

# Package ‘SightabilityModel’

February 18, 2023

**Type** Package

**Title** Wildlife Sightability Modeling

**Version** 1.5.2

**Date** 2023-02-16

**Description** Uses logistic regression to model the probability of detection as a function of covariates. This model is then used with observational survey data to estimate population size, while accounting for uncertain detection. See Steinhorst and Samuel (1989).

**URL** <https://github.com/jfieberg/SightabilityModel>

**Imports** formula.tools, Matrix, msm, plyr, mvtnorm, stats, survey, utils

**License** GPL-2

**LazyLoad** yes

**RoxygenNote** 7.2.3

**Encoding** UTF-8

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**VignetteBuilder** R.rsp, knitr, rmarkdown

**NeedsCompilation** no

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SightabilityModel-package  
*Wildlife Sightability Modeling*

---

### Description

Uses logistic regression to model the probability of detection as a function of covariates. This model is then used with observational survey data to estimate population size, while accounting for uncertain detection. See Steinhorst and Samuel (1989).

### Details

Package:	SightabilityModel
Type:	Package
Version:	1.3
Date:	2014-10-03
License:	GPL-2
LazyLoad:	yes

**Author(s)**

John Fieberg

Maintainer: John Fieberg <jfieberg@umn.edu>

**References**

Fieberg, J. 2012. Estimating Population Abundance Using Sightability Models: R Sightability-Model Package. *Journal of Statistical Software*, 51(9), 1-20. URL <https://doi.org/10.18637/jss.v051.i09>

Steinhorst, Kirk R. and Samuel, Michael D. 1989. Sightability Adjustment Methods for Aerial Surveys of Wildlife Populations. *Biometrics* 45:415–425.

---

check.sightability.model.args

*Check the sightability model arguments for consistency*

---

**Description**

Check the sightability model arguments for consistency

**Usage**

```
check.sightability.model.args(data, sight.model, sight.beta, sight.beta.cov)
```

**Arguments**

data	Data.frame containing covariates for sightability model
sight.model	Formula with sightability model
sight.beta	Parameter estimates (from fitted sightability model)
sight.beta.cov	Estimated variance-covariance matrix for parameter estimates from fitted sightability model.

**Value**

Error condition or invisible

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**Examples**

```
sightability.table <- data.frame(VegCoverClass=1:5)
sight.beta <- c(4.2138, -1.5847)
sight.beta.cov <- matrix(c(0.7821634, -0.2820000, -0.2820000, 0.1114892), nrow=2)
check.sightability.model.args( sightability.table,
                               ~VegCoverClass,
                               sight.beta,
                               sight.beta.cov)

## Not run:
check.sightability.model.args( sightability.table,
                               ~VegCoverClass2,
                               sight.beta,
                               sight.beta.cov)

check.sightability.model.args( sightability.table,
                               ~VegCoverClass,
                               sight.beta[1],
                               sight.beta.cov)

## End(Not run)
```

---

compute.detect.prob     *Compute the detection probability given a sightability model*

---

**Description**

Compute the detection probability given a sightability model

**Usage**

```
compute.detect.prob(
  data,
  sight.model,
  sight.beta,
  sight.beta.cov,
  check.args = FALSE
)
```

**Arguments**

data	Data.frame containing covariates for sightability model
sight.model	Formula with sightability model
sight.beta	Parameter estimates (from fitted sightability model
sight.beta.cov	Estimated variance-covariance matrix for parameter estimates from fitted sightability model.
check.args	Should the sightability model arguments be checked for consistency/

**Value**

Vector of detection probabilities

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**See Also**

[compute.SCF](#)

**Examples**

```
sightability.table <- data.frame(VegCoverClass=1:5)
sight.beta <- c(4.2138, -1.5847)
sight.beta.cov <- matrix(c(0.7821634, -0.2820000, -0.2820000, 0.1114892), nrow=2)
sightability.table$detect.prob <- compute.detect.prob( sightability.table,
                                                    ~VegCoverClass,
                                                    sight.beta,
                                                    sight.beta.cov)
sightability.table$SCF <- compute.SCF( sightability.table,
                                       ~VegCoverClass,
                                       sight.beta,
                                       sight.beta.cov)

sightability.table
# "Note that the SCF != 1/detect.prob because of correction terms for covariance of beta.terms"
```

---

compute.SCF

*Compute the sightability correction factor given a sightability and covariates*

---

**Description**

Compute the sightability correction factor given a sightability and covariates

**Usage**

```
compute.SCF(
  data,
  sight.model,
  sight.beta,
  sight.beta.cov,
  check.args = FALSE,
  adjust = TRUE
)
```

**Arguments**

data	Data.frame containing covariates for sightability model
sight.model	Formula with sightability model
sight.beta	Parameter estimates (from fitted sightability model)
sight.beta.cov	Estimated variance-covariance matrix for parameter estimates from fitted sightability model.
check.args	Should the sightability model arguments be checked for consistency/
adjust	Should the sightability value be adjusted for the sight.beta.cov.

**Value**

Vector of sightability factors (SCF)

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**See Also**

[compute.detect.prob](#)

**Examples**

```
sightability.table <- data.frame(VegCoverClass=1:5)
sight.beta <- c(4.2138, -1.5847)
sight.beta.cov <- matrix(c(0.7821634, -0.2820000, -0.2820000, 0.1114892), nrow=2)
sightability.table$detect.prob <- compute.detect.prob( sightability.table,
                                                    ~VegCoverClass,
                                                    sight.beta,
                                                    sight.beta.cov)
sightability.table$SCF <- compute.SCF ( sightability.table,
                                       ~VegCoverClass,
                                       sight.beta,
                                       sight.beta.cov)

sightability.table
# "Note that the SCF != 1/detect.prob because of correction terms for covariance of beta.terms"
```

---

covtheta

*Estimates var/cov matrix of inflation factors (1/prob detection) using a non-parametric bootstrap.*

---

**Description**

Estimates var/cov matrix of inflation factors (1/prob detection) using a non-parametric bootstrap. Called by function Sight.Est if Vm.boot = TRUE.

**Usage**

```
covtheta(total, srates, stratum, subunit, covars, betas, varbetas, nboots)
```

**Arguments**

total	Number of animals in each independently sighted group
srates	Plot sampling probability (associated with the independently observed animal groups)
stratum	Stratum identifiers (associated with the independently observed animal groups)
subunit	Plot ID (associated with the independently observed animal groups)
covars	Matrix of sightability covariates (associated with the independently observed animal groups)
betas	Logistic regression parameter estimates (from fitted sightability model)
varbetas	Estimated variance-covariance matrix for the logistic regression parameter estimates (from fitted sightability model)
nboots	Number of bootstrap resamples.

**Value**

smat	Estimated variance-covariance matrix for the inflation factors $\theta = (1/\text{probability of detection})$ . This is an $n.\text{animal} \times n.\text{animal}$ matrix.
------	---

**Author(s)**

John Fieberg

**See Also**

[Sight.Est](#)

---

exp.m	<i>Experimental (test trials) data set used to estimate detection probabilities for moose in MN</i>
-------	---

---

**Description**

Experimental (test trials) data set used to estimate detection probabilities for moose in MN

**Format**

A data frame with 124 observations on the following 4 variables.

**year** year of the experimental survey (test trial)

**observed** Boolean variable (=1 if moose was observed and 0 otherwise)

**voc** measurement of visual obstruction

**grpsize** group size (number of observed moose in each independently sighted group)

**References**

Giudice, J H. and Fieberg, J. and Lenarz, M. S. 2012. Spending Degrees of Freedom in a Poor Economy: A Case Study of Building a Sightability Model for Moose in Northeastern Minnesota. Journal of Wildlife Management 76(1):75-87.

**Examples**

```
data(exp.m)
exp.m[1:5,]
```

---

g.fit

*Mountain Goat Sightability Model Information*

---

**Description**

Model averaged regression parameters and unconditional variance-covariance matrix for mountain goat sightability model (Rice et al. 2009)

**Format**

The format is: beta.g = list of regression parameters (intercept and parameters associated with GroupSize, Terrain, and X.VegCover) varbeta.g = variance-covariance matrix (associated with beta.g)

**References**

Rice C.G., Jenkins K.J., Chang W.Y. (2009). A Sightability Model for Mountain Goats. The Journal of Wildlife Management, 73(3), 468-478.

**Examples**

```
data(g.fit)
```



---

gdat

---

*Mountain Goat Survey Data from Olympic National park*


---

**Description**

Mountain Goat Survey Data from Olympic National park collected in 2004

**Format**

A data frame with 113 observations on the following 9 variables.

**GroupSize** number of animals observed in each independently sighted group [cluster size]

**Terrain** measure of terrain obstruction

**pct.VegCover** measure of vegetative obstruction

**stratum** stratum identifier

**total** number of animals observed in each independently sighted group [same as GroupSize]

**subunit** a numeric vector, Plot ID

**Source**

Patti Happe (Patti\_Happe@nps.gov)

**References**

Jenkins, K. J., Happe, P.J., Beirne, K.F, Hoffman, R.A., Griffin, P.C., Baccus, W. T., and J. Fieberg. In press. Recent population trends in mountain goats in the Olympic mountains. Northwest Science.

**Examples**

```
data(gdat)
```

---

MoosePopR

---

*R function that gives the same functionality as the MoosePop program.*


---

**Description**

A stratified random sample of blocks in a survey area is conducted. In each block, groups of moose are observed (usually through an aerial survey). For each group of moose, the number of moose is recorded along with attributes such as sex or age. MoosePopR() assumes that sightability is 100%. Use the SightabilityPopR() function to adjust for sightability < 100%.

**Usage**

```

MoosePopR(
  survey.data,
  survey.block.area,
  stratum.data,
  density = NULL,
  abundance = NULL,
  numerator = NULL,
  denominator = NULL,
  block.id.var = "Block.ID",
  block.area.var = "Block.Area",
  stratum.var = "Stratum",
  stratum.blocks.var = "Stratum.Blocks",
  stratum.area.var = "Stratum.Area",
  conf.level = 0.9,
  survey.lonely.psu = "fail"
)

```

**Arguments**

survey.data	A data frame containing counts of moose in each group along with a variable identifying the stratum (see stratum.var) and block (see block.id.var)
survey.block.area	A data frame containing for each block, the block id (see block.id.var), the area of the block (see block.area.var). The data frame can contain information for other blocks that were not surveyed (e.g. for the entire population of blocks) and information from these additional blocks will be ignored.
stratum.data	A data frame containing for each stratum, the stratum id (see stratum.var), the total number of blocks in the stratum (see stratum.blocks.var) and the total area of the stratum (see stratum.area.var)
density, abundance, numerator, denominator	Right-handed formula identifying the variable(s) in the survey.data data frame for which the density, abundance, or ratio (numerator/denominator) are to be estimated.
block.id.var	Name of the variable in the data frames that identifies the block.id (the sampling unit)
block.area.var	Name of the variable in data frames that contains the area of the blocks (area of sampling unit)
stratum.var	Name of the variable in the data frames that identifies the classical stratum
stratum.blocks.var	Name of the variable in the stratum.data data frame that contains the total number of blocks in the stratum.
stratum.area.var	Name of the variable in the stratum.data data.frame that contains the total stratum area.
conf.level	Confidence level used to create confidence intervals.

survey.lonely.psu

How to deal with lonely PSU within strata. See surveyoptions in the survey package.

### Value

A data frame containing for each stratum and for all strata (identified as stratum id .OVERALL), the density, or abundance or ratio estimate along with its estimated standard error and large-sample normal-based confidence interval.

### Author(s)

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

### References

To Be Added.

### Examples

```
##---- See the vignettes for examples on how to run this analysis.
```

---

MoosePopR\_DomStrat      *Classical and Domain Stratification using MoosePopR()*

---

### Description

This function allows for classical or domain stratification when using MoosePopR(). Caution **\*\*SE** are NOT adjusted for measurements on multiple domains on the same sampling unit. Bootstrapping may be required\*\*. Consult the vignette for more details.

MoosePopR\_DomStrat() assumes that sightability is 100%. Use the SightabilityPopR\_DomStrat() function to adjust for sightability < 100%.

### Usage

```
MoosePopR_DomStrat(
  stratum.data,
  selected.unit.data,
  waypoint.data,
  density = NULL,
  abundance = NULL,
  numerator = NULL,
  denominator = NULL,
  stratum.var = "Stratum",
  domain.var = "Domain",
  stratum.total.blocks.var = "Total.Blocks",
```

```

stratum.total.area.var = "Total.Area",
block.id.var = "Block.ID",
block.area.var = "Block.Area",
conf.level = 0.9,
survey.lonely.psu = "fail"
)

```

## Arguments

**stratum.data** A data frame containing for each combination of stratum and domain, the stratum id (see `stratum.var`), the domain id (see `domain.var`), the total number of blocks in the stratum (see `stratum.total.blocks.var`) and the total area of the stratum (see `stratum.total.area.var`)

**selected.unit.data** A data frame containing information on the selected survey units. Required variables are the stratum (see `stratum.var`), domain (see `domain.var`), block.id (see `block.id.var`), and the area of the block (see `block.area.var`).

**waypoint.data** A data frame containing counts of moose in each group along with a variable identifying the stratum (see `stratum.var`), domain (see `domain.var`) and block (see `block.id.var`). Additional variables can be included such as covariates for the sightability function (not currently used in MoosePopR)

**density, abundance, numerator, denominator** Right-handed formula identifying the variable(s) in the waypoint data frame for which the density, abundance, or ratio (numerator/denominator) are to be estimated.

**stratum.var** Name of the variable in the data frames that identifies the classical stratum

**domain.var** Name of the variable in the data frames that identifies the domain.

**stratum.total.blocks.var** Name of the variable in the `stratum.data` data frame that contains the total number of blocks in the stratum.

**stratum.total.area.var** Name of the variable in the `stratum.data` data.frame that contains the total stratum area.

**block.id.var** Name of the variable in the data frames that identifies the block.id (the sampling unit)

**block.area.var** Name of the variable in data frames that contains the area of the blocks (area of sampling unit)

**conf.level** Confidence level used to create confidence intervals.

**survey.lonely.psu** How to deal with lonely PSU within strata. See `surveyoptions` in the `survey` package.

## Value

A data frame containing for each stratum and for all combinations of strata and domains (identified as stratum id `.OVERALL`), the density, or abundance or ratio estimate along with its estimated standard error and large-sample normal-based confidence interval.

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**References**

To Be Added.

**Examples**

```
##---- See the vignettes for examples on how to run this analysis.
```

---

```
MoosePopR_DomStrat_bootrep
```

```
Generate a bootstrap replicate of data for call to Moose-  
PopR_DomStrat()
```

---

**Description**

This function takes the data from a classical/domain stratification and generates a bootstrap replicate suitable for analysis using `MoosePopR_DomStrat()`. A sightability model is allowed which "adjusts" the input data for sightability. This can also be used for `SightabilityPopR()` models by forcing block areas to 1 and the total block area in stratum to the number of blocks to mimic a mean-per-unit estimator. See the vignette for examples of usage.

**Usage**

```
MoosePopR_DomStrat_bootrep(  
  stratum.data,  
  selected.unit.data,  
  waypoint.data,  
  density = NULL,  
  abundance = NULL,  
  numerator = NULL,  
  denominator = NULL,  
  sight.model = NULL,  
  sight.beta = NULL,  
  sight.beta.cov = NULL,  
  stratum.var = "Stratum",  
  domain.var = "Domain",  
  stratum.total.blocks.var = "Total.Blocks",  
  stratum.total.area.var = "Total.Area",  
  block.id.var = "Block.ID",  
  block.area.var = "Block.Area",  
  conf.level = 0.9,  
  survey.lonely.psu = "fail",
```

```

    check.args = TRUE
  )

```

### Arguments

- `stratum.data` A data frame containing for each combination of stratum and domain, the stratum id (see `stratum.var`), the domain id (see `domain.var`), the total number of blocks in the stratum (see `stratum.total.blocks.var`) and the total area of the stratum (see `stratum.total.area.var`)
- `selected.unit.data` A data frame containing information on the selected survey units. Required variables are the stratum (see `stratum.var`), domain (see `domain.var`), block.id (see `block.id.var`), and the area of the block (see `block.area.var`).
- `waypoint.data` A data frame containing counts of moose in each group along with a variable identifying the stratum (see `stratum.var`), domain (see `domain.var`) and block (see `block.id.var`). Additional variables can be included such as covariates for the sightability function (not currently used in MoosePopR)
- `density, abundance, numerator, denominator` Right-handed formula identifying the variable(s) in the waypoint data frame for which the density, abundance, or ratio (numerator/denominator) are to be estimated.
- `sight.model` A formula that identifies the model used to estimate sightability. For example `observed ~ VegCoverClass` would indicate that sightability is a function of the `VegCoverClass` variable in the survey data. The left hand variable is arbitrary. The right hand variables must be present in the `survey.data` data frame.
- `sight.beta` The vector of estimated coefficients for the logistic regression sightability model.
- `sight.beta.cov` The covariance matrix of `sight.beta`
- `stratum.var` Name of the variable in the data frames that identifies the classical stratum
- `domain.var` Name of the variable in the data frames that identifies the domain.
- `stratum.total.blocks.var` Name of the variable in the `stratum.data` data frame that contains the total number of blocks in the stratum.
- `stratum.total.area.var` Name of the variable in the `stratum.data` data.frame that contains the total stratum area.
- `block.id.var` Name of the variable in the data frames that identifies the block.id (the sampling unit)
- `block.area.var` Name of the variable in data frames that contains the area of the blocks (area of sampling unit)
- `conf.level` Confidence level used to create confidence intervals.
- `survey.lonely.psu` How to deal with lonely PSU within strata. See `surveyoptions` in the `survey` package.
- `check.args` Should arguments be checked. Turn off for extensive bootstrapping to save time.

**Value**

A list containing the input data (`input.data`), the bootstrap replicate (`boot.data`), and a data frame (`boot.res`) with the estimated density, or abundance or ratio along with its estimated standard error and large-sample normal-based confidence interval. The density/abundance/ratio over all strata is also given on the last line of the `data.frame`.

**Author(s)**

Schwarz, C. J. <[cschwarz.stat.sfu.ca@gmail.com](mailto:cschwarz.stat.sfu.ca@gmail.com)>.

**References**

To Be Added.

**Examples**

```
##---- See the vignettes for examples on how to use this function
```

---

obs.m

*MN moose survey data*

---

**Description**

Operational survey data for moose in MN (during years 2004-2007). Each record corresponds to an independently sighted group of moose, with variables that capture individual covariates (used in the detection model) as well as plot-level information (stratum identifier, sampling probability, etc).

**Format**

A data frame with 805 observations on the following 11 variables.

**year** year of survey

**stratum** stratum identifier

**subunit** sample plot ID

**total** number of moose observed

**cows** number of cows observed

**calves** number of calves observed

**bulls** number of bulls observed

**unclass** number of unclassified animals observed (could not identify sex/age class)

**voc** measurement of visual obstruction

**grpsize** group size (cluter size)

**References**

Giudice, J H. and Fieberg, J. and Lenarz, M. S. 2012. Spending Degrees of Freedom in a Poor Economy: A Case Study of Building a Sightability Model for Moose in Northeastern Minnesota. *Journal of Wildlife Management* 76(1):75-87.

**Examples**

```
data(obs.m)
obs.m[1:5, ]
```

---

```
print.sightest      Print method for sightability estimators
```

---

**Description**

Prints fitted sightability model, sampling information, and sightability estimate (with confidence interval)

**Usage**

```
## S3 method for class 'sightest'
print(x, ...)
```

**Arguments**

x                   Sightability object, output from call to `Sight.Est()` or `Sight.Est.Ratio()` functions.  
...                  arguments to be passed to or from other methods

**Author(s)**

John Fieberg and Carl James Schwarz

**See Also**

[Sight.Est](#), [Sight.Est.Ratio](#), [summary.sightest](#), [summary.sightest\\_ratio](#)



---

sampinfo.m	<i>Data set containing sampling information for observation survey of moose in MN</i>
------------	---

---

**Description**

Data set containing sampling information from a survey of moose in MN (during years 2004-2007)

**Format**

A data frame with 12 observations on the following 5 variables.

**year** year of survey

**stratum** stratum identifier

**Nh** number of population units in stratum h

**nh** number of sample units in stratum h

**References**

Giudice, J H. and Fieberg, J. and Lenarz, M. S. 2012. Spending Degrees of Freedom in a Poor Economy: A Case Study of Building a Sightability Model for Moose in Northeastern Minnesota. Journal of Wildlife Management 76(1):75-87.

**Examples**

```
data(sampinfo.m)
sampinfo.m
```

---

Sight.Est	<i>Sightability Model Estimator</i>
-----------	-------------------------------------

---

**Description**

Estimates population abundance by 1) fitting a sightability (logistic regression) model to "test trial" data; 2) applying the fitted model to independent (operational) survey data to correct for detection rates < 1.

**Usage**

```
Sight.Est(
  form,
  sdat = NULL,
  odat,
  sampinfo,
  method = "Wong",
  logCI = TRUE,
  alpha = 0.05,
  Vm.boot = FALSE,
  nboot = 1000,
  bet = NULL,
  varbet = NULL
)
```

**Arguments**

form	a symbolic description of the sightability model to be fit (e.g., "y ~ x1 + x2 + ..."), where y is a binary response variable (= 1 if the animal is seen and 0 otherwise) and x1, x2, ... are a set of predictor variables thought to influence detection
sdat	'sightability' data frame. Each row represents an independent sightability trial, and columns contain the response (a binary random variable = 1 if the animal was observed and 0 otherwise) and the covariates used to model detection probabilities.
odat	'observational survey' data frame containing the following variable names ( <i>stratum</i> , <i>subunit</i> , <i>total</i> ) along with the same covariates used to model detection probabilities (each record corresponds to an independently sighted group of animals). <i>stratum</i> = stratum identifier (will take on a single value for non-stratified surveys); <i>subunit</i> = numeric plot unit identifier; <i>total</i> = total number of observed animals (for each independently sighted group of animals).
sampinfo	data frame containing sampling information pertaining to the observational survey. Must include the following variables ( <i>stratum</i> , <i>nh</i> , <i>Nh</i> ). <i>stratum</i> = stratum identifier (must take on the same values as <i>stratum</i> variable in observational data set), <i>nh</i> = number of sampled units in stratum h, <i>Nh</i> = number of population units in stratum h; note (this dataset will contain a single record for non-stratified designs).
method	method for estimating variance of the abundance estimator. Should be one of ("Wong", "SS"). See details for more information.
logCI	Boolean variable, default (= TRUE), indicates the confidence interval should be constructed under the assumption that $(\tau - T)$ has a lognormal distribution, where T is the total number of animals observed (see details)
alpha	type I error rate for confidence interval construction
Vm.boot	Boolean variable, when = TRUE indicates a bootstrap should be used to estimate $\text{cov}(\theta_{[i,j]}, \theta_{[i',j']})$ , var/cov matrix of the expansion factors (1/detection prob)

nboot	number of bootstrap replicates to use if Vm.boot = TRUE
bet	regression parameters (if the sightability model is not to be fit by Sight.Est). Make sure the order is consistent with the specification in the "form" argument.
varbet	variance-covariance matrix for beta^ (if the sightability model is not to be fit by Sight.Est). Make sure the order is consistent with the specification in the "form" argument.

### Details

Variance estimation methods: method = Wong implements the variance estimator from Wong (1996) and is the recommended approach. Method = SS implements the variance estimator of Steinhorst and Samuel (1989), with a modification detailed in the Appendix of Samuel et al. (1992).

Estimates of the variance may be biased low when the number of test trials used to estimate model parameters is small (see Wong 1996, Fieberg and Giudice 2008). A bootstrap can be used to aid the estimation process by specifying Vm.boot = TRUE [note: this method is experimental, and can be time intensive].

Confidence interval construction: often the sampling distribution of tau^ is skewed right. If logCI = TRUE, the confidence interval for tau^ will be constructed under an assumption that (tau^ - T) has a lognormal distribution, where T is the total number of animals seen. In this case, the upper and lower limits are constructed as follows [see Wong(1996, p. 64-67)]:

$LCL = T + ((\tau^ - T)/C) * \sqrt{1 + cv^2}$ ,  $UCL = T + ((\tau^ - T) * C) * \sqrt{1 + cv^2}$ , where  $cv^2 = \text{var}(\tau^)/(\tau^ - T)^2$  and  $C = \exp[z[\alpha/2] * \sqrt{\ln(1 + cv^2)}]$ .

### Value

An object of class sightest, a list that includes the following elements:

sight.model	the fitted sightability model
est	abundance estimate [tau.hat] and its estimate of uncertainty [Vartot] as well as variance components due to sampling [Varsamp], detection [VarSight], and model uncertainty [VarMod]

The list also includes the original test trial and operational survey data, sampling information, and information needed to construct a confidence interval for the population estimate.

### Author(s)

John Fieberg, Wildlife Biometrician, Minnesota Department of Natural Resources

### References

- Fieberg, J. 2012. Estimating Population Abundance Using Sightability Models: R Sightability-Model Package. *Journal of Statistical Software*, 51(9), 1-20. URL <https://doi.org/10.18637/jss.v051.i09>.
- Fieberg, John and Giudice, John. 2008 Variance of Stratified Survey Estimators With Probability of Detection Adjustments. *Journal of Wildlife Management* 72:837-844.
- Samuel, Michael D. and Steinhorst, R. Kirk and Garton, Edward O. and Unsworth, James W. 1992. Estimation of Wildlife Population Ratios Incorporating Survey Design and Visibility Bias. *Journal of Wildlife Management* 56:718-725.

Steinhorst, R. K., and M.D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. *Biometrics* 45:415-425.

Wong, C. 1996. Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

## Examples

```
# Load data frames
data(obs.m) # observational survey data frame
data(exp.m) # experimental survey data frame
data(sampinfo.m) # information on sampling rates (contained in a data frame)

# Estimate population size in 2007 only
sampinfo <- sampinfo.m[sampinfo.m$year == 2007,]
Sight.Est(observed ~ voc, odat = obs.m[obs.m$year == 2007,],
          sdat = exp.m, sampinfo, method = "Wong",
          logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)

# BELOW CODE IS SOMEWHAT TIME INTENSIVE (fits models using 2 variance estimators to 3 years of data)
# Estimate population size for 2004-2007
# Compare Wong's and Steinhorst and Samuel variance estimators
tau.Wong <- tau.SS <- matrix(NA,4,3)
count <- 1
for(i in 2004:2007){
  sampinfo <- sampinfo.m[sampinfo.m$year == i,]

# Wong's variance estimator
  temp <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year == i,],
                    sdat = exp.m, sampinfo, method = "Wong",
                    logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)
  tau.Wong[count, ] <- unlist(summary(temp))

# Steinhorst and Samuel (with Samuel et al. 1992 modification)
  temp <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year == i,],
                    sdat = exp.m, sampinfo, method = "SS")
  tau.SS[count, ] <- unlist(summary(temp))
  count<-count+1
}
rownames(tau.Wong) <- rownames(tau.SS) <- 2004:2007
colnames(tau.Wong) <- colnames(tau.SS) <- c("tau.hat", "LCL", "UCL")
(tau.Wong <- apply(tau.Wong, 1:2,
  FUN=function(x){as.numeric(gsub(","," ", x, fixed = TRUE))}))
(tau.SS <- (tau.Wong <- apply(tau.Wong, 1:2,
  FUN = function(x){as.numeric(gsub(","," ", x, fixed = TRUE))}))

## Not run:
require(gplots)
par(mfrow = c(1,1))
plotCI(2004:2007-.1, tau.Wong[,1], ui = tau.Wong[,3],
       li = tau.Wong[,2], type = "l", xlab = "",
```

```

      ylab = "Population estimate", xaxt = "n",
      xlim=c(2003.8, 2007.2))
plotCI(2004:2007+.1, tau.SS[,1], ui = tau.SS[,3], li = tau.SS[,2],
       type = "b", lty = 2, add = TRUE)
axis(side = 1, at = 2004:2007, labels = 2004:2007)

## End(Not run)

```

---

Sight.Est.Ratio

*Sightability Model Estimator - Ratio of variables*


---

### Description

Estimates population ratios by 1) fitting a sightability (logistic regression) model to "test trial" data; 2) applying the fitted model to independent (operational) survey data to correct for detection rates < 1.

### Usage

```

Sight.Est.Ratio(
  form,
  sdat = NULL,
  odat,
  sampinfo,
  method = "Wong",
  logCI = TRUE,
  alpha = 0.05,
  Vm.boot = FALSE,
  nboot = 1000,
  bet = NULL,
  varbet = NULL
)

```

### Arguments

form	a symbolic description of the sightability model to be fit (e.g., "y ~ x1 + x2 + ..."), where y is a binary response variable (= 1 if the animal is seen and 0 otherwise) and x1, x2, ... are a set of predictor variables thought to influence detection
sdat	'sightability' data frame. Each row represents an independent sightability trial, and columns contain the response (a binary random variable = 1 if the animal was observed and 0 otherwise) and the covariates used to model detection probabilities.
odat	'observational survey' data frame containing the following variable names ( <i>stratum</i> , <i>subunit</i> , <i>numerator</i> , <i>denominator</i> ) along with the same covariates used to model detection probabilities (each record corresponds to an independently

	sighted group of animals). <i>stratum</i> = stratum identifier (will take on a single value for non-stratified surveys); <i>subunit</i> = numeric plot unit identifier; <i>numerator</i> = total number of observed animals (for each independently sighted group of animals for numerator of ratio); <i>denominator</i> = total number of observed animals (for each independently sighted group of animals for denominator of ratio).
sampinfo	data frame containing sampling information pertaining to the observational survey. Must include the following variables ( <i>stratum</i> , <i>nh</i> , <i>Nh</i> ). <i>stratum</i> = stratum identifier (must take on the same values as <i>stratum</i> variable in observational data set), <i>nh</i> = number of sampled units in stratum h, <i>Nh</i> = number of population units in stratum h; note (this dataset will contain a single record for non-stratified designs).
method	method for estimating variance of the abundance estimator. Should be one of ("Wong", "SS"). See details for more information.
logCI	Boolean variable, default (= TRUE), indicates the confidence interval should be constructed under the assumption that $(\tau^{\wedge} - T)$ has a lognormal distribution, where T is the total number of animals observed (see details)
alpha	type I error rate for confidence interval construction
Vm.boot	Boolean variable, when = TRUE indicates a bootstrap should be used to estimate $\text{cov}(\theta_{[i,j]}, \theta_{[i',j']})$ , var/cov matrix of the expansion factors (1/detection prob)
nboot	number of bootstrap replicates to use if Vm.boot = TRUE
bet	regression parameters (if the sightability model is not to be fit by Sight.Est). Make sure the order is consistent with the specification in the "form" argument.
varbet	variance-covariance matrix for $\beta^{\wedge}$ (if the sightability model is not to be fit by Sight.Est). Make sure the order is consistent with the specification in the "form" argument.

## Details

Variance estimation methods: *method* = Wong implements the variance estimator from Wong (1996) and is the recommended approach. *Method* = SS implements the variance estimator of Steinhorst and Samuel (1989), with a modification detailed in the Appendix of Samuel et al. (1992).

Estimates of the variance may be biased low when the number of test trials used to estimate model parameters is small (see Wong 1996, Fieberg and Giudice 2008). A bootstrap can be used to aid the estimation process by specifying *Vm.boot* = TRUE [note: this method is experimental, and can be time intensive].

Confidence interval construction: often the sampling distribution of  $\tau^{\wedge}$  is skewed right. If *logCI* = TRUE, the confidence interval for  $\tau^{\wedge}$  will be constructed under an assumption that  $(\tau^{\wedge} - T)$  has a lognormal distribution, where T is the total number of animals seen. In this case, the upper and lower limits are constructed as follows [see Wong(1996, p. 64-67)]:

$LCL = T + [(\tau^{\wedge} - T)/C] * \sqrt{1 + cv^2}$ ,  $UCL = T + [(\tau^{\wedge} - T) * C] * \sqrt{1 + cv^2}$ , where  $cv^2 = \text{var}(\tau^{\wedge}) / (\tau^{\wedge} - T)^2$  and  $C = \exp[z[\alpha/2] * \sqrt{\ln(1 + cv^2)}]$ .

**Value**

An object of class `sightest_ratio`, a list that includes the following elements:

<code>sight.model</code>	the fitted sightability model
<code>est</code>	ratio estimate, <code>ratio.hat</code> , abundance estimate [ <code>tau.hat</code> ] and its estimate of uncertainty [ <code>Varratio</code> ] as well as variance components due to sampling [ <code>Varsamp</code> ], detection [ <code>VarSight</code> ], and model uncertainty [ <code>VarMod</code> ]

The list also includes the estimates for the numerator and denominator total, the original test trial and operational survey data, sampling information, and information needed to construct a confidence interval for the population estimate.

**Author(s)**

Carl James Schwarz, StatMathComp Consulting by Schwarz, [cschwarz.stat.sfu.ca@gmail.com](mailto:cschwarz.stat.sfu.ca@gmail.com)

**References**

- Fieberg, J. 2012. Estimating Population Abundance Using Sightability Models: R Sightability-Model Package. *Journal of Statistical Software*, 51(9), 1-20. URL <https://doi.org/10.18637/jss.v051.i09>.
- Fieberg, John and Giudice, John. 2008 Variance of Stratified Survey Estimators With Probability of Detection Adjustments. *Journal of Wildlife Management* 72:837-844.
- Samuel, Michael D. and Steinhorst, R. Kirk and Garton, Edward O. and Unsworth, James W. 1992. Estimation of Wildlife Population Ratios Incorporating Survey Design and Visibility Bias. *Journal of Wildlife Management* 56:718-725.
- Steinhorst, R. K., and M.D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. *Biometrics* 45:415-425.
- Wong, C. 1996. Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

**Examples**

```
# Load data frames
data(obs.m) # observational survey data frame
data(exp.m) # experimental survey data frame
data(sampinfo.m) # information on sampling rates (contained in a data frame)

# Estimate ratio of bulls to cows in 2007 only
sampinfo <- sampinfo.m[sampinfo.m$year == 2007,]

obs.m$numerator <- obs.m$bulls
obs.m$denominator <- obs.m$cows

Sight.Est.Ratio(observed ~ voc, odat = obs.m[obs.m$year == 2007,],
  sdat = exp.m, sampinfo, method = "Wong",
  logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)
```

---

SightabilityPopR	<i>R function that interfaces with the SightabilityModel package and gives similar functionality as the AerialSurvey program</i>
------------------	--

---

### Description

A stratified random sample of blocks in a survey area is conducted. In each block, groups of moose are observed (usually through an aerial survey). For each group of moose, the number of moose is recorded along with attributes such as sex or age.

The SightabilityPopR() function adjusts for sightability < 100%.

### Usage

```
SightabilityPopR(
  survey.data,
  survey.block.area,
  stratum.data,
  density = NULL,
  abundance = NULL,
  numerator = NULL,
  denominator = NULL,
  sight.formula = observed ~ 1,
  sight.beta = 10,
  sight.beta.cov = matrix(0, nrow = 1, ncol = 1),
  sight.logCI = TRUE,
  sight.var.method = c("Wong", "SS")[1],
  block.id.var = "Block.ID",
  block.area.var = "Block.Area",
  stratum.var = "Stratum",
  stratum.blocks.var = "Stratum.Blocks",
  stratum.area.var = "Stratum.Area",
  conf.level = 0.9
)
```

### Arguments

survey.data	A data frame containing counts of moose in each group along with a variable identifying the stratum (see stratum.var) and block (see block.id.var)
survey.block.area	A data frame containing for each block, the block id (see block.id.var), the area of the block (see block.area.var). The data frame can contain information for other blocks that were not surveyed (e.g. for the entire population of blocks) and information from these additional blocks will be ignored.
stratum.data	A data frame containing for each stratum, the stratum id (see stratum.var), the total number of blocks in the stratum (see stratum.blocks.var) and the total area of the stratum (see stratum.area.var)



density, abundance, numerator, denominator	Right-handed formula identifying the variable(s) in the survey.data data frame for which the density, abundance, or ratio (numerator/denominator) are to be estimated.
sight.formula	A formula that identifies the model used to estimate sightability. For example <code>observed ~ VegCoverClass</code> would indicate that sightability is a function of the <code>VegCoverClass</code> variable in the survey data. The left hand variable is arbitrary. The right hand variables must be present in the survey.data data frame.
sight.beta	The vector of estimated coefficients for the logistic regression sightability model.
sight.beta.cov	The covariance matrix of <code>sight.beta</code>
sight.logCI	Should confidence intervals for the sightability adjusted estimates be computed using a normal-based confidence interval on $\log(\text{abundance})$
sight.var.method	What method should be used to estimate the variances after adjusting for sightability.
block.id.var	Name of the variable in the data frames that identifies the block.id (the sampling unit)
block.area.var	Name of the variable in data frames that contains the area of the blocks (area of sampling unit)
stratum.var	Name of the variable in the data frames that identifies the classical stratum
stratum.blocks.var	Name of the variable in the stratum.data data frame that contains the total number of blocks in the stratum.
stratum.area.var	Name of the variable in the stratum.data data.frame that contains the total stratum area.
conf.level	Confidence level used to create confidence intervals.

**Value**

A data frame containing for each stratum and for all strata (identified as `stratum id .OVERALL`), the density, or abundance or ratio estimate along with its estimated standard error and large-sample normal-based confidence interval. Additional information on the components of variance is also reported.

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**References**

To Be Added.

**Examples**

```
##---- See the vignettes for examples on how to run this analysis.
```

---

SightabilityPopR\_DomStrat

*Classical and Domain Stratification using SightabilityPopR()*


---

## Description

This function allows for classical or domain stratification when using SightabilityPopR(). Caution **\*\*SE are NOT adjusted for measurements on multiple domains on the same sampling unit. Bootstrapping may be required\*\***. Consult the vignette for more details.

SightabilityPopR\_DomStrat() adjusts for sightability < 100%.

## Usage

```
SightabilityPopR_DomStrat(
  stratum.data,
  selected.unit.data,
  waypoint.data,
  density = NULL,
  abundance = NULL,
  numerator = NULL,
  denominator = NULL,
  sight.formula = ~1,
  sight.beta = 10,
  sight.beta.cov = matrix(0, nrow = 1, ncol = 1),
  sight.logCI = TRUE,
  sight.var.method = c("Wong", "SS")[1],
  stratum.var = "Stratum",
  domain.var = "Domain",
  stratum.total.blocks.var = "Total.Blocks",
  stratum.total.area.var = "Total.Area",
  block.id.var = "Block.ID",
  block.area.var = "Block.Area",
  conf.level = 0.9
)
```

## Arguments

- stratum.data** A data frame containing for each combination of stratum and domain, the stratum id (see stratum.var), the domain id (see domain.var), the total number of blocks in the stratum (see stratum.total.blocks.var) and the total area of the stratum (see stratum.total.area.var)
- selected.unit.data** A data frame containing information on the selected survey units. Required variables are the stratum (see stratum.var), domain (see domain.var), block.id (see block.id.var), and the area of the block (see block.area.var).

waypoint.data	A data frame containing counts of moose in each group along with a variable identifying the stratum (see stratum.var), domain (see domain.var) and block (see block.id.var). Additional variables can be included such as covariates for the sightability function (not currently used in MoosePopR)
density, abundance, numerator, denominator	Right-handed formula identifying the variable(s) in the waypoint data frame for which the density, abundance, or ratio (numerator/denominator) are to be estimated.
sight.formula	A formula that identifies the model used to estimate sightability. For example observed ~ VegCoverClass would indicate that sightability is a function of the VegCoverClass variable in the survey data. The left hand variable is arbitrary. The right hand variables must be present in the survey.data data frame.
sight.beta	The vector of estimated coefficients for the logistic regression sightability model.
sight.beta.cov	The covariance matrix of sight.beta
sight.logCI	Should confidence intervals for the sightability adjusted estimates be computed using a normal-based confidence interval on log(abundance)
sight.var.method	What method should be used to estimate the variances after adjusting for sightability.
stratum.var	Name of the variable in the data frames that identifies the classical stratum
domain.var	Name of the variable in the data frames that identifies the domain.
stratum.total.blocks.var	Name of the variable in the stratum.data data frame that contains the total number of blocks in the stratum.
stratum.total.area.var	Name of the variable in the stratum.data data.frame that contains the total stratum area.
block.id.var	Name of the variable in the data frames that identifies the block.id (the sampling unit)
block.area.var	Name of the variable in data frames that contains the area of the blocks (area of sampling unit)
conf.level	Confidence level used to create confidence intervals.

**Value**

A data frame containing for each stratum and for all combinations of strata and domains (identified as stratum id .OVERALL), the density, or abundance or ratio estimate along with its estimated standard error and large-sample normal-based confidence interval.

**Author(s)**

Schwarz, C. J. <cschwarz.stat.sfu.ca@gmail.com>.

**References**

To Be Added.

**Examples**

```
##---- See the vignettes for examples on how to run this analysis.
```

---

SS.est	<i>Sightability estimate with variance components estimator from Steinhorst and Samuel (1989) and Samuel et al. (1992).</i>
--------	---

---

**Description**

Estimates population size, with variance estimated using Steinhorst and Samuel (1989) and Samuel et al.'s (1992) estimator. Usually, this function will be called by Sight.Est

**Usage**

```
SS.est(
  total,
  srates,
  nh,
  Nh,
  stratum,
  subunit,
  covars,
  beta,
  varbeta,
  smat = NULL
)
```

**Arguments**

total	Number of animals in each independently sighted group
srates	Plot-level sampling probability
nh	Number of sample plots in each stratum
Nh	Number of population plots in each stratum
stratum	Stratum identifiers (associated with the independently observed animal groups)
subunit	Plot ID (associated with the independently observed animal groups)
covars	Matrix of sightability covariates (associated with the independently observed animal groups)
beta	Logistic regression parameter estimates (from fitted sightability model)
varbeta	Estimated variance-covariance matrix for the logistic regression parameter estimates (from fitted sightability model)
smat	Estimated variance-covariance matrix for the inflation factors (1/probability of detection). This is an n.animal x n.animal matrix, and is usually calculated within the SS.est function. Non-null values can be passed to the function (e.g., if a bootstrap is used to estimate uncertainty due to the estimated detection parameters).

**Value**

tau.hat	Sightability estimate of population size, $\tau^{\wedge}$
VarTot	Estimated variance of $\tau^{\wedge}$
VarSamp	Estimated variance component due to sampling aerial units
VarSight	Estimated variance component due to sighting process (i.e., series of binomial rv for each animal group)
VarMod	Estimated variance component due to estimating detection probabilities using test trial data

**Author(s)**

John Fieberg

**References**

Steinhorst, R. K., and M.D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. *Biometrics* 45:415-425.

Wong, C. 1996. Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

**See Also**

[Sight.Est](#), [Wong.est](#)

---

SS.est.Ratio	<i>Sightability estimate or ratio with variance components estimator from Steinhorst and Samuel (1989) and Samuel et al. (1992). This is merely a stub and has not been implemented.</i>
--------------	--

---

**Description**

Estimates ratio, with variance estimated using Steinhorst and Samuel (1989) and Samuel et al.'s (1992) estimator. Usually, this function will be called by `Sight.Est.Ratio()`

**Usage**

```
SS.est.Ratio(
  numerator,
  denominator,
  srates,
  nh,
  Nh,
  stratum,
  subunit,
  covars,
```

```

    beta,
    varbeta,
    smat = NULL
  )

```

### Arguments

numerator, denominator	Number of animals for the numerator and denominator of the ratio in each independently sighted group
srates	Plot-level sampling probability
nh	Number of sample plots in each stratum
Nh	Number of population plots in each stratum
stratum	Stratum identifiers (associated with the independently observed animal groups)
subunit	Plot ID (associated with the independently observed animal groups)
covars	Matrix of sightability covariates (associated with the independently observed animal groups)
beta	Logistic regression parameter estimates (from fitted sightability model)
varbeta	Estimated variance-covariance matrix for the logistic regression parameter estimates (from fitted sightability model)
smat	Estimated variance-covariance matrix for the inflation factors (1/probability of detection). This is an n.animal x n.animal matrix, and is usually calculated within the SS.est.Ratio function. Non-null values can be passed to the function (e.g., if a bootstrap is used to estimate uncertainty due to the estimated detection parameters).

### Value

ratio.hat	Sightability estimate of ratio, ratio <sup>^</sup>
VarRatio	Estimated variance of ratio <sup>^</sup>
VarSamp, VarSight, VarMod	Estimated variance component due to sampling, sightability and model set to NA

### Author(s)

Carl James Schwarz, [cschwarz.stat.sfu.ca@gmail.com](mailto:cschwarz.stat.sfu.ca@gmail.com)

### References

- Steinhorst, R. K., and M.D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. *Biometrics* 45:415-425.
- Wong, C. 1996. Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

### See Also

[Sight.Est](#), [Wong.est](#)

---

summary.sightest	<i>Summarize sightability estimator</i>
------------------	---

---

**Description**

Calculates confidence interval (based on asymptotic [normal or log-normal assumption])

**Usage**

```
## S3 method for class 'sightest'
summary(object, ...)
```

**Arguments**

object	Sightability object, output from call to Sight.Est function.
...	arguments to be passed to or from other methods

**Value**

Nhat or Ratiohat	Sightability population estimate
lcl	Lower confidence limit
ucl	Upper confidence limit

**Author(s)**

John Fieberg and Carl James Schwarz

**See Also**

[Sight.Est](#), [Sight.Est.Ratio](#)

---

vardiff	<i>Function to estimate the variance of the difference between two population estimates</i>
---------	---

---

**Description**

Function to estimate the variance of the difference between two population estimates formed using the same sightability model (to correct for detection).

**Usage**

```
vardiff(sight1, sight2)
```

**Arguments**

sight1	Sightability model object for the first population estimate (formed by calling Sight.Est function)
sight2	Sightability model object for the second population estimate (formed by calling Sight.Est function)

**Details**

Population estimates constructed using the same sightability model will NOT be independent (they will typically exhibit positive covariance). This function estimates the covariance due to using the same sightability model and subtracts it from the summed variance.

**Value**

vardiff            numeric =  $\text{var}(\tau^{[1]}) + \text{var}(\tau^{[2]}) - 2 * \text{cov}(\tau^{[1]}, \tau^{[2]})$

**Author(s)**

John Fieberg

**Examples**

```
# Example using moose survey data
data(obs.m) # observational moose survey data
data(exp.m) # experimental moose survey data
data(sampinfo.m) # information on sampling rates

# Estimate population size in 2006 and 2007
sampinfo <- sampinfo.m[sampinfo.m$year == 2007, ]
tau.2007 <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year == 2007, ],
                     sdat = exp.m, sampinfo.m[sampinfo.m$year == 2007, ],
                     method = "Wong", logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)
tau.2006 <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year == 2006, ],
                     sdat = exp.m, sampinfo.m[sampinfo.m$year == 2006, ],
                     method = "Wong", logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)

# naive variance
tau.2007$est[2] + tau.2006$est[2]

# variance after subtracting positive covariance
vardiff(tau.2007, tau.2006)
```



---

varlog.lam	<i>Calculates the variance of the log rate of change between 2 population estimates that rely on the same sightability model.</i>
------------	---

---

**Description**

Calculates the variance of the log rate of change between 2 population estimates that rely on the same sightability model.

**Usage**

```
varlog.lam(sight1, sight2)
```

**Arguments**

sight1	Sightability model object for the first population estimate (formed by calling Sight.Est function)
sight2	Sightability model object for the second population estimate (formed by calling Sight.Est function)

**Details**

This function uses the delta method to calculate an approximate variance for the log rate of change,  $\log(\tau^{[t+1]}) - \log(\tau^{[t]})$ , while accounting for the positive covariance between the two estimates (as a result of using the same sightability model to correct for detection).

**Value**

loglambda	log rate of change = $\log(\tau^{[t+1]}/\tau^{[t]})$
varloglambda	approximate variance of loglambda

**Author(s)**

John Fieberg

**See Also**

[vardiff](#)

**Examples**

```
# Example using moose survey data
data(obs.m) # observational moose survey data
data(exp.m) # experimental moose survey data
data(sampinfo.m) # information on sampling rates

# Estimate population size in 2006 and 2007
```

```

sampinfo <- sampinfo.m[sampinfo.m$year==2007, ]
tau.2007 <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year==2007, ],
                    sdat = exp.m, sampinfo.m[sampinfo.m$year == 2007, ],
                    method = "Wong", logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)
tau.2006 <- Sight.Est(observed ~ voc, odat = obs.m[obs.m$year==2006, ],
                    sdat = exp.m, sampinfo.m[sampinfo.m$year == 2006, ],
                    method = "Wong", logCI = TRUE, alpha = 0.05, Vm.boot = FALSE)

# Log rate of change
varlog.lam(tau.2006, tau.2007)

```

---

Wong.est

*Sightability estimate with variance components estimator from Wong (1996)*


---

### Description

Estimates population size, with variance estimated using Wong's (1996) estimator. This function will usually be called by Sight.Est function (but see details).

### Usage

```

Wong.est(
  total,
  srates,
  nh,
  Nh,
  stratum,
  subunit,
  covars,
  beta,
  varbeta,
  smat = NULL
)

```

### Arguments

total	Number of animals in each independently sighted group
srates	Vector of plot-level sampling probabilities (same dimension as total).
nh	Number of sample plots in each stratum
Nh	Number of population plots in each stratum
stratum	Stratum identifiers (associated with the independently observed animal groups)
subunit	Plot ID (associated with the independently observed animal groups)
covars	Matrix of sightability covariates (associated with the independently observed animal groups)

beta	Logistic regression parameter estimates (from fitted sightability model)
varbeta	Estimated variance-covariance matrix for the logistic regression parameter estimates (from fitted sightability model)
smat	Estimated variance-covariance matrix for the inflation factors (1/probability of detection). This is an n.animal x n.animal matrix, and is usually calculated within the Wong.est function. Non-null values can be passed to the function (e.g., if a bootstrap is used to estimate uncertainty due to the estimated detection parameters).

### Details

This function is called by Sight.Est, but may also be called directly by the user (e.g., in cases where the original sightability [test trial] data are not available, but the parameters and var/cov matrix from the logistic regression model is available in the literature).

### Value

tau.hat	Sightability estimate of population size, $\tau^{\wedge}$
VarTot	Estimated variance of $\tau^{\wedge}$
VarSamp	Estimated variance component due to sampling aerial units
VarSight	Estimated variance component due to sighting process (i.e., series of binomial rv for each animal group)
VarMod	Estimated variance component due to estimating detection probabilities using test trial data

### Author(s)

John Fieberg

### References

Rice CG, Jenkins KJ, Chang WY (2009). Sightability Model for Mountain Goats." The Journal of Wildlife Management, 73(3), 468- 478.

Steinhorst, R. K., and M.D. Samuel. (1989). Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.

Wong, C. (1996). Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

### See Also

[Sight.Est](#), [SS.est](#)

---

Wong.est.Ratio	<i>Sightability estimate of ratio with variance components estimator from Wong (1996)</i>
----------------	---

---

### Description

Estimates population ratio, with variance estimated using Wong's (1996) estimator. This function will usually be called by Sight.Est,Ratio() function (but see details).

### Usage

```
Wong.est.Ratio(
  numerator,
  denominator,
  srates,
  nh,
  Nh,
  stratum,
  subunit,
  covars,
  beta,
  varbeta,
  smat = NULL
)
```

### Arguments

numerator, denominator	Number of animals in numerator and denominator of each independently sighted group
srates	Vector of plot-level sampling probabilities (same dimension as total).
nh	Number of sample plots in each stratum
Nh	Number of population plots in each stratum
stratum	Stratum identifiers (associated with the independently observed animal groups)
subunit	Plot ID (associated with the independently observed animal groups)
covars	Matrix of sightability covariates (associated with the independently observed animal groups)
beta	Logistic regression parameter estimates (from fitted sightability model)
varbeta	Estimated variance-covariance matrix for the logistic regression parameter estimates (from fitted sightability model)
smat	Estimated variance-covariance matrix for the inflation factors (1/probability of detection). This is an n.animal x n.animal matrix, and is usually calculated within the Wong.est function. Non-null values can be passed to the function (e.g., if a bootstrap is used to estimate uncertainty due to the estimated detection parameters).

**Details**

This function is called by Sight.Est.Ratio, but may also be called directly by the user (e.g., in cases where the original sightability [test trial] data are not available, but the parameters and var/cov matrix from the logistic regression model is available in the literature).

**Value**

ratio.hat	Sightability estimate of ratio, ratio <sup>^</sup>
Vartot	Estimated variance of ratio <sup>^</sup>
VarSamp, VarSight, VarMod	Estimated variance component due to sampling, sightability, model are set to NA

**Author(s)**

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**References**

- Rice CG, Jenkins KJ, Chang WY (2009). Sightability Model for Mountain Goats." The Journal of Wildlife Management, 73(3), 468- 478.
- Steinhorst, R. K., and M.D. Samuel. (1989). Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.
- Wong, C. (1996). Population size estimation using the modified Horvitz-Thompson estimator with estimated sighting probabilities. Dissertation, Colorado State University, Fort Collins, USA.

**See Also**

[Sight.Est.Ratio](#), [SS.est.Ratio](#)

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