H., Yu C.-P. 2017. Strong impact of anthropogenic contamination on the co-occurrence patterns of a riverine microbial community. *Environmental Microbiology* **19**:4993-5009 | N | N |
| 28 | Ribeiro J., Colli G.R., Caldwell J.P., Ferreira E., Batista R., Soares A. 2017. Evidence of neotropical anuran community disruption on rice crops: a multidimensional evaluation. *Biodiversity and Conservation* **26**:3363-3383 | N | N |
| 29 | Ulrich W., Kryszewski W., Sewerniak P., Puchałka R., Strona G., Gotelli N.J. 2017. A comprehensive framework for the study of species co-occurrences, nestedness and turnover *Oikos* **126**:1607-1616 | N | N |
| 30 | Papanikolaou A.D., Kuhn I., Frenzel M., Kuhlmann M., Poschlod P., Potts S.G., Roberts S.P.M., Schweiger O. 2017. Wild bee and floral diversity co-vary in response to the direct and indirect impacts of land use. *Ecosphere* **8**: e02008 | N | N |
| 31 | Favre-Bac L., Mony C., Burel F., Seimandi-Corda G., Ernoult A. 2017. Connectivity drives the functional diversity of plant dispersal traits in agricultural landscapes: the example of ditch metacommunitiesLandscape. *Ecology* **32**:2029-2040 | N | N |
| 32 | Pakeman R.J., Hewison R.L., Riach D., Fisher J.M., Hurskainen S., Fielding D.A., Mitchell R.J. 2017. Long-term functional structure and functional diversity changes in Scottish grasslands. *Agriculture, Ecosystems and Environment* **247**:352:362 | N | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| 33 | Concepción E.D., Götzenberger L., Nobis M.P., de Bello F., Obrist M.K., Moretti M. 2017. Contrasting trait assembly patterns in plant and bird communities along environmental and human-induced land-use gradients. *Ecography* **40**:753-763 | N | N |
| 34 | Valdivia N., Segovia-Rivera V., Fica E., Bonta C.C., Aguilera M.A., Broitman B.R. 2017. Context-dependent functional dispersion across similar ranges of trait space covered by intertidal rocky shore communities. *Ecology and Evolution* **7**:1882-1891 | N | N |
| 35 | Zhang H., Zhu S., John R., Li R., Liu H., Ye Q., 2017. Habitat filtering and exclusion of weak competitors jointly explain fern species assemblage along a light and water gradient. *Scientific Reports* **7**:298 | N | N |
| 36 | Yan Q., Li J., Yu Y., Wang J., He Z., Van Nostrand J.D., Kempher M.L., Wu L., Wang Y., Liao L., Li X., Wu S., Ni J., Wang C., Zhou J. 2016. Environmental filtering decreases with fish development for the assembly of gut microbiota. *Environmental Microbiology* **18**:4739-4754 | N | N |
| 37 | de Miguel J.M., Martín-Forés I., Acosta-Gallo B., del Pozo A., Ovalle C., Sánchez-Jardón L., Castro I., Casado M.A. 2016. Non-random co-occurrence of native and exotic plant species in Mediterranean grasslands. *Acta Oecologica* **77**:18-26 | N | N |
| 38 | Sfair J.C., Rosado B.H.P., Tabarelli M. 2016. The effects of environmental constraints on plant community organization depend on which traits are measured. *Journal of Vegetation Science* **27**:1264-1274 | N | N |
| 39 | Rolo V., Rivest D., Lorente M., Kattge J., Moreno G. 2016. Taxonomic and functional diversity in Mediterranean pastures: insights on the biodiversity–productivity trade-off. *Journal of Applied Ecology* **53**:1575-1584 | N | N |
| 40 | Aiba M., Kurokawa H., Onoda Y., Oguro M., Nakashizuka T., Masaki T. 2016. Context-dependent changes in the functional composition of tree communities along successional gradients after land-use change. *Journal of Ecology* **104**:1347-1356 | N | N |
| 41 | Yuan Z., Gazol A., Lin F., Wang X., Ye J., Suo Y., Fang S., Mellard J., Hao Z. 2016. Scale-dependent effect of biotic interactions and environmental conditions in community assembly: insight from a large temperate forest plot. *Plant* | N | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| | *Ecology* **217**:1003-1014 | | |
| 42 | Gazol A., Uria-Diez J., Elustondo D., Garrigó J., Ibáñez R. 2016. Fertilization triggers 11 yr of changes in community assembly in Mediterranean grassland. *Journal of Vegetation Science* **27**:728-738 | N | N |
| 43 | Schamp B.S., Aarssen L.W., Piggott G.S.J., Dante S.K. 2016. The impact of non-reproductive plant species on assessments of community structure and species co-occurrence patterns. *Journal of Vegetation Science* **27**:668-678 | N | N |
| 44 | Matsuzaki S.-I.S., Sasaki T., Akasaka M. 2016. Invasion of exotic piscivores causes losses of functional diversity and functionally unique species in Japanese lakes. *Freshwater Biology* **61**:1128-1142 | N | N |
| 45 | Stoll S., Breyer P., Tonkin J.D., Früh D., Haase P. 2016. Scale-dependent effects of river habitat quality on benthic invertebrate communities - Implications for stream restoration practice. *Science of the Total Environment* **553**:495-503 | N | N |
| 46 | Li D., Waller D. 2016. Long-term shifts in the patterns and underlying processes of plant associations in Wisconsin forests. *Global Ecology and Biogeography* **25**:516-526 | N | N |
| 47 | Plass-Johnson J.G., Taylor M.H., Husain A.A.A., Teichberg M.C., Ferse S.C.A. 2016. Non-random variability in functional composition of coral reef fish communities along an environmental gradient. *PLoS ONE* **11**:e0154014 | N | N |
| 48 | Bennett J.R., Gilbert B. 2016. Contrasting beta diversity among regions: How do classical and multivariate approaches compare? *Global Ecology and Biogeography* **25**:368-377 | N | N |
| 49 | Dedieu N., Clavier S., Vigouroux R., Cerdan P., Céréghino R. 2016. A Multimetric Macroinvertebrate Index for the Implementation of the European Water Framework Directive in French Guiana, East Amazonia. *River Research and Applications* **32**:501-515 | N | N |
| 50 | Barker G.M. 2016. Land snail communities respond to control of invasive rats in New Zealand forests. *New Zealand Journal of Ecology* **40**:310-320 | N | N |
| 51 | Zhang H., Qi W., John R., Wang W., Song F., Zhou S. 2015. Using functional trait diversity to evaluate the contribution of | N | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| | multiple ecological processes to community assembly during succession. *Ecography* **38**:1176-1186 | | |
| 52 | Kreisinger J., Čízková D., Kropácková L., Albrecht T. 2015. Cloacal microbiome structure in a long-distance migratory bird assessed using deep 16sRNA pyrosequencing. *PLoS ONE* **10**:e0137401 | N | N |
| 53 | Marimon B.S., Colli G.R., Marimon-Junior B.H., Mews H.A., Eisenlohr P.V., Feldpausch T.R., Phillips O.L. 2015. Ecology of floodplain campos de murundus savanna in southern Amazonia. *International Journal of Plant Sciences* **176**:670-681 | N | N |
| 54 | Bar-Massada A. 2015. Complex relationships between species niches and environmental heterogeneity affect species co-occurrence patterns in modelled and real communities. *Proceedings of the Royal Society B: Biological Sciences* **282**: 20150927 | N | N |
| 55 | Obertegger U., Flaim G. 2015. Community assembly of rotifers based on morphological traits. *Hydrobiologia* **753**:31-45 | N | N |
| 56 | Vaz A.S., Macedo J.A., Alves P., Honrado J.P., Lomba A. 2015. Plant species segregation in dune ecosystems emphasises competition and species sorting over facilitation. *Plant Ecology and Diversity* **8**:113-125 | N | N |
| 57 | Ortega J.C.G., Dias R.M., Petry A.C., Oliveira E.F., Agostinho A.A. 2015. Spatio-temporal organization patterns in the fish assemblages of a Neotropical floodplain. *Hydrobiologia* **745**:31-41 | N | N |
| 58 | Vela A.I., Casas-Díaz E., Fernández-Garayzábal J.F., Serrano E., Agustí S., Porrero M.C., Sánchez del Rey V., Marco I., Lavín S., Domínguez L. 2015. Estimation of Cultivable Bacterial Diversity in the Cloacae and Pharynx in Eurasian Griffon Vultures (Gyps fulvus). *Microbial Ecology* **69**:597-607 | N | N |
| 59 | Palmquist K.A., Peet R.K., Mitchell S.R. 2015. Scale-dependent responses of longleaf pine vegetation to fire frequency and environmental context across two decades. *Journal of Ecology* **103**:998-1008 | N | N |
| 60 | Schamp B.S., Arnott S.E., Joslin K.L. 2015. Dispersal strength influences zooplankton co-occurrence patterns in experimental | N | N |

| | Paper | Did it use SES for estimating p-value? | Did it check/assume symmetry or normality? |
|---|---|---|---|
| | mesocosms- *Ecology* **96**:1074-1083 | | |
| 61 | Luza A.L., Gonçalves G.L., Hartz S.M. 2015. Phylogenetic and morphological relationships between nonvolant small mammals reveal assembly processes at different spatial scales. *Ecology and Evolution* **5**:889-902 | N | N |
| 62 | Carmona C.P., Mason N.W.H., Azcárate F.M., Peco B. 2015. Inter-annual fluctuations in rainfall shift the functional structure of Mediterranean grasslands across gradients of productivity and disturbance. *Journal of Vegetation Science* **26**:538-551 | N | N |
| 63 | Camarota F., Powell S., S. Melo A., Priest G., J. Marquis R., L. Vasconcelos H. 2016. Co-occurrence patterns in a diverse arboreal ant community are explained more by competition than habitat requirements. *Ecology and Evolution* **6**:8907-8918 | N | N |

**Appendix 2: The relationship of SES and p-values when normality assumption is satisfied**

The aim of this appendix is to summarize the mathematical knowledge necessary to understand arguments in the main text. Because p-values are calculated using cumulative distribution functions, I began by defining this function.

The cumulative distribution function (CDF) describes the probability that a variate X takes on a value less than or equal to a value *x*. However, any distribution can be characterized by its CDF. In textbooks continuous distributions are illustrated by their probability functions, which is simply the derivative of CDF, because probability functions are visually more different than CDFs (Figure S1). For symmetric distributions CDF($x$ = mean) = 0.5.

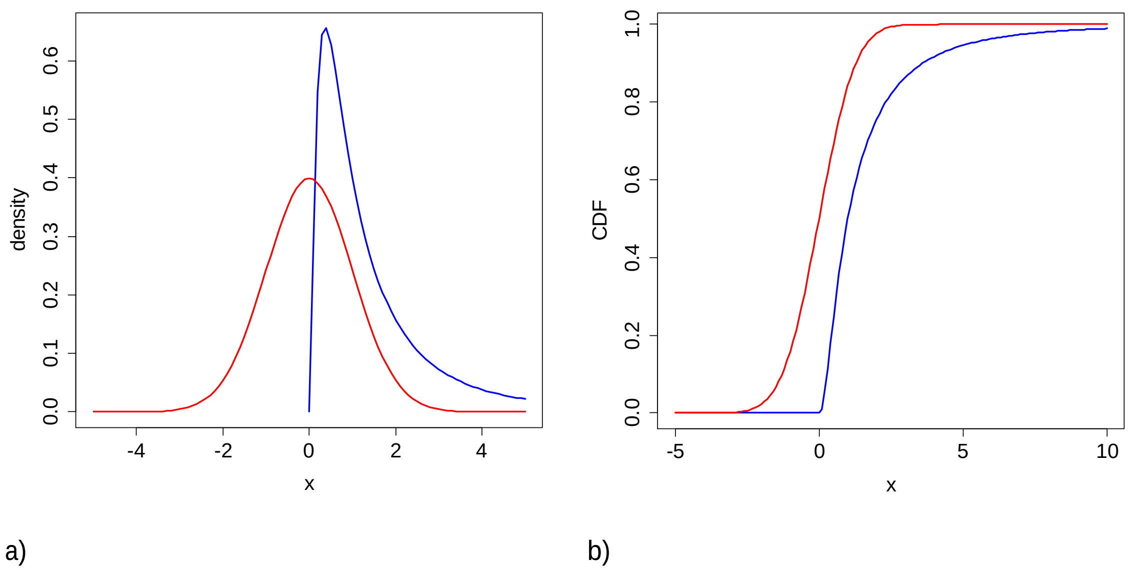


Figure S1: Density (a) and cumulative distribution function (b) of standard normal (red lines) and log-normal distribution with $\mu = 0$, $\sigma = 1$ parameters (blue lines)

In the hypothesis testing approach, the meaning of significant values of the test statistic or p-vales (i.e. probability of Type I error) is often illustrated by the area under the probability function. However, due to the relationship between CDF and probability function, for continuous null-distributions p-values can be calculated from CDF more easily. We denote the observed value of the test statistic by $x_{obs}$. For one-sided tests, p-value is

$$p = \Pr(X \leq x_{obs} | H_o) = \mathrm{CDF}(\mathrm{x_{obs}})$$

or

$$p = \Pr(X \geq x_{obs} | H_o) = 1 - \mathrm{CDF}(\mathrm{x_{obs}})$$

depending on the type of the alternative hypothesis. For two-sided test p-value is

$$p = 2\min\{\mathrm{CDF}(\mathrm{x_{obs}}), 1 - \mathrm{CDF}(\mathrm{x_{obs}})\}$$

If the distribution is Gaussian with the expected value $\mu$ and standard deviation $\sigma$

$$CDF(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$$

where Φ denoted the CDF of standard normal distribution (i.e. Gaussian distribution with zero expected value and unit standard deviation). This relationship remains approximately valid if the expected value and standard deviation are replaced by their large sample estimates. If we apply this relationship in the context of the standardized effect size, and the normality assumption is satisfied, we obtain::

$$CDF(I_{obs}) = \Phi(\mathrm{SES})$$

Thus, the p-value in the one sided test is 1-Φ(SES) or Φ(SES), depending on the alternative hypothesis, while in the two-sided test, $p$ = 2min{ Φ(SES), 1–Φ(SES)}. Since 1-Φ($x$) = Φ(-$x$) and $\Phi(-|x|) \leq \Phi(|x|)$, for the two-sided test the relationship can be written in the $p = 2 * \Phi(-|SES|)$ form.

**Appendix 3: R function for calculating p-values applying approach Knijnenburg et al. 2009**

```
PValue<-function(x,stat,k=250,lower=F)
# Calculation of p-values by algorithm proposed by Knijnenburg, T.
# A., L. F. A. Wessels, M. J. T. Reinders, and I. Shmulevich. 2009.
# Fewer permutations, more accurate P-values. Bioinformatics
# 25:i161–i168.
#
# Parameters:
# x = vector of test statistic generated by randomization algorithm
# stat = observed value of test statistic
# k = maximum number of most extreme values used for fitting
      generalized Pateto distribution
# lower = if H1 is that stat is lower than expected
{
require(evd)
require(DescTools)
n<-length(x)
if (n<k) stop("Error: Too few random values", "\n")
if (lower)
{
m<-max(c(x,stat))
x<-m-x
stat<-m-stat
}
p<-(sum(stat<x)+sum(stat==x)/2)/n
if (p<0.05)
{
x<-sort(x,decreasing=T)
k<-250
repeat
{
tresh<-(x[k]+x[k+1])/2
M<-fpot(x, tresh,std.err=F)
AD.test<-AndersonDarlingTest(x[1:k], null =
"pgpd",loc=tresh,scale=M$estimate[1],shape=M$estimate[2])
```

```
if (AD.test$p.value>0.05) break
k<-k-10
if (k==0) break
}
if (k==0) stop("Error: Generalized Pareto distribution cannot be
fitted", "\n")
p<-pgpd(tresh,M$estimate[1],M$estimate[2])
}
return(p)
}
```