cutthroatRivLahontanMt15CMt5m model summary

Contents

Overview

This document summarizes the results of a global sensitivity and uncertainty analysis for the **cutthroatRivLahontanMt15CMt5m** habitat suitability index (HSI) model for *Oncorhynchus clarkii*. 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: **Lahontan basin riverine cutthroat trout habitat in streams when temperatures are more than 15 degrees Celsius and widths are more than 5m; equal component method**

The cutthroatRivLahontanMt15CMt5m model is comprised of **19** variables and **5** components.

Variables:

Table 1. SIV variables included in the cutthroatRivLahontanMt15CMt5m 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	avg.max.wtr.temp.ad.juv.fry.SIV	numeric	14
SIV2	avg.max.temp.emb.SIV	numeric	18
SIV3	avg.min.DO.adult.juv.fry.emb.SIV	numeric	10
SIV4	avg.thalweg.d.SIV	numeric	12
SIV5	avg.vel.spwn.areas.cmps.SIV	numeric	6
SIV6	cov.pct.juv.SIV	numeric	9
SIV6B	cov.pct.ad.SIV	numeric	9
SIV7	avg.subs.size.SIV	numeric	16
SIV8	subs.size.class.10.to.40cm.SIV	numeric	3
SIV9	dominant.subs.type.rffl.run.SIV	categorical	3
SIV10	pct.pls.SIV	numeric	13
SIV11	avg.veg.SIV	numeric	8
SIV12	avg.rooted.veg.SIV	numeric	14
SIV13	annual.max.or.min.pH.SIV	numeric	13
SIV14	avg.annual.base.flow.regime.SIV	numeric	3
SIV15	pl.late.growing.season.SIV	categorical	3
SIV16	fines.spawning.SIV	numeric	10
SIV16B	fines.riffle.run.SIV	numeric	12
SIV17	shaded.strm.area.SIV	numeric	7

[1] https://ecolibrary.sec.usace.army.mil/resource/8f46d0ea-c31c-4a41-d41f-3ad4f6aee969

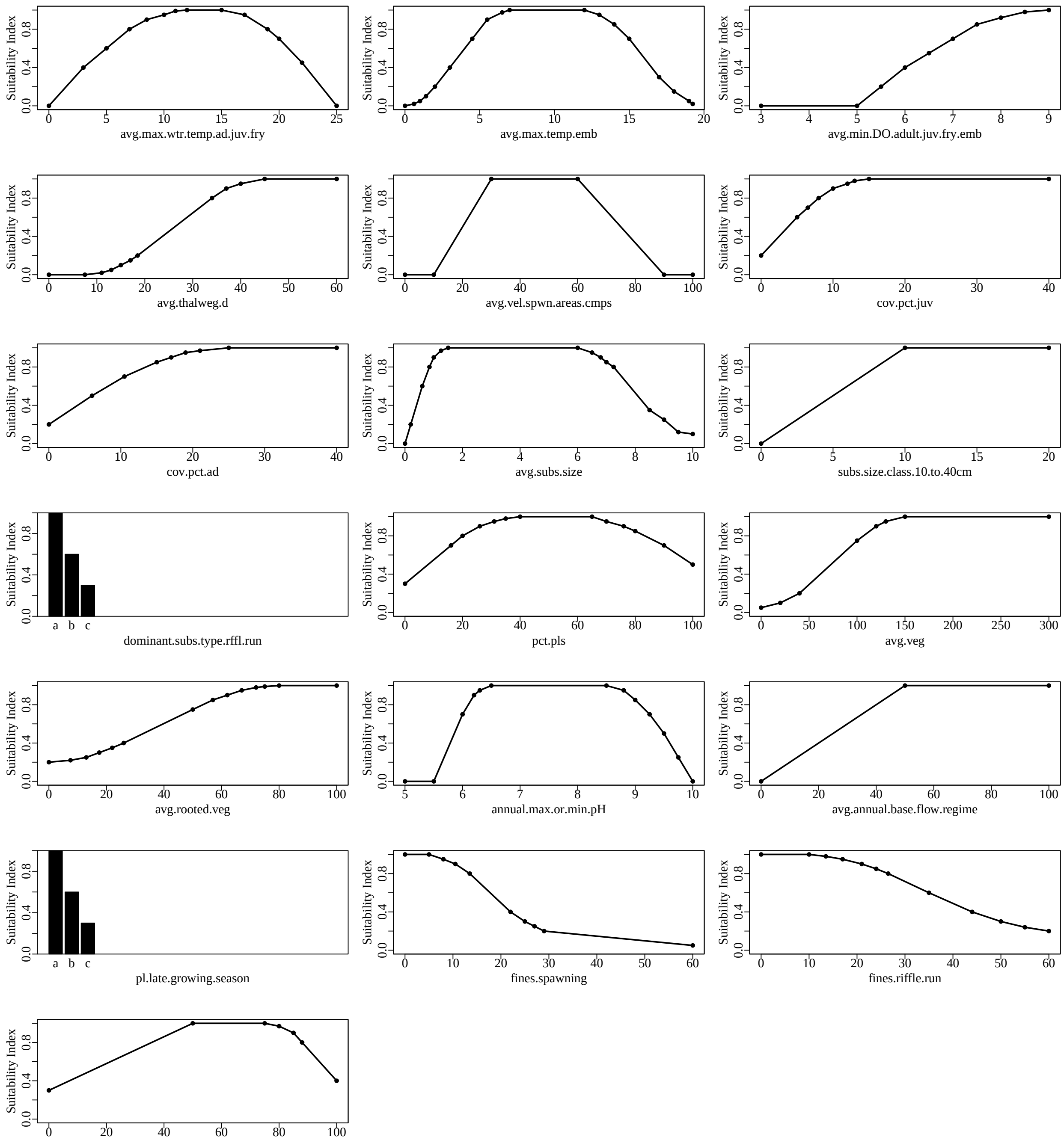

Figure 1. Suitability index graphs for variables included in the cutthroatRivLahontanMt15CMt5m model in ecorest.

Components:

Table 2. Components included in the cutthroatRivLahontanMt15CMt5m model in ecorest.

	Component	Equation
COT	Other component	((((SIV9*SIV16B)^(1/2)+SIV11)/2)*prod(SIV1,SIV3,SIV12,SIV13,SIV14,SIV17)^(1/length(na.omit(c(SIV1,SIV3,SIV12,SIV13,SIV14,SIV17)))))^(1/2)
CE	Embryo component	min(SIV2,SIV3,(SIV5*SIV7*SIV16)^(1/3))
CJ	Juvenile component	ifelse(SIV6<=0.4|SIV10<=0.4|SIV15<=0.4,min(SIV6,SIV10,SIV15),((SIV6+SIV10+SIV15)/3))
CFr	Fry component	ifelse(SIV10<=0.4|(SIV8*SIV16B)^(1/2)<=0.4,min(SIV10,(SIV8*SIV16B)^(1/2)),(SIV10*(SIV8*SIV16B)^(1/2))^(1/2))
CA	Adult component	ifelse(SIV4<=0.4|(SIV10*SIV15)^(1/2)<=0.4,min(SIV4,(SIV10*SIV15)^(1/2)),ifelse(SIV6B>(SIV10*SIV15)^(1/2),(SIV4*SIV6B*(SIV10*SIV15)^(1/2))^(1/3),(SIV4*(SIV10*SIV15)^(1/2))^(1/2)))

Model equation:

The equation to calculate an overall HSI index for the cutthroatRivLahontanMt15CMt5m model is:

ifelse ((! is .na(CA)&CA<=0.4)|(!is.na(CJ)&CJ<=0.4)|(!is.na(CFr)&CFr<=0.4)|(!is.na(CE)&CE<=0.4)|(!is.na(COT)&COT<=0.4),min(CA,CJ,CFr,CE,COT,na.rm=T), ifelse(CA<prod(CA,CJ,CFr,CE,COT,na.rm=T)^(1/length(na.omit(c(CA,CJ,CFr,CE,COT)))),CA,prod(CA,CJ,CFr,CE,COT,na.rm=T)^(1/length(na.omit(c(CA,CJ,CFr,CE,COT))))))

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 cutthroatRivLahontanMt15CMt5m 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)	-	19
Base sample size (n)	-	10000
Number of model evaluations (N)	n*(M+2)	210000
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 cutthroatRivLahontanMt15CMt5m model using the original equation outlined in the documentation from Hickman and Raleigh (1982) and using arithmetic mean, geometric mean, limiting factor, and multiplicative equations to contrast the results across different equation structures.

Model uncertainty

We ran the cutthroatRivLahontanMt15CMt5m model using 210000 combinations of its SIV variables, which were sampled from a uniform distribution spanning the range of possible values listed in the cutthroatRivLahontanMt15CMt5m 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.

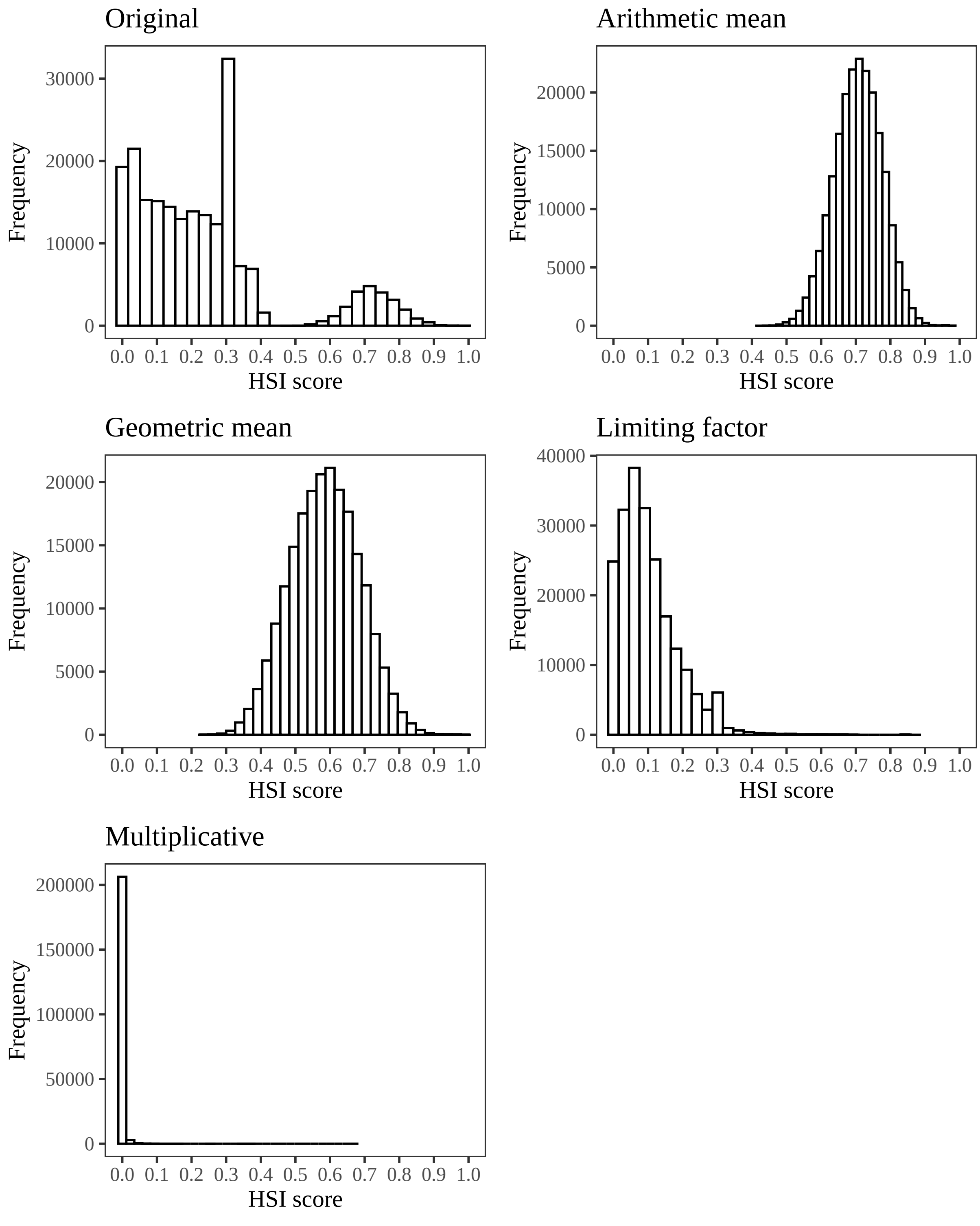

Figure 2. Empirical distributions of HSI scores for the cutthroatRivLahontanMt15CMt5m model using the original author-specified model equation from Hickman and Raleigh (1982), and an arithmetic mean, geometric mean, limiting factor, and multiplicative structure incorporating all SIV variables. Note differences 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 cutthroatRivLahontanMt15CMt5m 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	0.01	0.08	0.20	0.30	0.73	0.78	0.82	0.99
Arithmetic	0.54	0.57	0.59	0.66	0.71	0.75	0.82	0.84	0.86	0.98
Geometric	0.36	0.39	0.42	0.52	0.59	0.66	0.75	0.78	0.81	0.98
Limiting	0.00	0.00	0.01	0.04	0.08	0.14	0.27	0.30	0.34	0.87
Multiplicative	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.67

The empirical distribution of the original cutthroatRivLahontanMt15CMt5m model has a coefficient of variation (CV) of **0.876**, while the arithmetic mean model has a CV of **0.097**, the geometric mean model has a CV of **0.171**, the limiting factor model has a CV of **0.81**, and the multiplicative model has a CV of **8.013**. 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 cutthroatRivLahontanMt15CMt5m 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

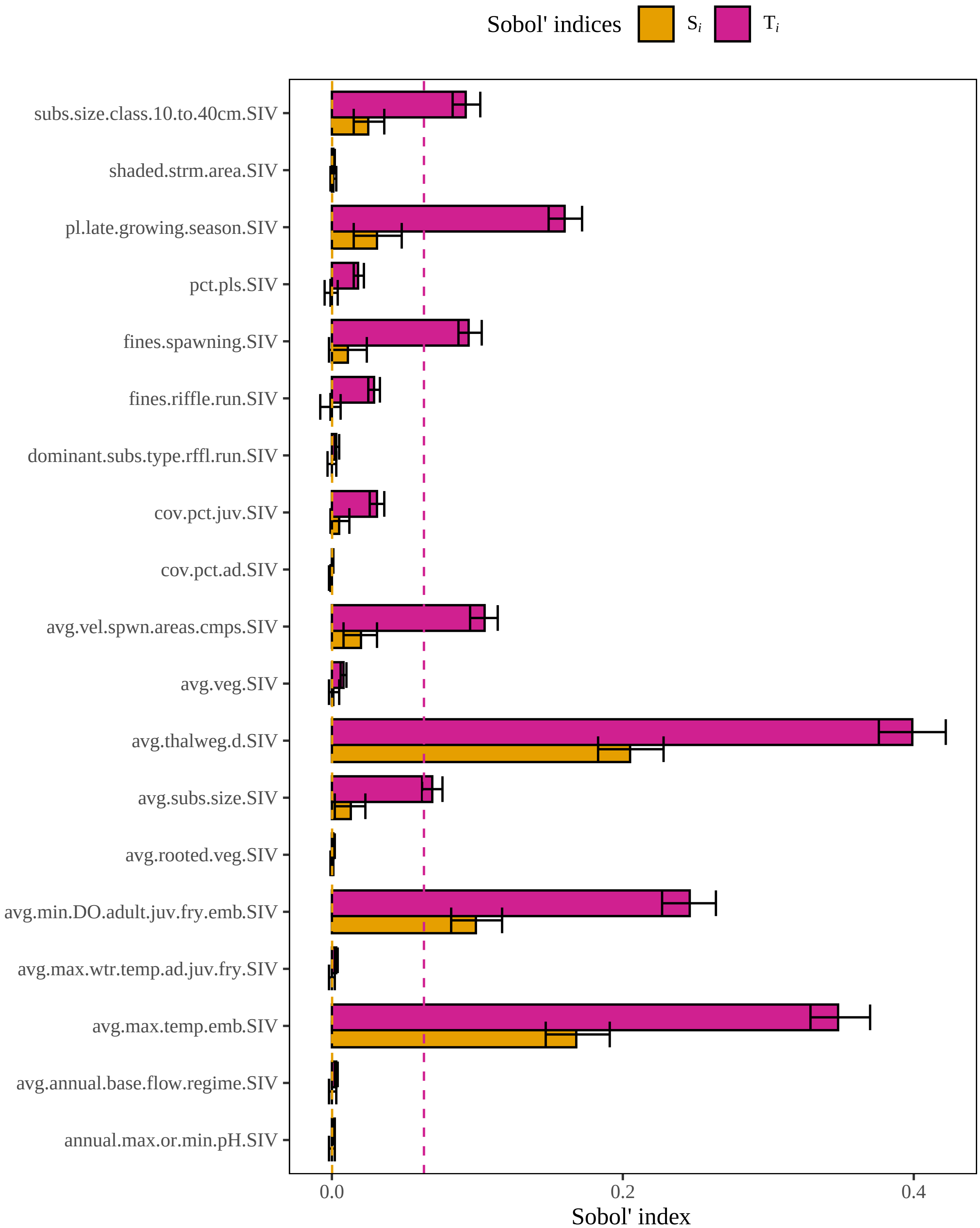

Figure 3. Results of a sensitivity analysis for the cutthroatRivLahontanMt15CMt5m model based on the original author-specified model outlined in Hickman and Raleigh (1982). Dashed lines represent baseline numerical approximation error for S$_i$ and T$_i$ (*i.e.*, dummy variables).

Arithmetic mean model

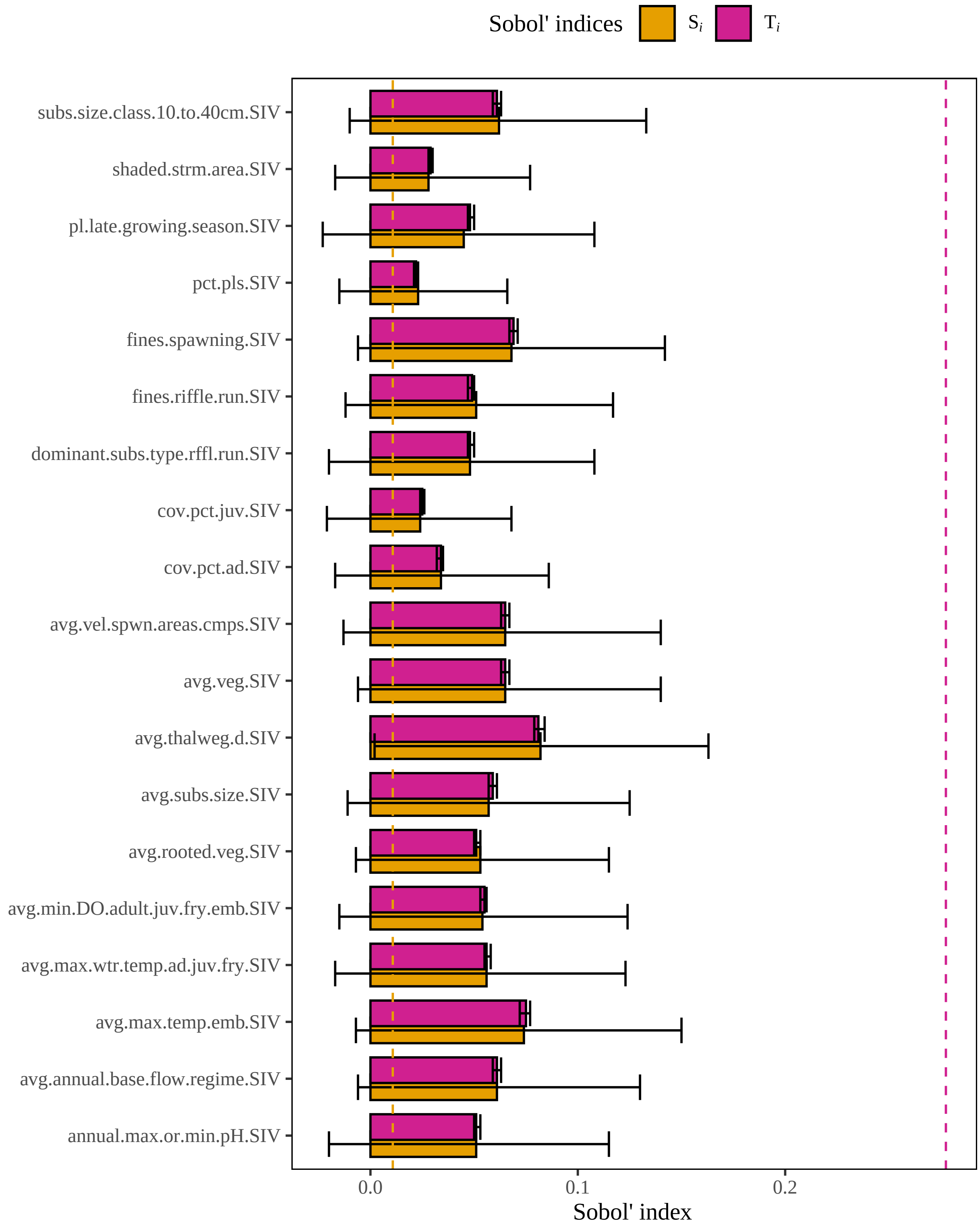

Figure 4. Results of a sensitivity analysis for the cutthroatRivLahontanMt15CMt5m model based on an arithmetic mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Geometric mean model

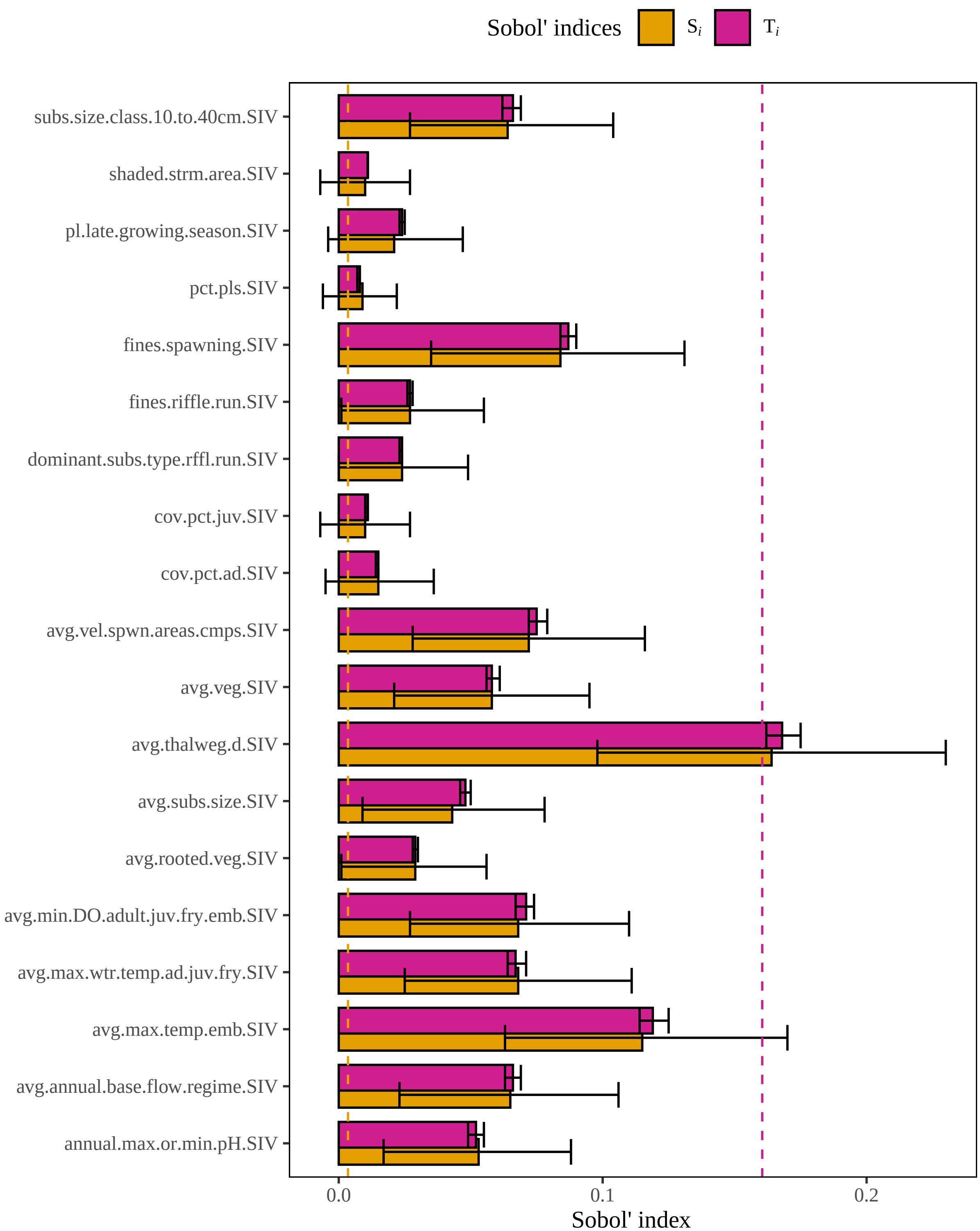

Figure 5. Results of a sensitivity analysis for the cutthroatRivLahontanMt15CMt5m model based on a geometric mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Limiting factor model

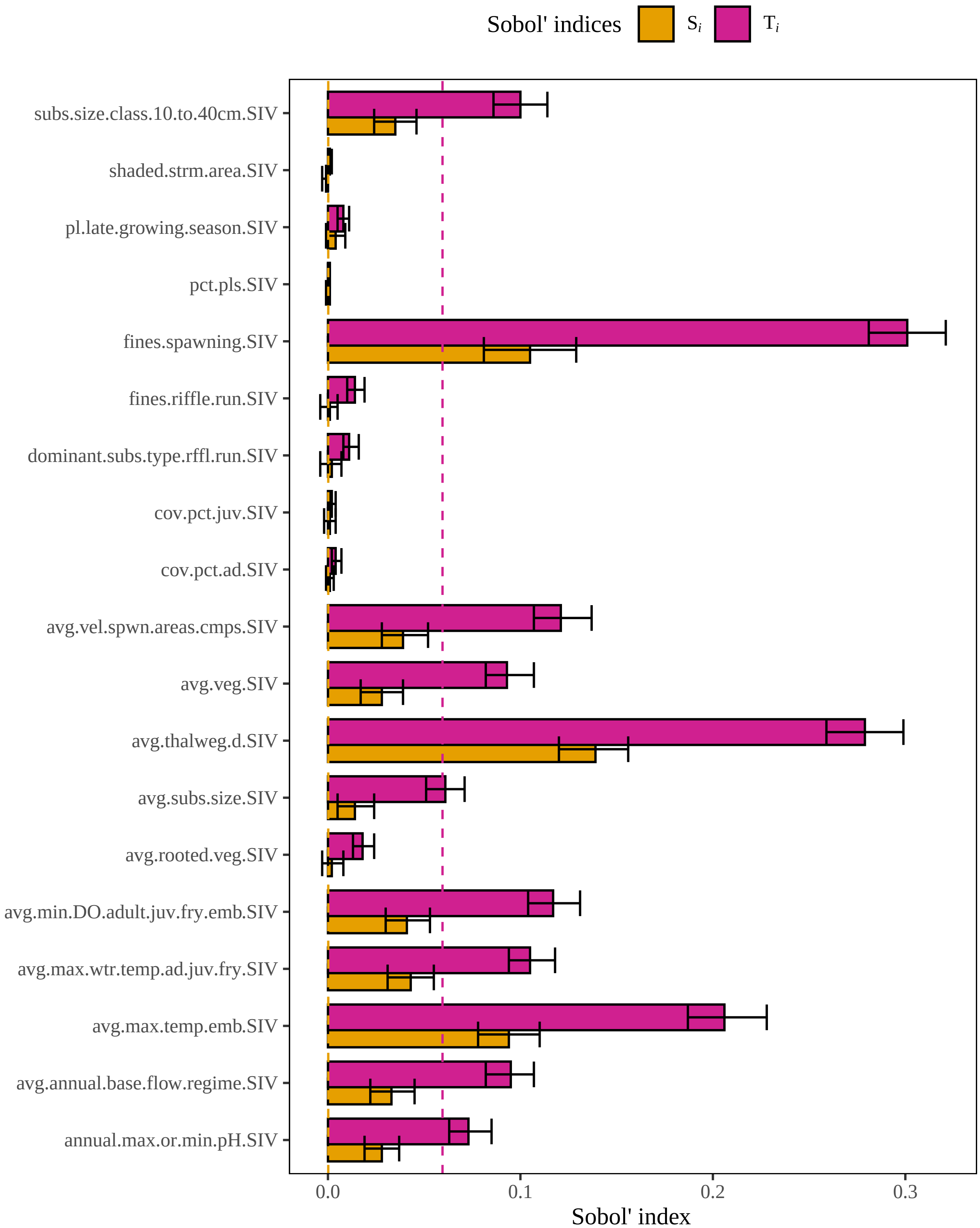

Figure 6. Results of a sensitivity analysis for the cutthroatRivLahontanMt15CMt5m model based on a limiting factor structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Multiplicative model

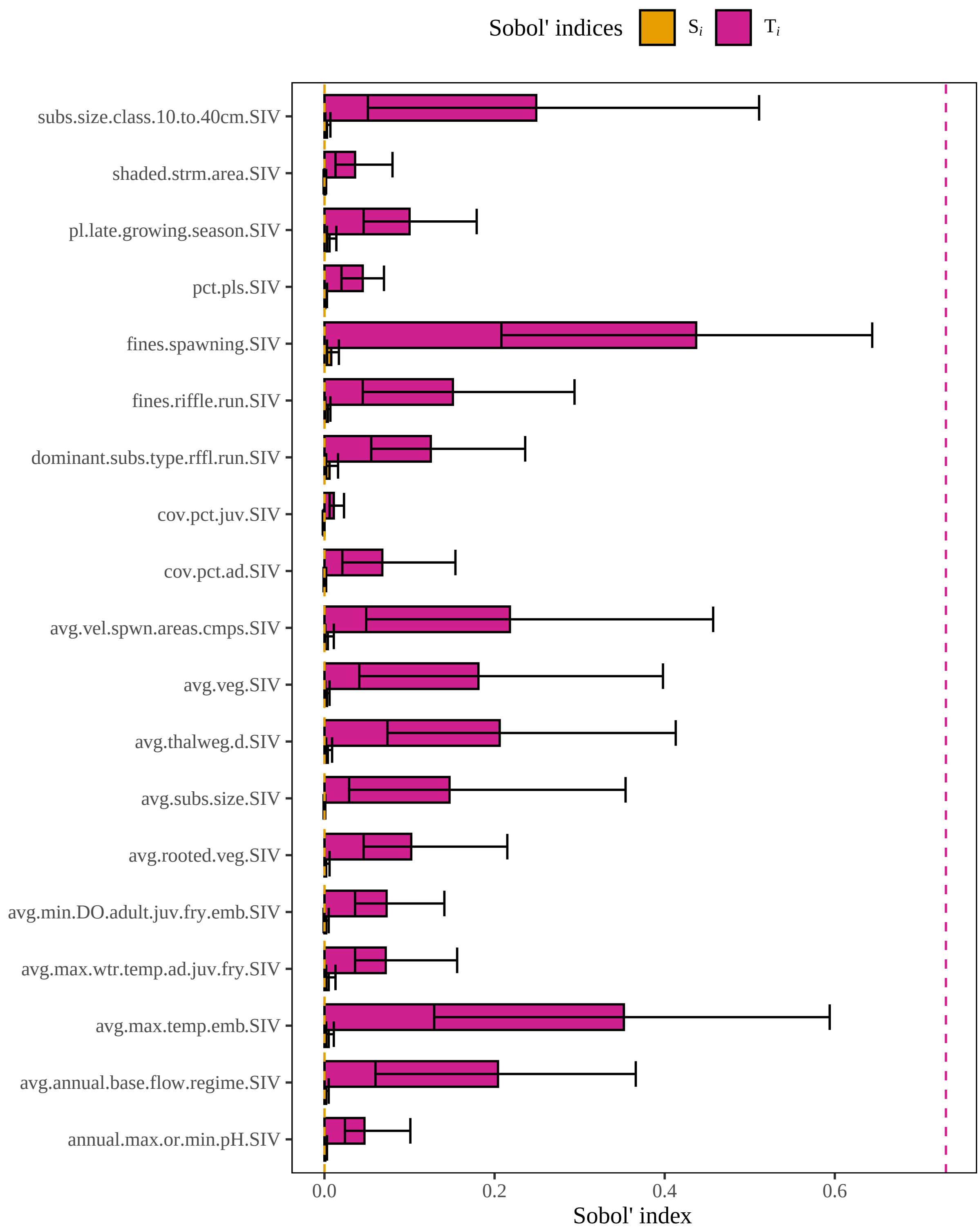

Figure 7. Results of a sensitivity analysis for the cutthroatRivLahontanMt15CMt5m model based on a multiplicative mean structure. Dashed lines represent baseline numerical approximation error for S_i and T_i (*i.e.*, dummy variables).

Summary of influential variables

Original model In the **original cutthroatRivLahontanMt15CMt5m** model, **8 of 19** variables are influential and **avg.thalweg.d.SIV** has the highest first order sensitivity. In addition, **avg.thalweg.d.SIV** has the highest total order sensitivity.

Un-influential variables in original model:

```
avg.max.wtr.temp.ad.juv.fry.SIV
cov.pct.juv.SIV
cov.pct.ad.SIV
dominant.subs.type.rffl.run.SIV
pct.pls.SIV
avg.veg.SIV
avg.rooted.veg.SIV
annual.max.or.min.pH.SIV
avg.annual.base.flow.regime.SIV
fines.riffle.run.SIV
shaded.strm.area.SIV
```

Arithmetic mean model In the **arithmetic mean cutthroatRivLahontanMt15CMt5m** model, **0 of 19** variables are influential and **avg.thalweg.d.SIV** has the highest first order sensitivity. In addition, **avg.thalweg.d.SIV** has the highest total order sensitivity.

Un-influential variables in arithmetic mean model:

```
avg.max.wtr.temp.ad.juv.fry.SIV
avg.max.temp.emb.SIV
avg.min.DO.adult.juv.fry.emb.SIV
avg.thalweg.d.SIV
avg.vel.spwn.areas.cmps.SIV
cov.pct.juv.SIV
cov.pct.ad.SIV
avg.subs.size.SIV
subs.size.class.10.to.40cm.SIV
dominant.subs.type.rffl.run.SIV
pct.pls.SIV
avg.veg.SIV
avg.rooted.veg.SIV
annual.max.or.min.pH.SIV
avg.annual.base.flow.regime.SIV
pl.late.growing.season.SIV
fines.spawning.SIV
fines.riffle.run.SIV
shaded.strm.area.SIV
```

Geometric mean model In the **geometric mean cutthroatRivLahontanMt15CMt5m** model, **11 of 19** variables are influential and **avg.thalweg.d.SIV** has the highest first order sensitivity. In addition, **avg.thalweg.d.SIV** has the highest total order sensitivity.

Un-influential variables in geometric mean model:

```
cov.pct.juv.SIV
cov.pct.ad.SIV
dominant.subs.type.rffl.run.SIV
```

```
pct.pls.SIV
avg.rooted.veg.SIV
pl.late.growing.season.SIV
fines.riffle.run.SIV
shaded.strm.area.SIV
```

Limiting factor model In the **limiting factor cutthroatRivLahontanMt15CMt5m** model, **11 of 19** variables are influential and **avg.thalweg.d.SIV** has the highest first order sensitivity. In addition, **fines.spawning.SIV** has the highest total order sensitivity.

Un-influential variables in limiting factor mean model:

```
cov.pct.juv.SIV
cov.pct.ad.SIV
dominant.subs.type.rffl.run.SIV
pct.pls.SIV
avg.rooted.veg.SIV
pl.late.growing.season.SIV
fines.riffle.run.SIV
shaded.strm.area.SIV
```

Multiplicative model In the **multiplicative mean cutthroatRivLahontanMt15CMt5m** model, **10 of 19** variables are influential and **fines.spawning.SIV** has the highest first order sensitivity. In addition, **fines.spawning.SIV** has the highest total order sensitivity.

Un-influential variables in multiplicative model:

```
avg.min.DO.adult.juv.fry.emb.SIV
cov.pct.juv.SIV
cov.pct.ad.SIV
avg.subs.size.SIV
pct.pls.SIV
avg.rooted.veg.SIV
annual.max.or.min.pH.SIV
avg.annual.base.flow.regime.SIV
shaded.strm.area.SIV
```

References

1. Hickman, T, and RF Raleigh. 1982. Habitat suitability index models: Cutthroat trout. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.5. 38 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