

Package ‘TrendNPS’

January 3, 2018

Type Package

Title NPS Trend Analyses for Complex Survey Designs

Version 0.0.5.3

Date 2018-01-03

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Description Analyze complex survey designs via trend estimation.

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BugReports <http://lar-git.west-inc.com/jasmyace/TrendNPS/issues>

Depends lme4, R(>= 2.10.0)

Imports lmerTest, spsurvey, stats

NeedsCompilation no

LazyData true

RoxygenNote 6.0.1

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AdjWgt	<i>Adjust design weights for nonsampling error.</i>
--------	---

Description

Using the evalstatus field in the design file, adjust the design weights for frame error and non-sampling error.

Usage

```
AdjWgt(dat, popn, evalstatus = "EvalStatus", wgt = "wgt")
```

Arguments

dat	Data frame containing columns at least for Site, WYear, Year, the outcome of interest, and the survey evaluation status EvalStatus. See section "Options for variable EvalStatus" below.
popn	Takes the value of "Target" or "Sampled" to reflect inference to either the original target population or to the subpopulation of sites that would not be subject to nonresponse, respectively.
evalstatus	Status of the survey at each site relative to frame error and nonresponse error. Note that this field is calculated separately for each year at a site.
wgt	Original design weight. The design weights for a given year should sum to the size of the population before accounting for any frame error.

Details

Adjusts the original sampling design weights for frame and nonresponse error. See (Starceвич et al. 2016) for more information on weighting adjustments and populations of inference. See (Starceвич et al. 2017) for an example on applying the AdjWgt_FrameNR function to a monitoring data set.

Value

Returns a vector of adjusted design weights that should sum to the extent of the population of interest after accounting for frame error (popn = "Target") or frame and nonresponse error (popn = "Sampled").

Options for variable evalstatus

The evalstatus field requires specific formatting for weighting adjustment. Valid options include:

"Target - Surveyed"	Site is in target population and was successfully surveyed.
"Target - Not Surveyed"	Site is in target population but was not successfully surveyed.
"Non-Target"	Site is not in target population, not surveyed.
"Not Evaluated"	Site was not evaluated as target or not, not surveyed.

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

Starcevich, L. A., G. DiDonato, T. McDonald, and J. Mitchell. (2016). A GRTS user's manual for the SDrawNPS package: A graphical user interface for generalized random tessellation stratified (GRTS) sampling and estimation. Natural Resource Report NPS/PWRO/NRR-2016/1233. National Park Service, Fort Collins, Colorado.

Starcevich, L. A., T. McDonald, A. Chung-MacCoubrey, A. Heard, and J. Nesmith. (2017). Trend Estimation for Complex Survey Designs. Natural Resource Report NPS/xxxx/NRR-2017/xxxx. National Park Service, Fort Collins, Colorado.

Examples

```
## Not run:
# ---- Read example data set.
LakeData$AdjWgt[LakeData$WYear == 0] = AdjWgt(dat=LakeData[LakeData$WYear == 0,],
                                              popn="Target",
                                              evalstatus = "EvalStatus",
                                              wgt = "wgt")

## End(Not run)
```

Cover_Acro

Acrosiphonia binary cover data.

Description

Acrosiphonia binary cover data.

Usage

```
data(Cover_Acro)
```

Format

A data frame with 1794 rows and 11 variables.

The file contains binary indicators of *Acrosiphonia* cover collected between 2009 and 2015 across two parks, Katmai National Park (KATM) and Kenai Fjords National Park (KEFJ) in the Southwest Alaskan Network. Data hierarchy includes Elevation class within Quadrat within Site. The variables are as follows:

- Site. Sampling unit selected with GRTS sampling.
- Park. National Park. KATM = Katmai NP and KEFJ = Kenai Fjords NP.
- Quad. Quadrat within Site.

- Elev. Elevation class within Quad Quadrat.
- Year. Survey year formatted as a factor for random effects estimation.
- WYear. Scalar year covariate for trend analysis.
- Gradient. Site gradient (degrees).
- Long. Site longitude.
- Lat. Site latitude.
- wgt. Design weight from the sample draw.
- PanelWt. Weight to account for temporal revisit design given sample inclusion.

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

Alaska Ocean Observing System Gulf of Alaska Data Integration Portal. 2017. Nearshore: Intertidal Systems in Gulf of Alaska data available at: <http://portal.aaos.org/gulf-of-alaska.php#metadata/53c052b6-8874-46d1-b40a-acc615a3879a/project/files>.

expit

"Expit" transform, or the backwards logit transform.

Description

Apply the standard backwards logit transform to a numeric vector of values.

Usage

`expit(x)`

Arguments

`x` A numeric vector.

Details

The `expit` function simply applies the standard backwards logit transform to the provided numeric vector `x`: $1/(1 + \exp(-x))$.

Author(s)

Leigh Ann Starcevich and Jason Mitchell of Western EcoSystems Technology, Inc.

See Also

`TrendNPS::logit`

Examples

```
x <- c(-0.8472979, -1.3862944, 2.1972246)
y <- expit(x)

y
# 0.3 0.2 0.9
```

GRTSsample

*NPS lake chemistry GRTS sample.***Description**

NPS lake chemistry GRTS sample.

Usage

```
data(GRTSsample)
```

Format

A data frame with 461 rows and 10 variables.

The design file containing the Sierra Nevada Network lake chemistry GRTS sample draw. Sites were stratified by Park and unequal probability sampling relative to a cost class (mdcaty) were drawn. The sample was drawn using the spsurvey package (Kincaid and Olsen 2015). The variables are as follows:

- siteID. Lake identifier.
- Park. National Park used as stratification variable. (SEKI = Sequoia-Kings Canyon, YOSE = Yosemite)
- WYear. The observation year minus 2008. (0–5)
- xcoord. UTM easting.
- ycoord. UTM northing.
- mdcaty. Multi-density category representing cost class from the unequal probability sample draw.
- panel. Temporal revisit panel, or oversample when an oversample site was used.
- wgt. Design weight from original GRTS sample draw.
- lake_area. Lake area in square meters.
- lake_perim. Lake perimeter in meters.

References

Heard, A.M., L.A. H. Starcevich, J.O. Sickman, M. Goldin Rose, and D.W. Schweizer. 2012. Sierra Nevada Network lake monitoring protocol. Natural Resource Report NPS/SIEN/NRR-2012/551. National Park Service, Fort Collins, Colorado.

Kincaid, T. M. and Olsen, A. R. 2015. spsurvey: Spatial Survey Design and Analysis. R package version 3.1. <http://www.epa.gov/nheerl/arm/>.

LakeDataRep	<i>NPS lake chemistry monitoring data for sites with at least two visits. Data have been merged with GRTS sampling design factors.</i>
-------------	--

Description

NPS lake chemistry monitoring data for sites with at least two visits. Data have been merged with GRTS sampling design factors.

Usage

```
data(LakeDataRep)
```

Format

A data frame with 77 rows and 17 variables.

A dataset containing the Sierra Nevada Network lake chemistry data from Sequoia-Kings Canyon and Yosemite National Parks. See Starcevich et al. (2017) for more information. The variables are as follows:

- Site. Lake identifier.
- Park. National Park used as stratification variable. (SEKI = Sequoia-Kings Canyon, YOSE = Yosemite)
- Year. The observation year. (2008–2013)
- WYear. The observation year minus 2008. (0–5)
- xcoord. UTM easting.
- ycoord. UTM northing.
- mdcaty. Multi-density category representing cost class from the unequal probability sample draw.
- panel. Temporal revisit panel, or oversample when an oversample site was used.
- wgt. Design weight from original GRTS sample draw.
- lake_area. Lake area in square meters.
- lake_perim. Lake perimeter in meters.
- Elevation_m. Lake elevation in meters.
- pH. pH measurement of lake.
- Cl. Chloride measurement of lake.
- EvalStatus. Evaluation status of lake relative to frame and nonresponse error.
- AdjWgt. Design weight adjusted for frame error and nonresponse error.
- PanelWt. Panel weight, or the inverse of the panel inclusion probability.

References

Heard, A. M., L. A. H. Starcevich, J. O. Sickman, M. Goldin Rose, and D. W. Schweizer. 2012. Sierra Nevada Network lake monitoring protocol. Natural Resource Report NPS/SIEN/NRR-2012/551. National Park Service, Fort Collins, Colorado.

LakeData_orig	<i>NPS lake chemistry monitoring data for all sites.</i>
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Description

NPS lake chemistry monitoring data for all sites.

Usage

```
data(LakeData_orig)
```

Format

A data frame with 130 rows and 6 variables.

A dataset containing the Sierra Nevada Network lake chemistry data from Sequoia-Kings Canyon and Yosemite National Parks. See Starcevich et al. (2017) for more information. The variables are as follows:

- Site. Lake identifier.
- Year. The observation year. (2008–2013)
- Park. National Park used as stratification variable. (SEKI = Sequoia-Kings Canyon, YOSE = Yosemite)
- Elevation_m. Lake elevation in meters.
- pH. pH measurement of lake.
- Cl. Chloride measurement of lake.

References

Heard, A. M., L. A. H. Starcevich, J. O. Sickman, M. Goldin Rose, and D. W. Schweizer. 2012. Sierra Nevada Network lake monitoring protocol. Natural Resource Report NPS/SIEN/NRR-2012/551. National Park Service, Fort Collins, Colorado.

LinearizationVar	<i>Calculate linearization variance of trend for the PWIGLS trend approach.</i>
------------------	---

Description

Calculate the linearization variance of the trend coefficient with a Taylor series approximation. This is an internal function called from PWIGLS_ALL.

Usage

```
LinearizationVar(Site, wij, xij, eij, varYij)
```

Arguments

Site	vector of Site names.
wij	vector of inclusion weights = Site-level design weight * Year-level panel weight.
xij	vector of shifted year variables (WYear) for trend estimation.
eij	vector of residuals from PWIGLS trend model.
varYij	vector of total variance estimates for yij, estimated from PWIGLS variance components estimates.

Details

The linearization variance is based on a Taylor series approximation. See Skinner (1989, p. 82-83) for more information.

Value

Scalar variance estimate of the trend regression coefficient.

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

Skinner, C. J., D. Holt, and T. M. F. Smith. 1989. Analysis of Complex Surveys. New York: Wiley.

See Also

TrendNPS_Cont, LinearizationVar_StRS

Examples

```
## Not run:
# ---- Read example data set.
TrendVar = LinearizationVar(Site,wij,xij,eij,varYij)

## End(Not run)
```

LinearizationVar_StRS *Calculate linearization variance of trend for stratified sampling.*

Description

Calculate the linearization variance of the trend coefficient with a Taylor series approximation when two-level stratification is used and a separate-slopes trend model is applied. This is an internal function called from PWIGLS_ALL.

Usage

```
LinearizationVar_StRS(Site, wij, xij, eij, varYij, str1prop)
```

Arguments

Site	vector of Site names.
wij	vector of inclusion weights = Site-level design weight * Year-level panel weight.
xij	vector of shifted year variables (WYear) for trend estimation.
eij	vector of residuals from PWIGLS trend model.
varYij	vector of total variance estimates for yij, estimated from PWIGLS variance components estimates.
str1prop	Proportion of the population represented by the first level of the stratification variable.

Details

The linearization variance is based on a Taylor series approximation. See Skinner (1989, p. 82-83) for more information.

Value

Scalar variance estimate of the trend regression coefficient.

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

Skinner, C. J., D. Holt, and T. M. F. Smith. 1989. Analysis of Complex Surveys. New York: Wiley.

See Also

TrendNPS_Cont, LinearizationVar

Examples

```
## Not run:
# ---- Read example data set.
TrendVar = LinearizationVar_StRS(Site,wij,xij,eij,varYij,str1prop)

## End(Not run)
```

logit	<i>Logit transform.</i>
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Description

Apply the standard logit transform to a numeric vector of values.

Usage

```
logit(x)
```

Arguments

x A numeric vector.

Details

The logit function simply applies the standard logit transform to the provided numeric vector x:
 $\log(x/(1 - x))$.

Author(s)

Leigh Ann Starcevich and Jason Mitchell of Western EcoSystems Technology, Inc.

See Also

```
TrendNPS::expit
```

Examples

```
x <- c(0.3,0.2,0.9)
y <- logit(x)

y
# -0.8472979 -1.3862944  2.1972246
```

mv_alaska_1mil_py	<i>Alaska Coastline 1:1,000,000 - Digital Chart of the World (DCW).</i>
-------------------	---

Description

Alaska Coastline 1:1,000,000 - Digital Chart of the World (DCW).

Format

A shapefile with 811 constituent polygons. To use, run

```
AK <- rgdal::readOGR(paste0(find.package("TrendNPS"), "/extdata"), "mv_alaska_1mil_py").
```

The shapefile contains the polygonal extent of the US state of Alaska. This coverage was taken from ESRI's Digital Chart of the World and clipped to the State of Alaska. The data was extracted from the PONET coverage from each tile. For more information, see the DCW Data Dictionary.

The attribute table contains the following variables, whose rows contain the same data:

- TYPE. Uniformly "A" throughout. Unknown meaning.
- REFRESH_01. Uniformly "2011-03-23" throughout. Unknown meaning.
- POLNSTAT. Uniformly 0.0000 throughout. Unknown meaning.
- POLNTYPE. Uniformly 0.0000 throughout. Unknown meaning.

Author(s)

Leigh Ann Starceovich of Western EcoSystems Technology, Inc.

References

Alaska Department of Natural Resources, Information Resource Management.

Accessed January 13, 2017 and available at <http://asgdc.alaska.gov#2972>.

PWIGLS_ALL	<i>Probability-weighted iterative generalized least squares (PWIGLS).</i>
------------	---

Description

Calculate trend from data collected with complex survey designs by incorporating weights with a linear mixed model. This is an internal function called from TrendNPS_Cont.

Usage

```
PWIGLS_ALL(Z, dat, stage1wt, stage2wt, type, stratum, slope)
```

Arguments

<code>Z</code>	Random-effects design matrix from the unweighted (PO) model.
<code>dat</code>	Data frame containing columns at least for <code>Site</code> , <code>WYear</code> , <code>Year</code> , and the continuous outcome of interest <code>Y</code> . See section "Data frame <code>dat</code> " below.
<code>stage1wt</code>	Design weights from the original sample draw without accounting for temporal revisit designs.
<code>stage2wt</code>	Panel inclusion weights for each site each year.
<code>type</code>	Scaling type when <code>method="PWIGLS"</code> . Valid values include "Aonly", "A", "AI", "B", "BI", "C". See section "Options for variable type" below.
<code>stratum</code>	Text string identifying an optional two-level stratification factor in <code>dat</code> . Use <code>stratum = NA</code> to indicate no stratification used.
<code>slope</code>	Logical value indicating inclusion of a random site-level slope effect in the variance components structure in addition to the Site- and Year- level random intercept terms. Default = TRUE.

Details

Calculates the probability-weighted iterative generalized least squares (PWIGLS) trend model (Pfeffermann et al. 1998; Asparouhov 2006).

Value

Returns a vector of regression coefficient estimates for the trend model.

Options for variable type

Selection of `method="PWIGLS"` requires further specification of argument `type`. Valid options include

"Aonly"	Probability weighting but no scaling at either stage
"A"	Panel-weights scaling with mean site-level design weight
"AI"	Panel-weights scaling with mean site-level design weight, but no site-level scaling
"B"	Panel-weights scaling with effective mean site-level design weight
"BI"	Panel-weights scaling with effective mean site-level design weight, but no site-level scaling
"C"	Year-level scaling only with inverse of the average year-level weight

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

- Asparouhov, T. (2006). General multi-level modeling with sampling weights. *Communications in Statistics - Theory and Methods* 35: 439-460.
- Pfeffermann, D., C.J. Skinner, D.J. Holmes, H. Goldstein, and J. Rasbash (1998). Weighting for unequal selection probabilities in multilevel models. *Journal of the Royal Statistical Society, Series*

B 60(1): 23-40.

See Also

TrendNPS_Cont, LinearizationVar

Examples

```
## Not run:
# ---- Read example data set.
fit<-PWIGLS_ALL(Z=getME(fit_PO,"Z"),
               dat=dat,
               stage1wt=stage1wt,
               stage2wt=stage2wt,
               type=type,
               stratum=stratum,
               slope=slope)

## End(Not run)
```

Seastar

Seastar count data.

Description

Seastar count data.

Usage

data(Seastar)

Format

A data frame with 65 rows and 10 variables.

The file contains counts of *Dermasterias imbricata* (leather seastar) collected between 2009 and 2015 across two parks, Katmai National Park (KATM) and Kenai Fjords National Park (KEFJ) in the Southwest Alaskan Network. The variables are as follows:

- Site. Sampling unit selected with GRTS sampling.
- Park. National Park. KATM = Katmai NP and KEFJ = Kenai Fjords NP.
- Year. Survey year formatted as a factor for random effects estimation.
- WYear. Scalar year covariate for trend analysis.
- Gradient. Site gradient (degrees).
- Long. Site longitude.
- Lat. Site latitude.
- Count. Number of sea stars observed.
- wgt. Design weight from the sample draw.
- PanelWt. Weight to account for temporal revisit design given sample inclusion.

Author(s)

Leigh Ann Starcevich of Western EcoSystems Technology, Inc.

References

Alaska Ocean Observing System Gulf of Alaska Data Integration Portal. 2017. Nearshore: Intertidal Systems in Gulf of Alaska data available at: <http://portal.aos.org/gulf-of-alaska.php#metadata/53c052b6-8874-46d1-b40a-acc615a3879a/project/files>.

TrendNPS

TrendNPS: An R package for trend analysis for data from complex survey designs.

Description

TrendNPS: An R package for trend analysis for data from complex survey designs.

Description

The TrendNPS package provides trend analysis tools for complex survey designs. Please refer to the accompanying National Park Service Natural Resource Report (NRR) series report Starcevich et al. (2017) and Starcevich et al. (2018) for background on how and under what circumstances to use the trend analysis methods. Example analyses are provided using the tools offered in the TrendNPS R package.

TrendNPS functions

TrendNPS_Cont,
TrendNPS_Count,
TrendNPS_Binary,
LinearizationVar_StRS,
LinearizationVar,
PWIGLS_ALL

TrendNPS_Binary

Trend for Binary Outcomes from Complex Survey Designs

Description

TrendNPS_Binary fits trend models of binary outcomes for four approaches:

1. the unreplicated generalized linear mixed model with variance components as specified by Piepho and Ogutu (2002) that does not incorporate design weights ("PO");
2. simple linear regression of annual design-based estimates ("SLRDB");
3. weighted linear regression of annual design-based estimates ("WLRDB");

4. and probability-weighted iterative generalized least squares ("PWIGLS")

Fixed effects structure includes a year term for trend estimation and an optional two-level stratification factor. The function assumes random site and year intercepts, and an optional random site-level slope effect may be included.

Usage

```
TrendNPS_Binary(alpha, dat, method, slope = TRUE, type = NA, stratum = NA,
  Y, lat = NA, long = NA, stage1wt = NA, stage2wt = NA, str1prop = NA,
  nbhd = TRUE)
```

Arguments

alpha	The probability of a Type I error.
dat	Data frame containing columns at least for Site, WYear, Year, and the binary outcome of interest Y. See section "Data frame dat" below.
method	Method for trend estimation entered as a string. Valid values include "PO" for the generalized linear mixed model extension of the Piepho and Ogutu (2002) unreplicated linear mixed model, "SLRDB" for simple linear regression of design-based estimates, "WLRDB" for weighted linear regression of design-based estimates, or "PWIGLS" for probability-weighted iterative generalized least squares (Pfeffermann et al. 1998, Asparouhov 2002).
slope	Logical value indicating inclusion of a random site-level slope effect in the variance components structure used for the "PO" and "PWIGLS" trend methods. Site- and year-level random intercept terms included as default.
type	Scaling type when method="PWIGLS". Valid values include "Aonly", "A", "AI", "B", "BI", "C". See section "Options for variable type" below.
stratum	Text string identifying an optional two-level stratification factor in dat.
Y	Text string indicating the binary outcome variable in dat.
lat	Site latitudes using an equal-area projection, e.g., UTM or Albers.
long	Site longitudes using an equal-area projection, e.g., UTM or Albers.
stage1wt	Design weights from the original sample draw without accounting for temporal revisit designs.
stage2wt	Panel inclusion weights for each site each year.
str1prop	Proportion of the first stratum in the population in a two-level stratification variable.
nbhd	Logical indicator for the neighborhood variance estimator when method="WLRDB". If FALSE, "WLRDB" calculates the design-based mean estimate's standard error assuming independent random sampling.

Details

For long-term monitoring, TrendNPS_Binary assumes a single annual sampling occasion per unique record of WYear and Site in data frame dat.

Sampling (stage1wt) and temporal-revisit (stage2wt) design weights must be adjusted for any missing data or frame error prior to trend analysis. See Oh and Scheuren (1983), Little and Rubin (2002), and Starceovich et al. (2016).

For background on the variance structure, see Piepho & Ogutu (2002). For information on the probability-weighted generalized least squares approach, see Pfeiffermann et al. (1998), Asparouhov (2006), and Starceovich et al. (2017).

Value

A list containing three or four elements, depending on the specified trend method. The first element of the list, ModelEstimates, contains a data frame with the trend model output:

mu	Estimated intercept from the trend model.
trend	Estimated trend of the outcome Y on the link function scale from the trend model.
SEtrend	Estimated standard error of the trend estimate.
sig2a	Estimated site-to-site variation.
sig2b	Estimated year-to-year variation.
sig2t	Estimated variation among site-level slopes.
sig2e	Estimated residual variation.
eta	Degrees of freedom used to test for trend and calculate confidence intervals.

The contents of the second list element, TrendTest, include the trend coefficient on the link scale, the trend standard error, the t-statistic, degrees of freedom, and p-value for a two-sided test of no trend.

The contents of the third list element, TrendCI, include the back-transformed trend on the original scale and the lower and upper $(1-\alpha)*100\%$ -confidence interval bounds.

A fourth list element, DBests, contains the annual design-based estimates and is returned only when the SLRDB and WLRDB trend approaches are used. The design-based estimates may be used to assess the assumption of independence for the linear regression models. The output of the DBests list element include:

Year	Year of survey.
Est.Mean	Design-based estimate of the mean of the outcome of interest.
SE	Estimated standard error of design-based mean estimate if nbhd=TRUE.
WYear	WYear variable.
Resid	Residuals from the linear model fit.

Method requirements

Spatially balanced samples utilizing method="SLRDB" or method="WLRDB" require specification of lat and long on setting the neighborhood variance estimator nbhd=TRUE. If spatial balance cannot be assumed, set option nbhd=FALSE for non-spatially balanced designs so that the "SLRDB" and "WLRDB" methods assume independent random sampling for standard errors.

The stratification variable stratum is required for all methods when design strata are used. Note that method="PWIGLS" further requires a value for type. See section "Options for variable type" below.

Specify stage1wt and stage2wt for all methods except unweighted method="P0".

Data frame dat

Data frame dat requires at least variables Site, WYear, Year, and Y. Variable Site defines the sampling unit.

Underlying statistical functions called by TrendNPS_Cont require two separate temporal variables: Year is a factor and WYear is a scalar-year value. WYear is shifted so that the year for which Y is least variable is centered on 0. See Piepho & Ogutu (2002) for more information.

Ultimately, WYear represents time in the fixed-effects portion of the trend model. The regression coefficient associated with WYear provides the basis for trend estimation and testing.

Variable Year enters the model as a random effect and provides the basis for estimation of random year-to-year variation among survey occasions.

Variable Y must contain only binary values coded as 0 or 1.

Options for variable type

Selection of method="PWIGLS" requires further specification of argument type. Valid options include

"Aonly"	Probability weighting but no scaling at either stage
"A"	Panel-weights scaling with mean site-level design weight
"AI"	Panel-weights scaling with mean site-level design weight, but no site-level scaling
"B"	Panel-weights scaling with effective mean site-level design weight
"BI"	Panel-weights scaling with effective mean site-level design weight, but no site-level scaling
"C"	Year-level scaling only with inverse of the average year-level weight

Author(s)

Leigh Ann Starcevich and Jason Mitchell of Western EcoSystems Technology, Inc.

References

- Asparouhov, T. (2006). General multi-level modeling with sampling weights. *Communications in Statistics - Theory and Methods* 35: 439-460.
- Little, J. A. R., and D. B. Rubin. (2002). *Statistical analysis with missing data*, 2nd edition. John Wiley and Sons, Inc., New Jersey.
- Oh, H. L., and F. J. Scheuren. (1983). Weighting adjustment for unit nonresponse. Pages 143-184 in W.G. Madow, I. Olkin, and D.B. Rubin, editors. *Incomplete data and in sample surveys*. (Vol. 2). Academic Press, New York.
- Pfeffermann, D., C. J. Skinner, D. J. Holmes, H. Goldstein, and J. Rasbash (1998). Weighting for unequal selection probabilities in multilevel models. *Journal of the Royal Statistical Society, Series B* 60(1): 23-40.
- Piepho, H. P., & Ogutu, J. O. (2002). A simple mixed model for trend analysis in wildlife populations. *Journal of Agricultural, Biological, and Environmental Statistics*, 7(3), 350-360.

Starcevich, L. A., G. DiDonato, T. McDonald, and J. Mitchell. (2016). A GRTS user's manual for the SDrawNPS package: A graphical user interface for generalized random tessellation stratified (GRTS) sampling and estimation. Natural Resource Report NPS/PWRO/NRR-2016/1233. National Park Service, Fort Collins, Colorado.

Starcevich, L. A., T. McDonald, A. Chung-MacCoubrey, A. Heard, and J. Nesmith. (2017). Trend Estimation for Complex Survey Designs. Natural Resource Report NPS/xxxx/NRR-2017/xxxx. National Park Service, Fort Collins, Colorado.

R. Wolfinger. (1993). Laplace's approximation for nonlinear mixed models. *Biometrika* 80(4): 791-795.

See Also

lme4, lmerTest, spsurvey

Examples

```
# ---- Read example data set.
data(Cover_Acro)

# ---- Load dependent packages.
pkgList <- c("lme4", "lmerTest", "spsurvey")
inst <- pkgList %in% installed.packages()
if (length(pkgList[!inst]) > 0) install.packages(pkgList[!inst])
lapply(pkgList, library, character.only = TRUE)

#####
# Example 1: Trend analysis of a binary indicator of Acrosophonia presence
# with the PO approach: stratification and full random effects model.
TrendAcro_PO_StRS = TrendNPS_Binary(alpha=0.1,
dat=Cover_Acro, method="PO", slope=TRUE, type=NA, stratum="Park", Y="Y",
stage1wt="wt", stage2wt="PanelWt", str1prop=0.13227)

# $ModelEstimates
#      mu      trend      SEtrend      sig2a      sig2t      sigat      sig2b
# -0.2992415 0.221928 0.09341594 0.2867116 0.01394005 -0.04732509 0.2411157

# $TrendTest
#      trend      SEtrend      z-stat      pvalue
# 0.221928 0.09341594 2.375698 0.0175158

# $TrendCIofOddsRatio
#      Annual Pct Change      CI low      CI high
# 0.2484815 0.07065702 0.4558408

# Example 2: Trend analysis of a binary indicator of Acrosophonia presence
# with the SLRDB approach for stratification.
TrendAcro_SLRDB_StRS = TrendNPS_Binary(alpha=0.1,
dat=Cover_Acro, method="SLRDB", slope=TRUE, type=NA, stratum="Park", Y="Y",
lat="Lat", long="Long", stage1wt="wt", stage2wt="PanelWt",
```

```

str1prop=0.13227)
TrendAcro_SLRDB_StRS
# $ModelEstimates
#      mu      trend      SEtrend sig2a sig2t sigat sig2b
# -0.9909923 0.211127 0.08966504      0      0      0      0
#
# $TrendTest
#      trend      SEtrend      z-stat      pvalue
# 0.211127 0.08966504 2.354619 0.01854169
#
# $TrendCIofOddsRatio
# Annual Pct Change      CI low      CI high
#      0.2350692 0.06570992 0.4313426
#
# $DBests
# Year Est.Mean      SE WYear      Resid
# 2008 0.1604049 0.06934590      0 -0.6642261
# 2009 0.2652986 0.05963881      1 -0.2387430
# 2010 0.4121248 0.10439841      2 0.2135496
# 2011 0.6416667 0.07341420      3 0.9402165
# 2012 0.5439923 0.11698602      4 0.3229097
# 2013 0.5875758 0.03719284      5 0.2893100
# 2014 0.4954618 0.06389670      6 -0.2939231
# 2015 0.4794624 0.04936033      7 -0.5690937

num <- TrendAcro_SLRDB_StRS$DBests$Est.Mean
denom <- 1-TrendAcro_SLRDB_StRS$DBests$Est.Mean
TrendAcro_SLRDB_StRS$DBests$LogOdds = num / denom
plot(TrendAcro_SLRDB_StRS$DBests$Year,
      TrendAcro_SLRDB_StRS$DBests$LogOdds,
      xlab="Year", ylab="Odds ratio of cover proportion")
lines(2008:2015, exp(-0.9909923 + 0.211127*(0:7)), col=2)

# Plot trend on proportional cover scale
plot(TrendAcro_SLRDB_StRS$DBests$Year,
      TrendAcro_SLRDB_StRS$DBests$Est.Mean,
      xlab="Year", ylab="Cover proportion")
lines(2008:2015, TrendNPS::expit(-0.9909923 + 0.211127*(0:7)), col=2)

```

TrendNPS_Cont

Trend for Continuous Outcomes from Complex Survey Designs

Description

TrendNPS_Cont fits trend models of continuous outcomes for four approaches:

1. the unreplicated linear mixed model as specified by Piepho and Ogutu (2002) that does not incorporate design weights ("PO");
2. simple linear regression of annual design-based estimates ("SLRDB");
3. weighted linear regression of annual design-based estimates (WLRDB);

4. and probability-weighted iterative generalized least squares of a linear mixed model (PWIGLS) with 6 types of scaling.

Fixed effects structure includes a year term for trend estimation and an optional two-level stratification factor. The function assumes random site and year intercepts, and an optional random site-level slope effect may be included.

Usage

```
TrendNPS_Cont(alpha, dat, method, slope = TRUE, type = NA, stratum = NA,
  Y, lat = NA, long = NA, stage1wt = NA, stage2wt = NA, str1prop = NA,
  nbhd = TRUE)
```

Arguments

alpha	The probability of a Type I error.
dat	Data frame containing columns at least for Site, WYear, Year, and the continuous outcome of interest Y. See section "Data frame dat" below.
method	Method for trend estimation entered as a string. Valid values include "PO" for the Piepho and Ogutu (2002) unreplicated linear mixed model, "SLRDB" for simple linear regression of design-based estimates, "WLRDB" for weighted linear regression of design-based estimates, or "PWIGLS" for probability-weighted iterative generalized least squares (Pfeffermann et al. 1998, Asparouhov 2002).
slope	Logical value indicating inclusion of a random site-level slope effect in the variance components structure used for the "PO" and "PWIGLS" trend methods. Site- and year-level random intercept terms included as default.
type	Scaling type when method="PWIGLS". Valid values include "Aonly", "A", "AI", "B", "BI", "C". See section "Options for variable type" below.
stratum	Text string identifying an optional two-level stratification factor in dat.
Y	Text string indicating the outcome variable in dat.
lat	Site latitudes using an equal-area projection, e.g., UTM or Albers.
long	Site longitudes using an equal-area projection, e.g., UTM or Albers.
stage1wt	Design weights from the original sample draw without accounting for temporal revisit designs.
stage2wt	Panel inclusion weights for each site each year.
str1prop	Proportion of the first stratum in the population in a two-level stratification variable.
nbhd	Logical indicator for the neighborhood variance estimator when method="WLRDB". If FALSE, "WLRDB" calculates the design-based mean estimate's standard error assuming independent random sampling.

Details

For long-term monitoring, TrendNPS_Cont assumes single annual sampling occasions per unique record of WYear and Site in data frame dat.

Sampling (stage1wt) and temporal-revisit (stage2wt) design weights must be adjusted for any missing data or frame error prior to trend analysis. See Oh and Scheuren (1983), Little and Rubin (2002), and Starcevich et al. (2016).

For background on the unweighted linear mixed model, see Piepho & Ogutu (2002). For information on the probability-weighted generalized least squares approach, see Pfeiffermann et al. (1998), Asparouhov (2006), and Starcevich et al. (2017).

Value

A list containing three or four elements, depending on the specified trend method. The first element of the list contains a data frame containing the estimated intercept, trend estimate, trend standard error, estimated variance components, and degrees of freedom used for trend testing and confidence intervals construction.

The contents of the first list element, ModelEstimates, are:

mu	Estimated intercept from the trend model/
trend	Estimated trend of the logged outcome Y from the trend model.
SEtrend	Estimated standard error of the trend estimate for the logged outcome Y.
sig2a	Estimated site-to-site variation.
sig2b	Estimated year-to-year variation.
sig2t	Estimated variation among site-level slopes.
sig2e	Estimated residual variation.
eta	Degrees of freedom used to test for trend and calculate confidence intervals.

The contents of the second list element, TrendTest, include the trend coefficient on the logged scale, the trend standard error, the t-statistic, degrees of freedom, and p-value for a two-sided test of no trend.

The contents of the third list element, TrendCI, include the back-transformed trend on the original scale calculated as an annual proportional change and the lower and upper (1-alpha)*100%-confidence interval bounds.

A fourth list element, DBests, contains the annual design-based estimates and is returned only when the SLRDB and WLRDB trend approaches are used. The design-based estimates may be used to assess the assumption of independence for the linear regression models. The output of the DBests list element include:

Year	Year of survey.
Est.Mean	Design-based estimate of the mean of the outcome of interest.
SE	Estimated standard error of design-based mean estimate if nbhd=TRUE.
WYear	WYear variable.
Resid	Residuals from the linear model fit.

Method requirements

Spatially balanced samples utilizing method="SLRDB" or method="WLRDB" require specification of lat and long on setting the neighborhood variance estimator nbhd=TRUE. If spatial balance cannot

be assumed, set option nbhd=FALSE for non-spatially balanced designs so that the "SLRDB" and "WLRDB" methods assume independent random sampling for standard errors.

The stratification variable stratum is required for all methods when design strata are used. Note that method="PWIGLS" further requires a value for type. See section "Options for variable type" below.

Specify stage1wt and stage2wt for all methods except unweighted method="P0".

Data frame dat

Data frame dat requires at least variables Site, WYear, Year, and Y. Variable Site defines the sampling unit.

Underlying statistical functions called by TrendNPS_Cont require two separate temporal variables: Year is a factor and WYear is a scalar-year value. WYear is shifted so that the year for which Y is least variable is centered on 0. See Piepho & Ogutu (2002) for more information.

Ultimately, WYear represents time in the fixed-effects portion of the trend model. The regression coefficient associated with WYear provides the basis for trend estimation and testing.

Variable Year enters the model as a random effect and provides the basis for estimation of random year-to-year variation among survey occasions.

Variable Y must contain only positive non-zero values. Trend analyses approaches will implement a logarithmic transformation for trend modeling of variable Y, but the untransformed variable Y should be provided as an function call.

Options for variable type

Selection of method="PWIGLS" requires further specification of argument type. Valid options include

"Aonly"	Probability weighting but no scaling at either stage
"A"	Panel-weights scaling with mean site-level design weight
"AI"	Panel-weights scaling with mean site-level design weight, but no site-level scaling
"B"	Panel-weights scaling with effective mean site-level design weight
"BI"	Panel-weights scaling with effective mean site-level design weight, but no site-level scaling
"C"	Year-level scaling only with inverse of the average year-level weight

Author(s)

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See Also

lme4, lmerTest, spsurvey

Examples

```
# ---- Read example data set.
data(LakeDataRep)

# ---- Load dependent packages.
pkgList <- c("lme4", "lmerTest", "spsurvey")
inst <- pkgList %in% installed.packages()
if (length(pkgList[!inst]) > 0) install.packages(pkgList[!inst])
lapply(pkgList, library, character.only = TRUE)

#####
# Example 1: Trend analysis with the PO approach: stratification and full random
# effects model.
str1prop <- 808.6936/(808.6936+362.8214)
PO_ests <- TrendNPS_Cont(alpha=0.1, dat=LakeDataRep, method="PO", slope=TRUE,
  stratum="Park", Y="C1", str1prop=str1prop)
PO_ests
# $ModelEstimates
#      mu      trend  SETrend   sig2a   sig2t   sigat   sig2b
# 1.269532 -0.07196304 0.05624014 0.2846501 0.009663692 -0.05208829 0.04079863
#      sig2e      eta
# 0.08133577 24.94572

# $TrendTest
#      trend  SETrend  t-stat   eta  pvalue
# -0.07196304 0.05624014 -1.279567 24.94572 0.2124709

# $TrendCI
# Annual Pct Change   CI low  CI high
#      -0.06943471 -0.1546776 0.0244041
```

```
#####
# Example 2: Trend analysis with the WLRDB approach: stratification
# and full random effects model.
str1prop <- 808.6936/(808.6936+362.8214)
WLRDB_ests <- TrendNPS_Cont(alpha=0.1,dat=LakeDataRep, method="WLRDB",
                             slope=TRUE, stratum="Park", Y="C1", lat="ycoord",
                             long="xcoord", stage1wt="AdjWgt", stage2wt="PanelWt",
                             str1prop=str1prop)
WLRDB_ests
# $ModelEstimates
#      mu      trend    SEtrend sig2a sig2t sigat sig2b    sig2e eta
# 0.4218735 0.06037018 0.07802896    0    0    0    0 3.402272 4

# $TrendTest
#      trend    SEtrend    t-stat eta    pvalue
# 0.06037018 0.07802896 0.7736894 4 0.4822974

# $TrendCI
# Annual Pct Change    CI low    CI high
#      0.06222969 -0.1005534 0.2544735

# $DBests
# Year Est.Mean    SE WYear    Resid
# 2008 4.505724 0.55610529    0 1.083475074
# 2009 2.162006 0.20158290    1 0.288793000
# 2010 1.712219 0.03578556    2 -0.004823561
# 2011 1.592197 0.07584161    3 -0.137869385
# 2012 2.611047 0.14932238    4 0.296397135
# 2013 2.348186 0.18412120    5 0.129918636

#####
# Example 3: Trend analysis with the PWIGLS method with type="Aonly".
str1prop <- 808.6936/(808.6936+362.8214)
PWIGLS_Aonly_ests <- TrendNPS_Cont(alpha=0.1,dat=LakeDataRep, method="PWIGLS",
                                     type="Aonly", slope=TRUE, stratum="Park", Y="C1", lat="ycoord",
                                     long="xcoord", stage1wt="AdjWgt", stage2wt="PanelWt",
                                     str1prop=str1prop)
PWIGLS_Aonly_ests

# $ModelEstimates
#      mu      trend    SEtrend    sig2a    sig2t    sigat    sig2b
# 1.441448 -0.08109772 0.09649006 10.66269 0.3102913 -1.818939 0.4271289
#      sig2e    eta
# 0.09145612 24.94572

# $TrendTest
#      trend    SEtrend    t-stat    eta    pvalue
# -0.08109772 0.09649006 -0.8404774 24.94572 0.4086247

# $TrendCI
# Annual Pct Change    CI low    CI high
```

```
# -0.07789642 -0.2180231 0.08734037
```

TrendNPS_Count

Trend for Count Outcomes from Complex Survey Designs

Description

TrendNPS_Count fits trend models of count outcomes for four approaches:

1. the unreplicated generalized linear mixed model with variance components as specified by Piepho and Ogutu (2002) that does not incorporate design weights ("PO");
2. simple linear regression of annual design-based estimates ("SLRDB");
3. weighted linear regression of annual design-based estimates ("WLRDB");
4. and probability-weighted iterative generalized least squares ("PWIGLS")

Fixed effects structure includes a year term for trend estimation and an optional two-level stratification factor. The function assumes random site and year intercepts, and an optional random site-level slope effect may be included.

Usage

```
TrendNPS_Count(alpha, dat, method, slope = TRUE, type = NA, stratum = NA,
  Y, lat = NA, long = NA, stage1wt = NA, stage2wt = NA, str1prop = NA,
  nbhd = TRUE)
```

Arguments

alpha	The probability of a Type I error.
dat	Data frame containing columns at least for Site, WYear, Year, and the count outcome of interest Y. See section "Data frame dat" below.
method	Method for trend estimation entered as a string. Valid values include "PO" for the generalized linear mixed model extension of the Piepho and Ogutu (2002) unreplicated linear mixed model, "SLRDB" for simple linear regression of design-based estimates, "WLRDB" for weighted linear regression of design-based estimates, or "PWIGLS" for probability-weighted iterative generalized least squares (Pfeffermann et al. 1998, Asparouhov 2002).
slope	Logical value indicating inclusion of a random site-level slope effect in the variance components structure used for the "PO" and "PWIGLS" trend methods. Site- and year-level random intercept terms included as default.
type	Scaling type when method="PWIGLS". Valid values include "Aonly", "A", "AI", "B", "BI", "C". See section "Options for variable type" below.
stratum	Text string identifying an optional two-level stratification factor in dat.
Y	Text string indicating the binary outcome variable in dat.
lat	Site latitudes using an equal-area projection, e.g., UTM or Albers.

long	Site longitudes using an equal-area projection, e.g., UTM or Albers.
stage1wt	Design weights from the original sample draw without accounting for temporal revisit designs.
stage2wt	Panel inclusion weights for each site each year.
str1prop	Proportion of the first stratum in the population in a two-level stratification variable.
nbhd	Logical indicator for the neighborhood variance estimator when method="WLRDB". If FALSE, "WLRDB" calculates the design-based mean estimate's standard error assuming independent random sampling.

Details

For long-term monitoring, TrendNPS_Count assumes a single annual sampling occasion per unique record of WYear and Site in data frame dat.

Sampling (stage1wt) and temporal-revisit (stage2wt) design weights must be adjusted for any missing data or frame error prior to trend analysis. See Oh and Scheuren (1983), Little and Rubin (2002), and Starcevich et al. (2016).

For background on the variance structure, see Piepho & Ogutu (2002). For more information on the LaPlace approximation, see Wolfinger (1993) and Raudenbush et al. (2000). For information on the probability-weighted generalized least squares approach, see Pfeiffermann et al. (1998), Asparouhov (2006), and Starcevich et al. (2017).

Value

A list containing three or four elements, depending on the specified trend method. The first element of the list, ModelEstimates, contains a data frame with the trend model output:

mu	Estimated intercept from the trend model.
trend	Estimated trend of the outcome Y on the link function scale from the trend model.
SEtrend	Estimated standard error of the trend estimate.
sig2a	Estimated site-to-site variation.
sig2b	Estimated year-to-year variation.
sig2t	Estimated variation among site-level slopes.
sig2e	Estimated residual variation.
eta	Degrees of freedom used to test for trend and calculate confidence intervals.

The contents of the second list element, TrendTest, include the trend coefficient on the link scale, the trend standard error, the t-statistic, degrees of freedom, and p-value for a two-sided test of no trend.

The contents of the third list element, TrendCI, include the back-transformed trend on the original scale and the lower and upper $(1-\alpha)*100\%$ -confidence interval bounds.

A fourth list element, DBests, contains the annual design-based estimates and is returned only when the SLRDB and WLRDB trend approaches are used. The design-based estimates may be used to assess the assumption of independence for the linear regression models. The output of the DBests list element include:

Year	Year of survey.
Est.Mean	Design-based estimate of the mean of the outcome of interest.
SE	Estimated standard error of design-based mean estimate if nbhd=TRUE.
WYear	WYear variable.
Resid	Residuals from the linear model fit.

Method requirements

Spatially balanced samples utilizing method="SLRDB" or method="WLRDB" require specification of lat and long on setting the neighborhood variance estimator nbhd=TRUE. If spatial balance cannot be assumed, set option nbhd=FALSE for non-spatially balanced designs so that the "SLRDB" and "WLRDB" methods assume independent random sampling for standard errors.

The stratification variable stratum is required for all methods when design strata are used. Note that method="PWIGLS" further requires a value for type. See section "Options for variable type" below.

Specify stage1wt and stage2wt for all methods except unweighted method="P0".

Data frame dat

Data frame dat requires at least variables Site, WYear, Year, and Y. Variable Site defines the sampling unit.

Underlying statistical functions called by TrendNPS_Count require two separate temporal variables: Year is a factor and WYear is a scalar-year value. WYear is shifted so that the year for which Y is least variable is centered on 0. See Piepho & Ogutu (2002) for more information.

Ultimately, WYear represents time in the fixed-effects portion of the trend model. The regression coefficient associated with WYear provides the basis for trend estimation and testing.

Variable Year enters the model as a random effect and provides the basis for estimation of random year-to-year variation among survey occasions.

Variable Y must contain only integer count values coded as numeric values 0, 1, 2, 3, ...

Options for variable type

Selection of method="PWIGLS" requires further specification of argument type. Valid options include

"Aonly"	Probability weighting but no scaling at either stage
"A"	Panel-weights scaling with mean site-level design weight
"AI"	Panel-weights scaling with mean site-level design weight, but no site-level scaling
"B"	Panel-weights scaling with effective mean site-level design weight
"BI"	Panel-weights scaling with effective mean site-level design weight, but no site-level scaling
"C"	Year-level scaling only with inverse of the average year-level weight

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See Also

lme4, lmerTest, spsurvey

Examples

```
# ---- Read example data set.
data(Seastar)

# ---- Load dependent packages.
pkgList <- c("lme4", "lmerTest", "spsurvey")
inst <- pkgList %in% installed.packages()
if (length(pkgList[!inst]) > 0) install.packages(pkgList[!inst])
lapply(pkgList, library, character.only = TRUE)

#####
# Example 1: Trend analysis of annual site-level counts of leather sea stars
# with the PO approach: stratification and full random effects model.
TrendSeaster_PO_StRS = TrendNPS_Count(alpha=0.1,
dat=Seastar, method="PO", slope=TRUE, type=NA, stratum="Park", Y="Count",
stage1wt="wgt", stage2wt="PanelWt", str1prop=0.13227)
# $ModelEstimates
#          mu          trend      SEtrend      sig2a          sig2t          sigat          sig2b
```

```

# 1.470868 0.04604476 0.04518698 0.248528 0.001259151 -0.007764177 0.03724626
#
# $TrendTest
#      trend      SEtrend    z-stat    pvalue
# 0.04604476 0.04518698 1.018983 0.3082111
#
# $TrendCI
# Annual Pct Change      CI low    CI high
#      0.04712128 -0.02788504 0.1279149

# Example 2: Trend analysis of annual site-level counts of leather sea stars
# with the SLRDB approach for stratification.
TrendSeastar_SLRDB_StRS = TrendNPS_Count(alpha=0.1,
dat=Seastar,method="SLRDB",slope=TRUE,type=NA,stratum="Park",Y="Count",
lat="Lat",long="Long", stage1wt="wt",stage2wt="PanelWt",str1prop=0.13227)

# TrendSeastar_SLRDB_StRS
# $ModelEstimates
#      mu      trend      SEtrend sig2a sig2t sigat sig2b
# 2.687804 0.0317377 0.04920822      0      0      0      0
#
# $TrendTest
#      trend      SEtrend    z-stat    pvalue
# 0.0317377 0.04920822 0.6449674 0.5189483
#
# $TrendCI
# Annual Pct Change      CI low    CI high
#      0.03224671 -0.04801179 0.1192715
#
# $DBests
#   Year Est.Mean      SE WYear      Resid
# 2009 11.66248 2.268814      0 -0.23142756
# 2010 14.66567 4.057595      1 -0.03403269
# 2011 18.60000 6.206449      2  0.17188195
# 2012 17.17467 5.045078      3  0.06041852
# 2013 21.71013 5.658295      4  0.26302412
# 2014 20.29531 4.128595      5  0.16389719
# 2015 11.99475 2.917410      6 -0.39376154

# Plot trend on original scale
plot(TrendSeastar_SLRDB_StRS$DBests$Year,
      TrendSeastar_SLRDB_StRS$DBests$Est.Mean,
      xlab="Year", ylab="Mean Sea Star Counts")
lines(2009:2015, exp(2.687804 + 0.0317377*(0:6)), col=2)

```

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