lesserscaupBreeding model summary

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Overview

This document summarizes the results of a global sensitivity and uncertainty analysis for the **lesserscaupBreeding** habitat suitability index (HSI) model for *Aythya affinis*. Metadata for the model is stored in the ecorest package in R.

The original documentation for this model can be found here[1].

Sub-model: **Breeding habitat**

The lesserscaupBreeding model is comprised of **5** variables and **2** components.

Variables:

Table 1. SIV variables included in the lesserscaupBreeding model. Type indicates whether a variable is numeric or categorical and breakpoints indicates the number of distinct breakpoints in suitability graphs.

	Variable name	Type	Breakpoints
SIV1	herb.canopy.SIV	numeric	4
SIV2	herb.veg.h.SIV	numeric	4
SIV3	shrub.cov.SIV	numeric	5
SIV4	wtr.regime.SIV	categorical	6
SIV5	can.cov.emerg.herb.veg.SIV	numeric	4

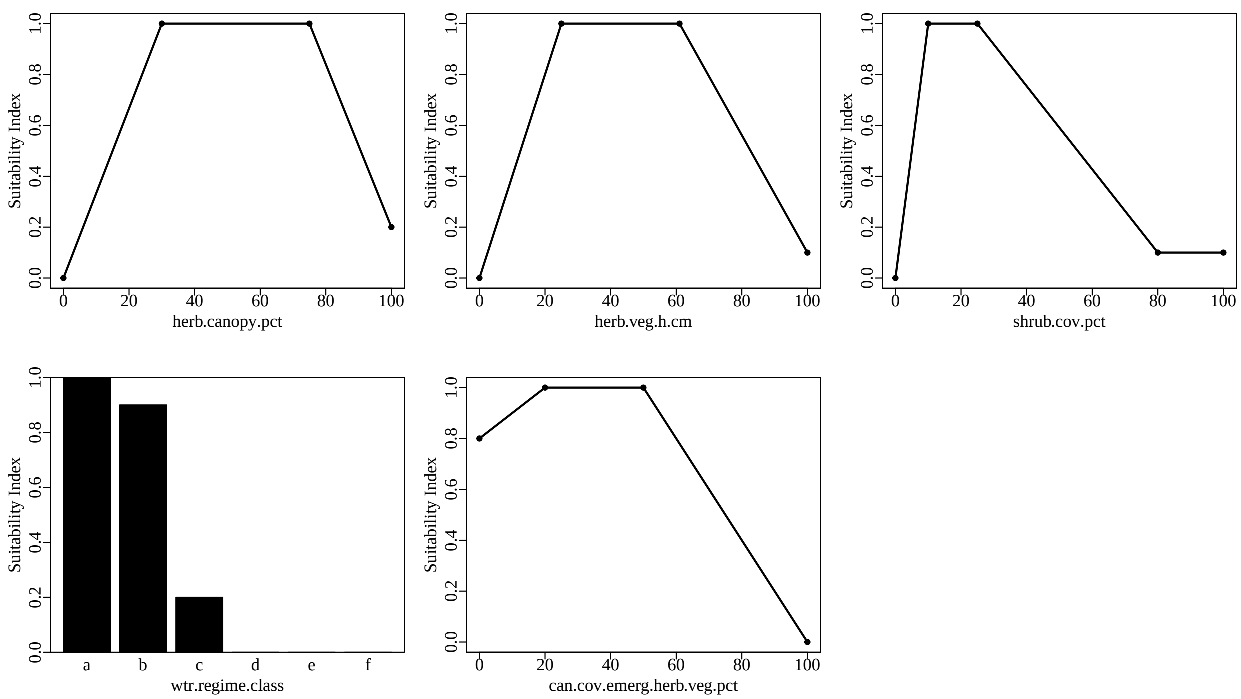

Figure 1. Suitability index graphs for variables included in the lesserscaupBreeding model in ecorest.

[1] https://ecolibrary.sec.usace.army.mil/resource/16b60284-bedd-4f1d-92fe-b07f5dcec951

Components:

Table 2. Components included in the lesserscaupBreeding model in ecorest.

	Component	Equation
CB	Brood component	(SIV4*(SIV5^2))^(1/3)
CN	Nesting component	(3*((SIV1*SIV2)^(1/2))+SIV3)/4

Model equation:

The equation to calculate an overall HSI index for the lesserscaupBreeding model is:

min(CB,CN)

According to our classification, this model's format is: **author-specified**

Global sensitivity and uncertainty analysis:

We ran global sensitivity and uncertainty analyses on the lesserscaupBreeding model using the sensobol package in R (Puy et al. 2022). The following parameters were used for the sensobol analysis:

Table 3. Parameters and settings used for sensobol sensitivity and uncertainty analyses.

Parameter	Equation	Value
Number of input variables (M)	-	5
Base sample size (n)	-	10000
Number of model evaluations (N)	n*(M+2)	70000
First order estimator	See Puy et al. (2022)	Saltelli
Total order estimator	See Puy et al. (2022)	Jansen
Number of bootstrap replications	-	1000
Sampling scheme	-	Quasi-random
Matrices	-	A, B, AB

We ran a sensitivity and uncertainty analysis for the lesserscaupBreeding model using the original equation outlined in the documentation from Allen (1986) and using arithmetic mean, geometric mean, limiting factor, and multiplicative equations to contrast the results across different equation structures.

Model uncertainty

We ran the lesserscaupBreeding model using 70000 combinations of its SIV variables, which were sampled from a uniform distribution spanning the range of possible values listed in the lesserscaupBreeding documentation. We limited the range of possible values for each parameter to the range in which the SIV values were greater than zero to prevent HSI score distributions with primarily zero values.

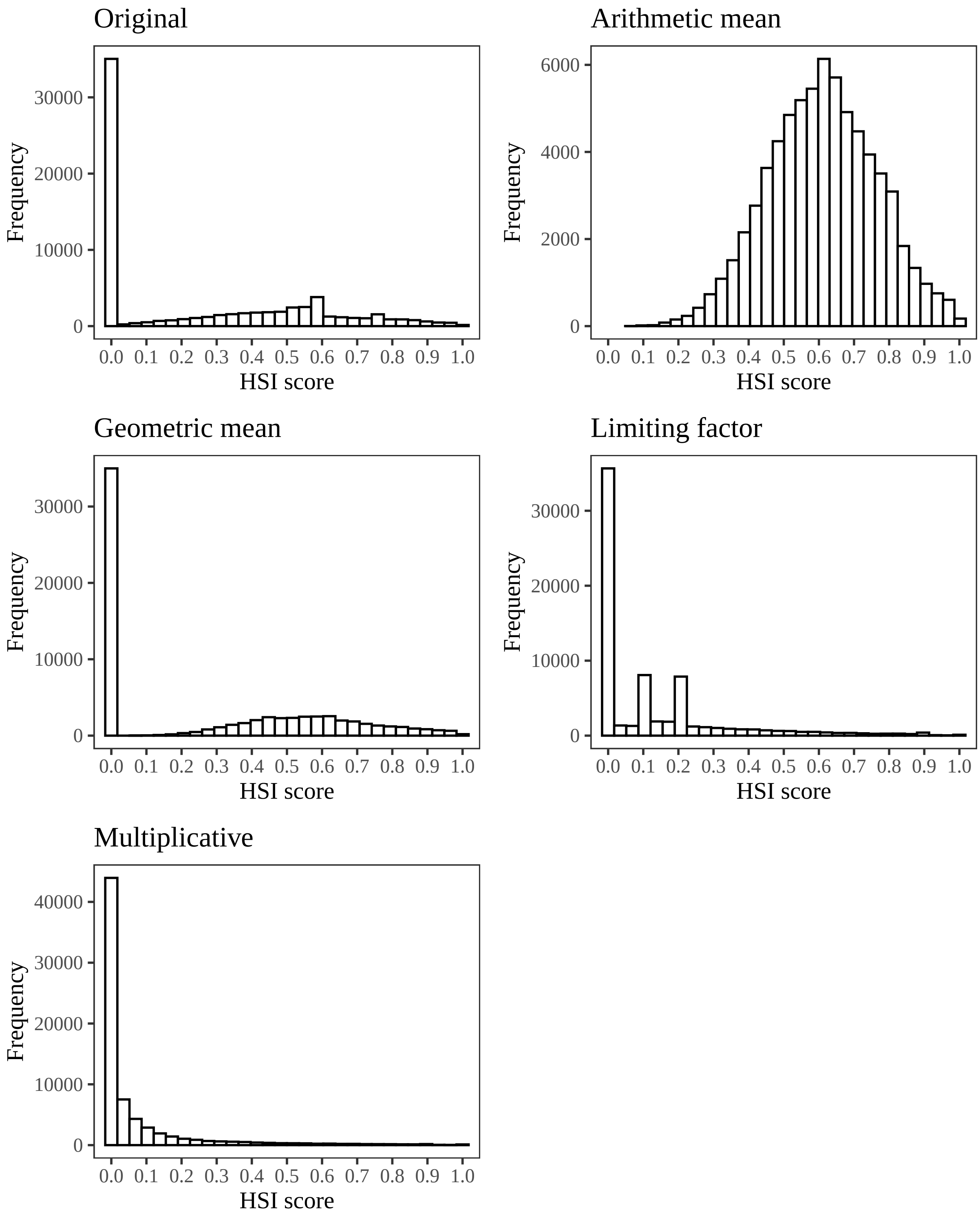

Figure 2. Empirical distributions of HSI scores for the lesserscaupBreeding model using the original author-specified model equation from Allen (1986), and an arithmetic mean, geometric mean, limiting factor, and multiplicative structure incorporating all SIV variables. Note differences in the y axis.

We assumed a uniform distribution for all parameters because we evaluated all ecorest models in batch. Should you decide to run your own sensitivity analysis, this assumption should be evaluated independently for each parameter in the model.

Table 4. Quantiles from the empirical distribution of HSI scores for the original lesserscaupBreeding model structure, an arithmetic mean equation, a geometric mean equation, a limiting factor equation, and a multiplicative equation structure.

	1%	**2.5%**	**5%**	**25%**	**50%**	**75%**	**95%**	**97.5%**	**99%**	**100%**
Original	0.00	0.00	0.00	0.0	0.00	0.52	0.80	0.88	0.94	1
Arithmetic	0.26	0.31	0.36	0.5	0.61	0.72	0.86	0.91	0.96	1
Geometric	0.00	0.00	0.00	0.0	0.08	0.57	0.84	0.90	0.96	1
Limiting	0.00	0.00	0.00	0.0	0.00	0.20	0.57	0.73	0.87	1
Multiplicative	0.00	0.00	0.00	0.0	0.00	0.06	0.41	0.61	0.80	1

The empirical distribution of the original lesserscaupBreeding model has a coefficient of variation (CV) of **1.16**, while the arithmetic mean model has a CV of **0.251**, the geometric mean model has a CV of **1.098**, the limiting factor model has a CV of **1.522**, and the multiplicative model has a CV of **2.215**. Hence, the **Multiplicative** model is the most uncertain, while the **Arithmetic mean** model is the least uncertain.

Model sensitivity

Below are the results of the global sensitivity analysis for the lesserscaupBreeding model using the original equation, an arithmetic mean, a geometric mean, a limiting factor, and a multiplicative model structure. The sensobol package uses variance-based sensitivity metrics, so the model's sensitivity to a given parameter is a measure of how much variance in the HSI score decreases in response to that parameter being fixed (Puy et al. 2022). For each parameter, the observed changes in the variance of the HSI score can be described with a first order sensitivity index (S_i) that accounts for the influence of a single parameter of interest on variance in HSI, or with a total order index (T_i) that accounts for the influence of a single parameter on its own and in combination with all other parameters (*i.e.*, interactions) (Puy et al. 2022). We can compare the 95% confidence intervals for the first and total order indices to a dummy parameter, which represents a parameter that has no influence on the variance in a model's output. While an uninfluential variable should theoretically have an S_i and T_i of zero, small approximation errors can lead variables to have a non-zero influence on a model's output (Puy et al. 2022). If the confidence interval of the S_i and T_i index for a given parameter overlaps the confidence interval of the dummy parameter, we can deduce that the parameter has a negligible effect on variance in HSI scores, both on its own and in combination with all other variables.

Original model

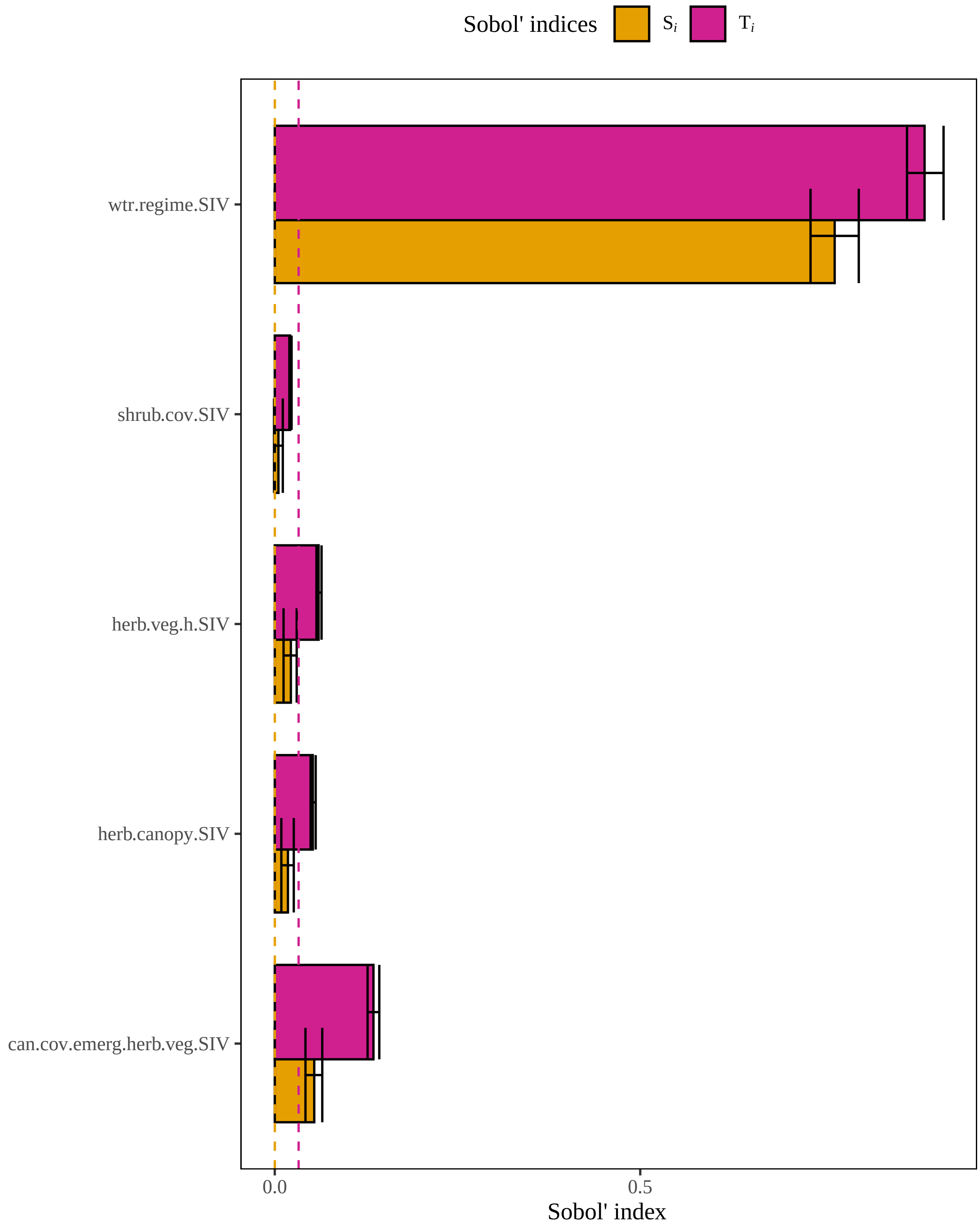

Figure 3. Results of a sensitivity analysis for the lesserscaupBreeding model based on the original author-specified model outlined in Allen (1986). Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Arithmetic mean model

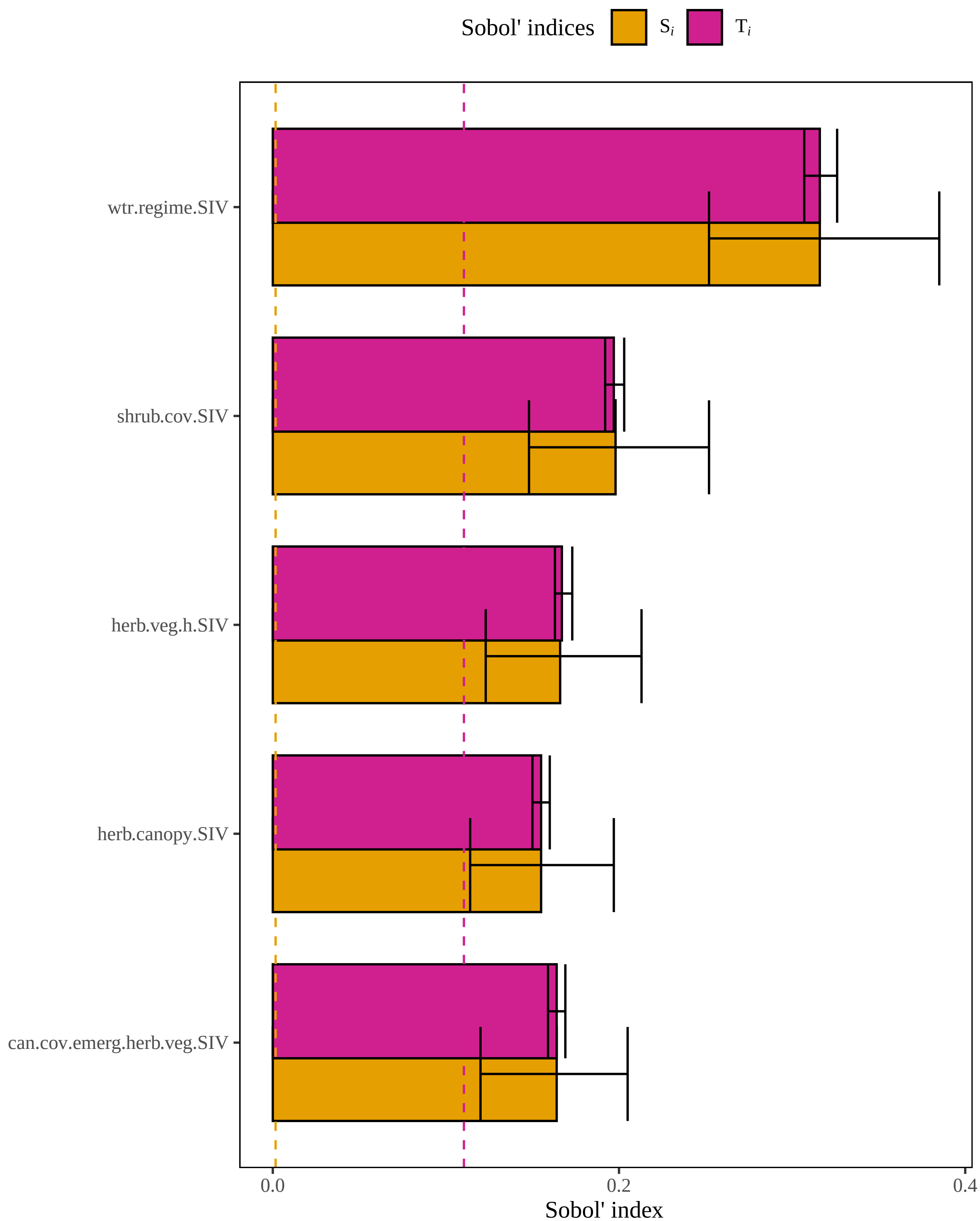

Figure 4. Results of a sensitivity analysis for the lesserscaupBreeding model based on an arithmetic mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Geometric mean model

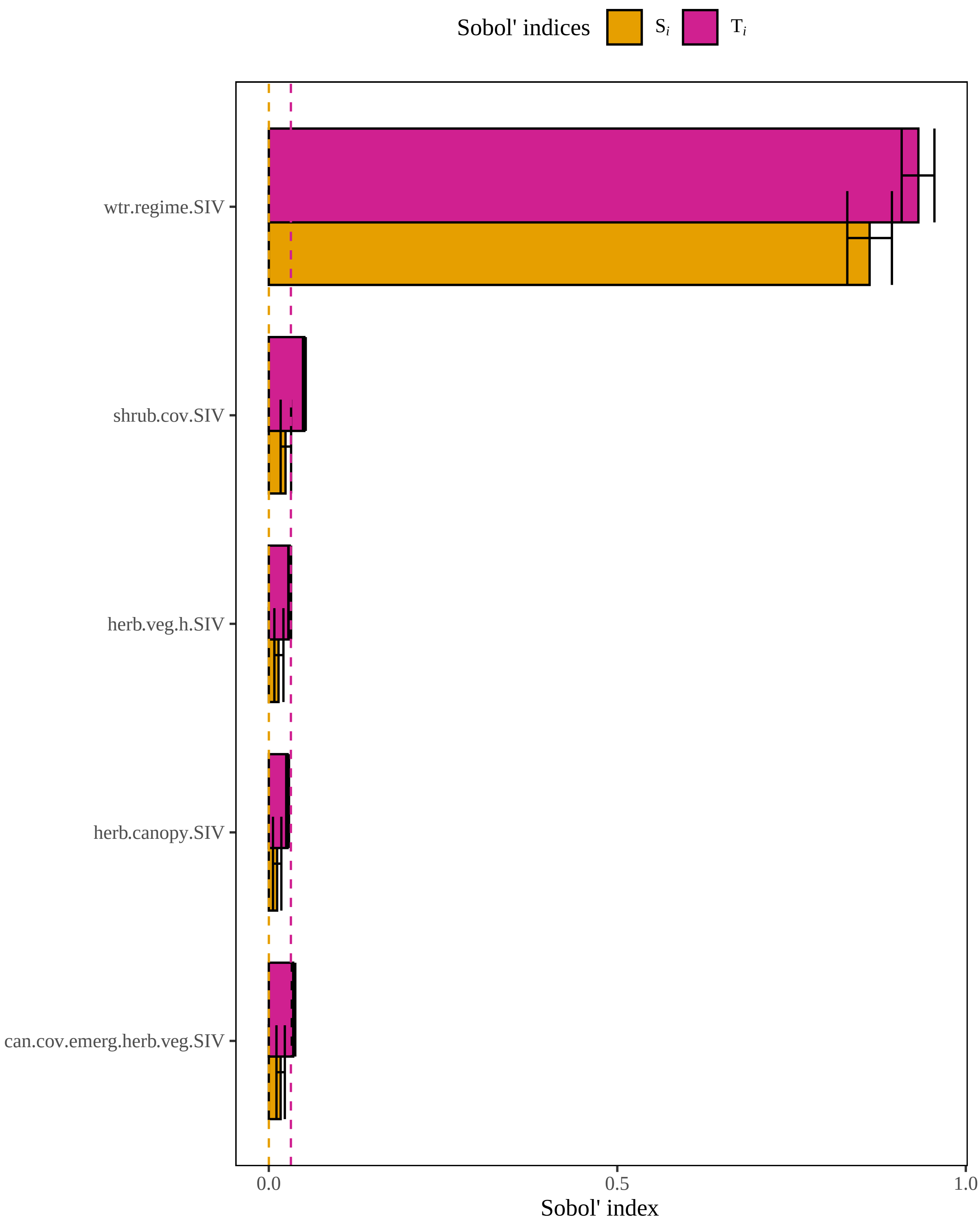

Figure 5. Results of a sensitivity analysis for the lesserscaupBreeding model based on a geometric mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Limiting factor model

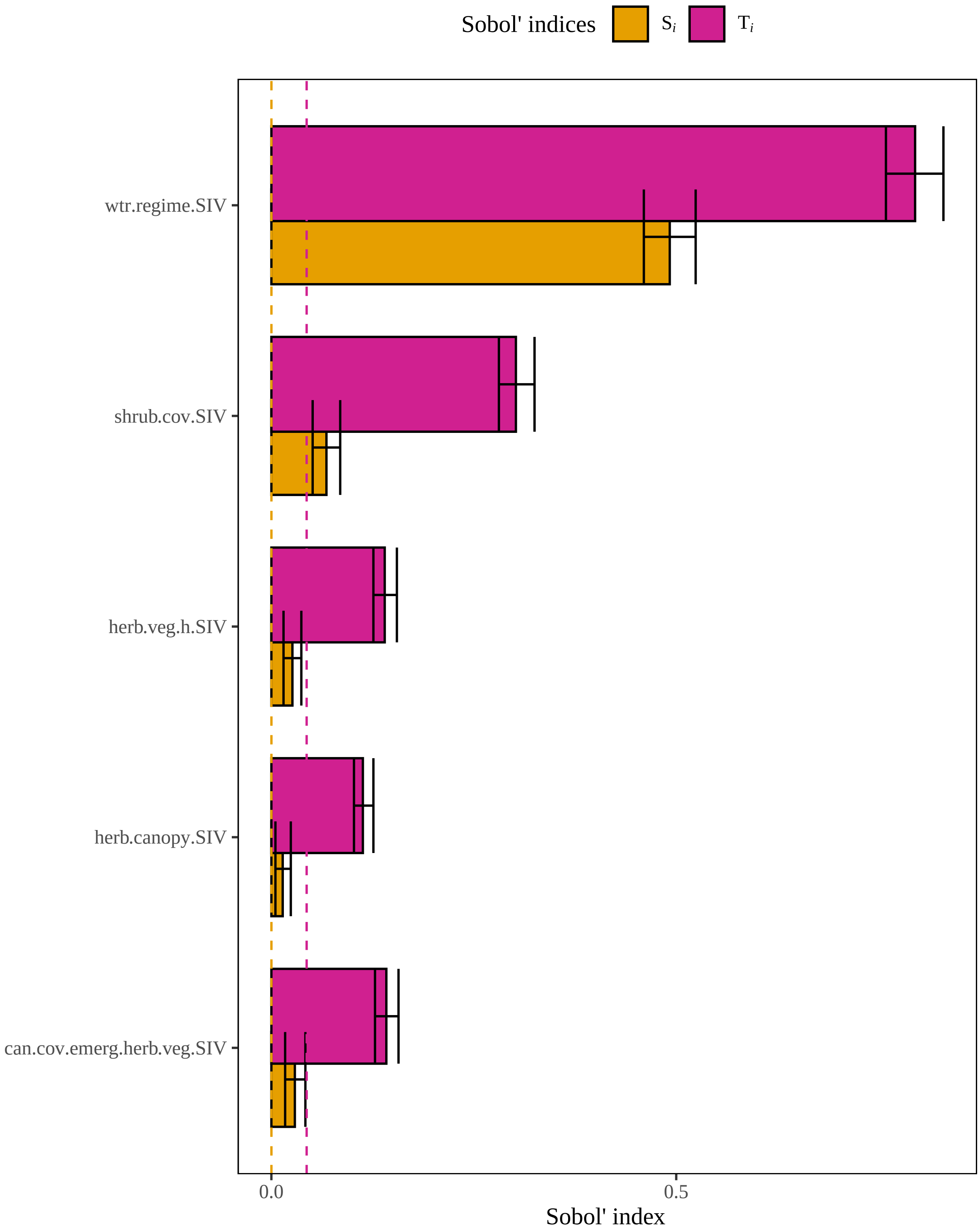

Figure 6. Results of a sensitivity analysis for the lesserscaupBreeding model based on a limiting factor structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Multiplicative model

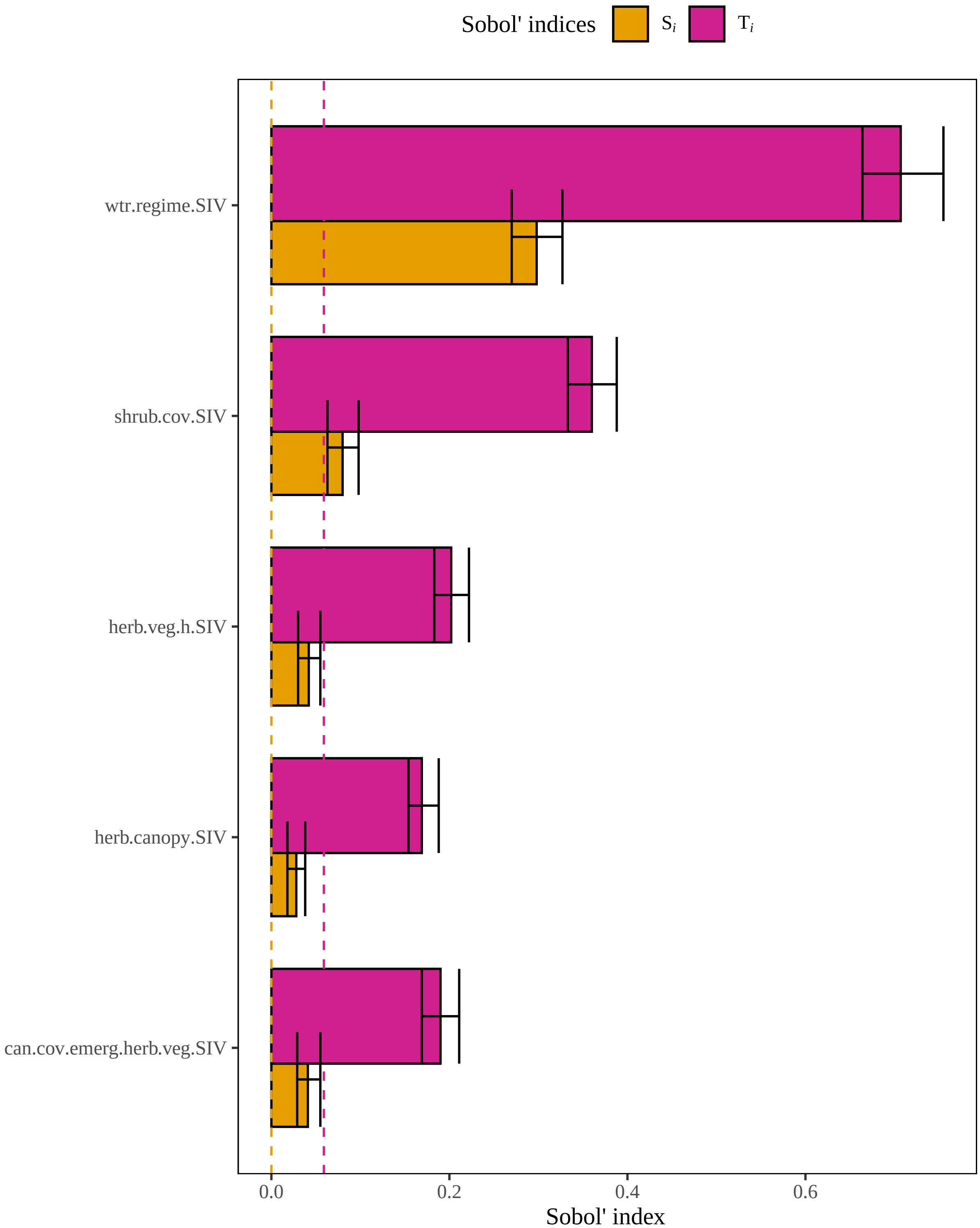

Figure 7. Results of a sensitivity analysis for the lesserscaupBreeding model based on a multiplicative mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Summary of influential variables

Original model In the **original lesserscaupBreeding** model, **4 of 5** variables are influential and **wtr.regime.SIV** has the highest first order sensitivity. In addition, **wtr.regime.SIV** has the highest total order sensitivity.

Un-influential variables in original model:

```
shrub.cov.SIV
```

Arithmetic mean model In the **arithmetic mean lesserscaupBreeding** model, **5 of 5** variables are influential and **wtr.regime.SIV** has the highest first order sensitivity. In addition, **wtr.regime.SIV** has the highest total order sensitivity.

Un-influential variables in arithmetic mean model:

None

Geometric mean model In the **geometric mean lesserscaupBreeding** model, **5 of 5** variables are influential and **wtr.regime.SIV** has the highest first order sensitivity. In addition, **wtr.regime.SIV** has the highest total order sensitivity.

Un-influential variables in geometric mean model:

None

Limiting factor model In the **limiting factor lesserscaupBreeding** model, **5 of 5** variables are influential and **wtr.regime.SIV** has the highest first order sensitivity. In addition, **wtr.regime.SIV** has the highest total order sensitivity.

Un-influential variables in limiting factor mean model:

None

Multiplicative model In the **multiplicative mean lesserscaupBreeding** model, **5 of 5** variables are influential and **wtr.regime.SIV** has the highest first order sensitivity. In addition, **wtr.regime.SIV** has the highest total order sensitivity.

Un-influential variables in multiplicative model:

None

References

1. Allen, AW. 1986. Habitat suitability index models: Lesser scaup (breeding). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.117). 16 pp.
2. McKay S, D Hernandez-Abrams, and K Cushway. 2024. ecorest: conducts analyses informing ecosystem restoration decisions. R package version 2.0.0, https://CRAN.R-project.org/package=ecorest.
3. Puy, A, S Lo Piano, A Saltelli, and SA Levin. 2022. sensobol: an R package to compute variance based sensitivity indices. Journal of Statistical Software 102(5):1-37. doi: 10.18637/jss.v102.i05