A review of spawning frequency estimates across *Trachurus* species worldwide: regional patterns and methodological variation

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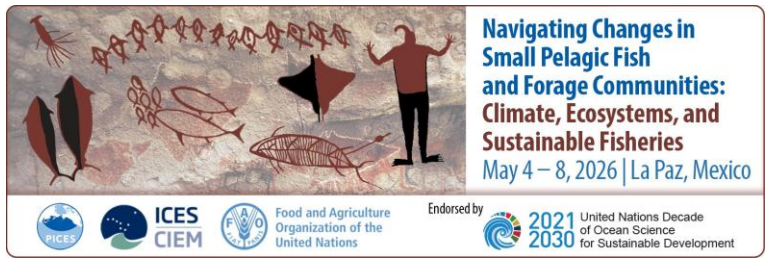


Daily egg production method (DEPM)
Small Pelagic Fish

Adult parameter:

Spawning Frequency

Number of mature female fish spawn per time (i.e., night)
(Hunter and Macewicz 1985)

Spawning Interval

Time lag between subsequent spawning events
(Wootton 1974)

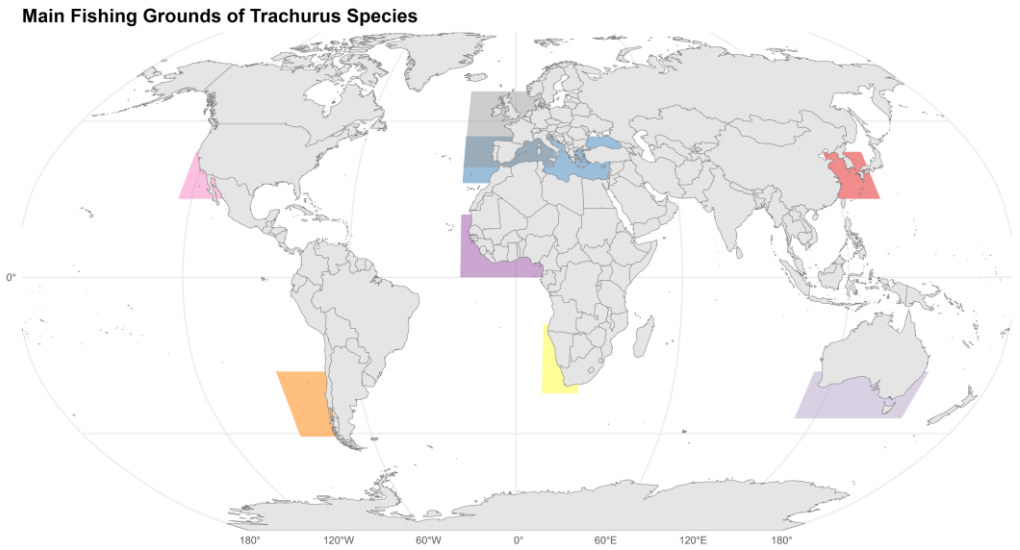
Spawning fraction

% females spawning per day
(Parker 1980)

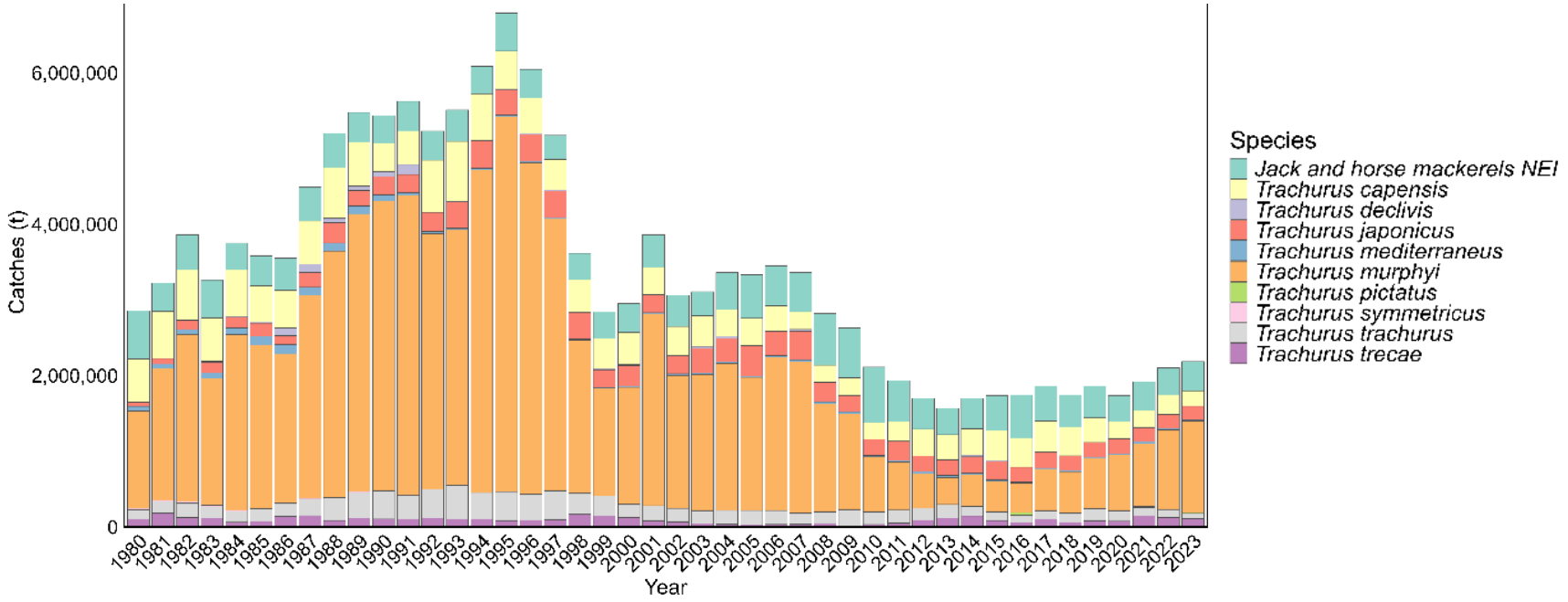
POF method
(Parker 1980)

- POF duration in the ovaries
- POF staging and ageing
- Sampling bias (i.e., fish aggregations)

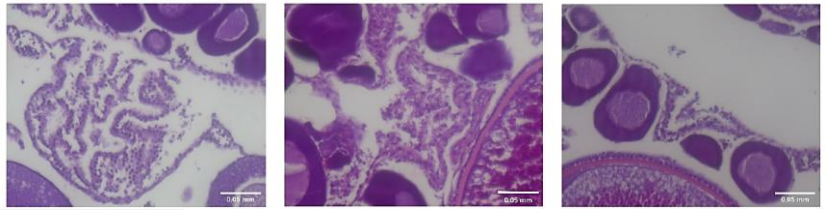
Trachurus spp. worldwide



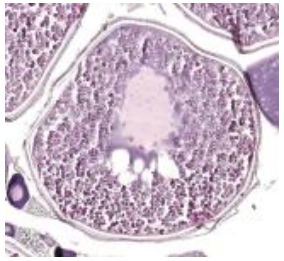
Trachurus spp. catches FAO Data



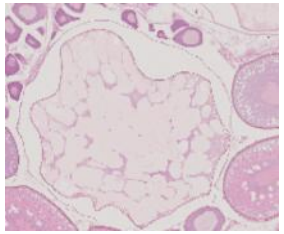
Methods applied in Trachurus spp.



Postovulatory Follicle Method
(POF Method)
Most common Method

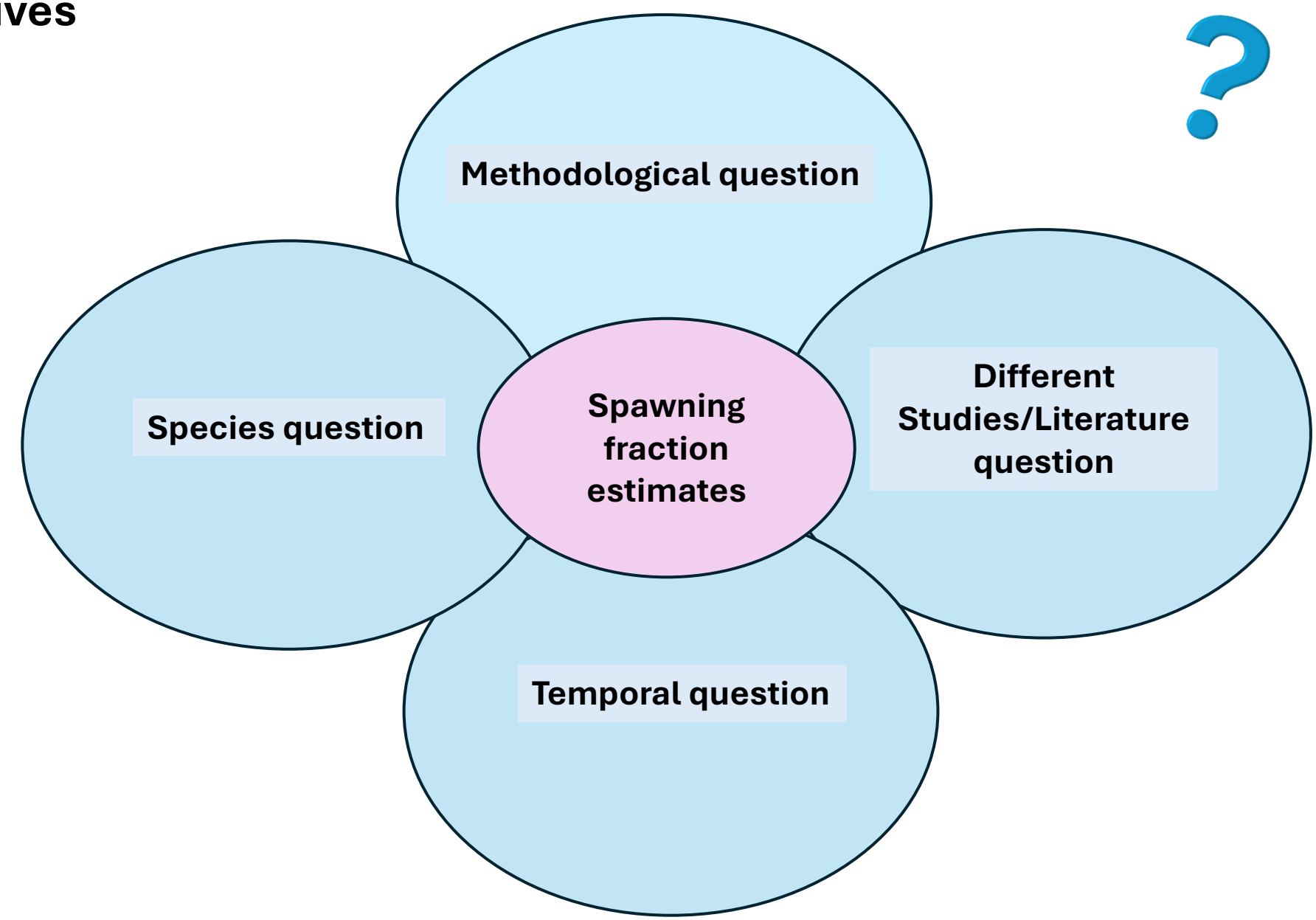


Migratory Nucleus (MN) Method



Hydrated Oocytes Method

Objectives


Methodological question
Species question
Spawning fraction estimates
Different Studies/Literature question
Temporal question

Methods

Literature review

scientific publications, and Reports

1st Approach

Group of the Methods

- **Non-POF** = MN, Hyd, MN+Hyd

Different duration of POFs

- **Short-POF** = POFs (≤1 day)
- **Medium-POF** = POFs (~1 day)
- **Long-POF** = POFs (≥2 day)

Relative bias :

Distance from a Reference method (Long POF)

$$\text{Bias}_{i,m} = \frac{SF_{i,m} - SF_{i,\text{ref}}}{SF_{i,\text{ref}}}$$

2nd Approach

PCA Clustering and Hierarchical clustering

Long POF Spawning fraction estimates

Standard Error (SE) adjusted

R Software

3rd Approach

Bayesian Meta-analysis Multilevel Model

Spawning fraction & SE adjusted

Species

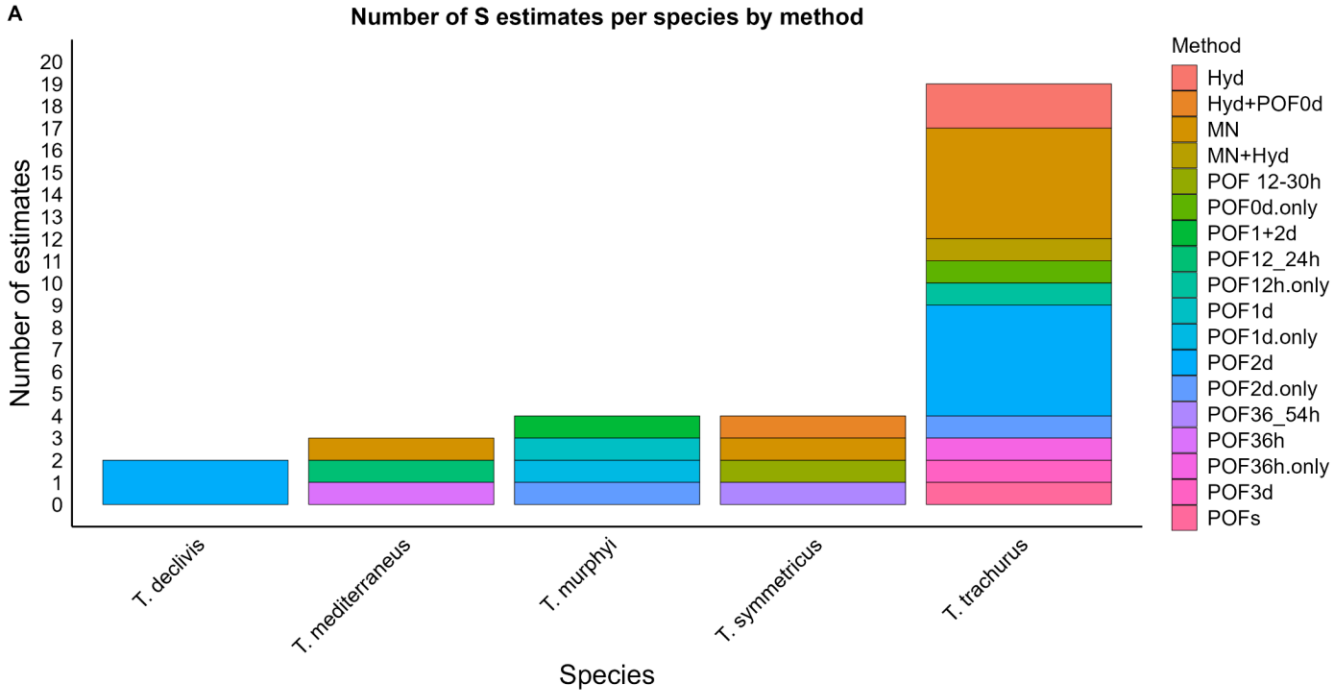
Study

Methods

Year

Literature Review

A



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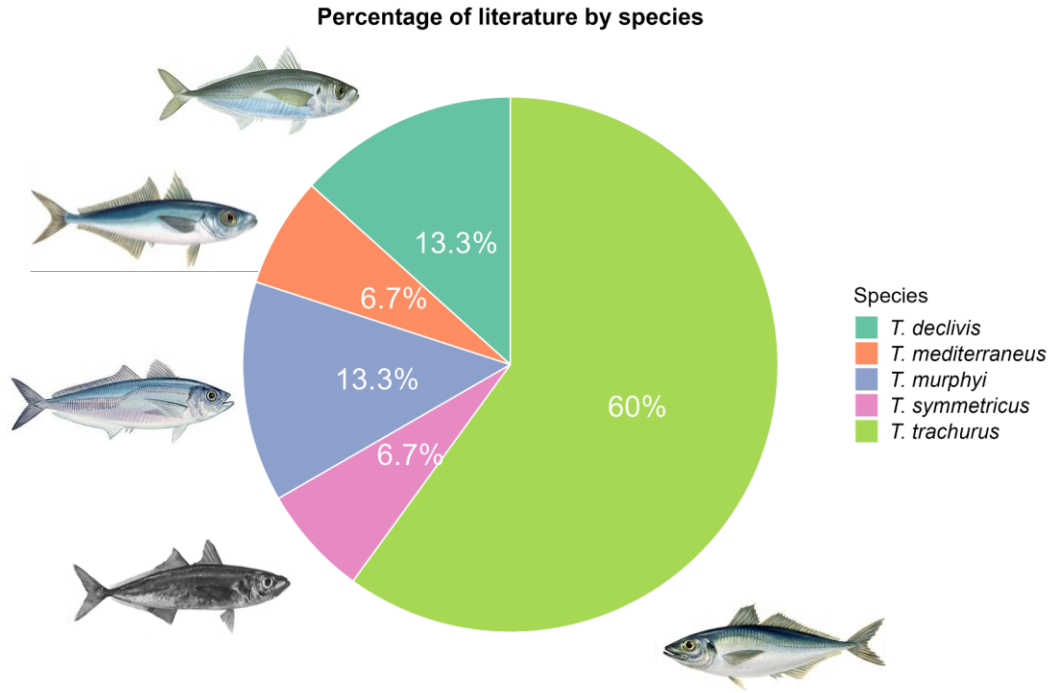

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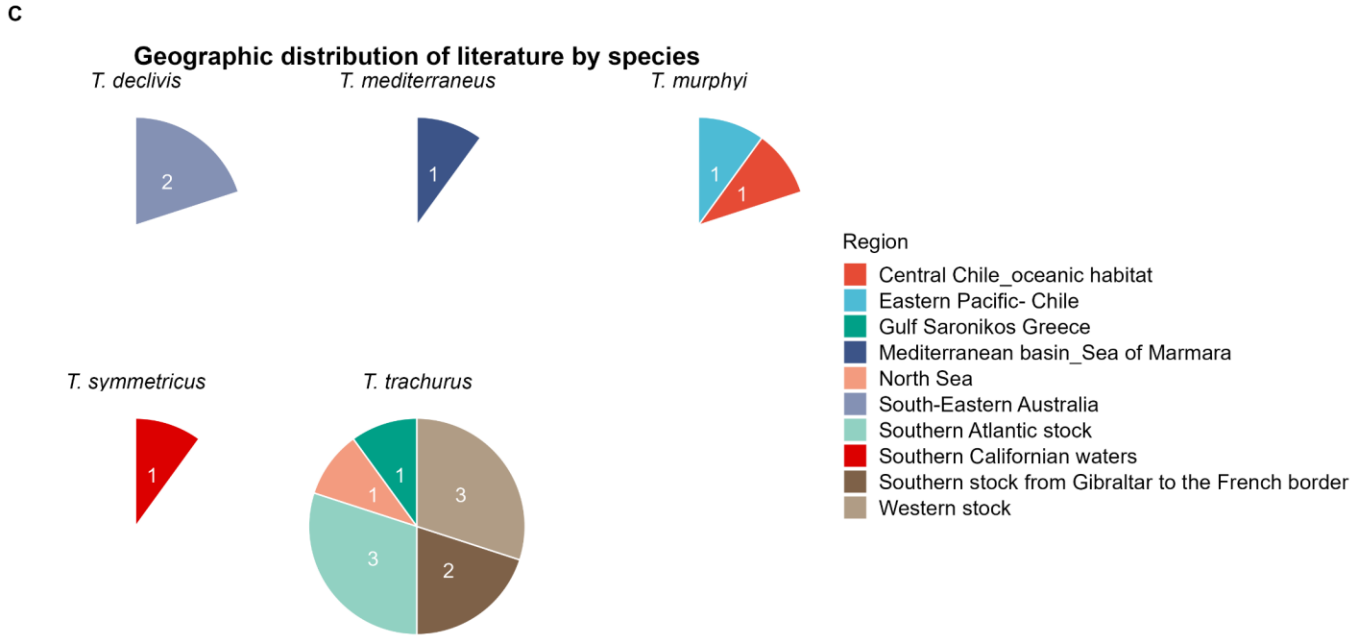
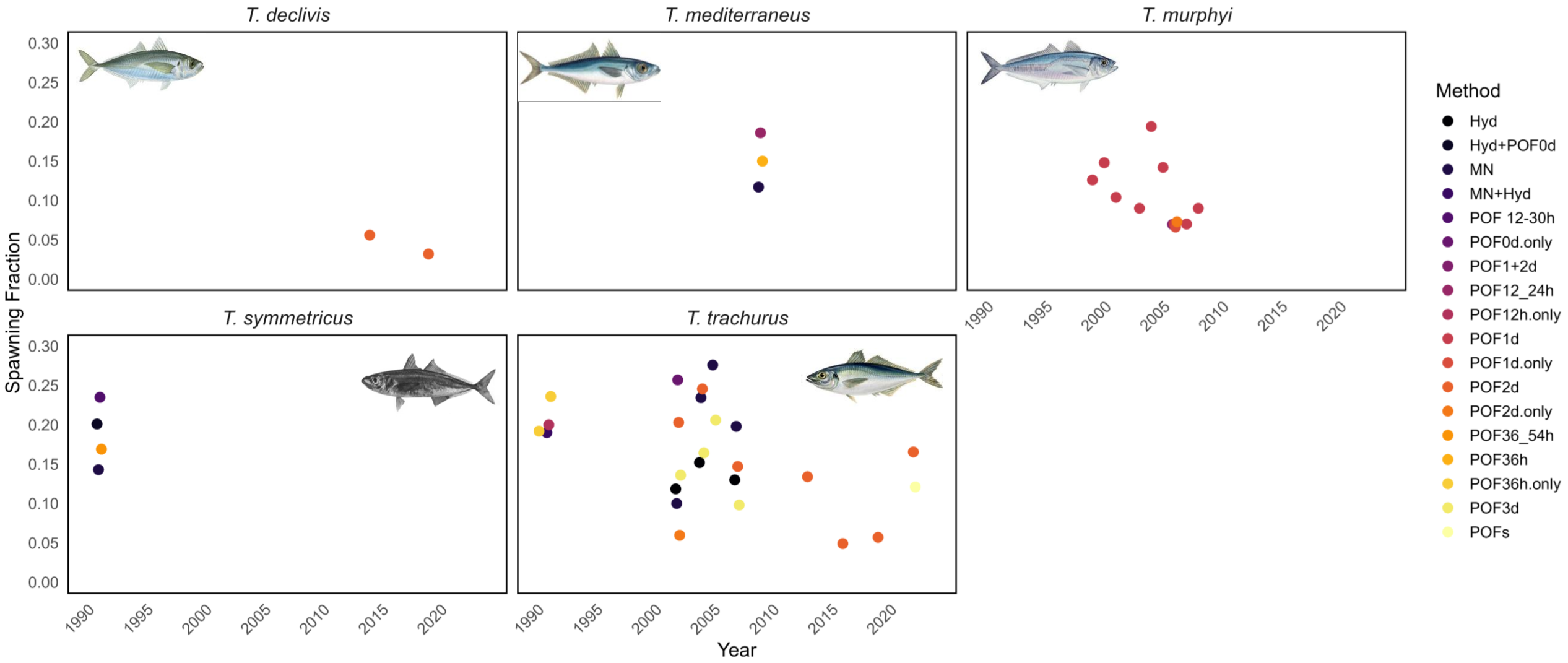


No. Studies= 15

No. Methods= 17

Literature *Trachurus* spp. Spawning Fraction by Year & Method



Global Spawning Fraction Estimates

Meta-analysis Across *Trachurus* spp.

T. trachurus

Min. – Max.
0.049-
0.339
Range of average spawning fraction

20.4- 2.9 d
Spawning intervals in days

T. murphyi

Min. – Max.
0.066-
0.194
Range of average spawning fraction

15.1- 5.2 d
Spawning intervals in days

T. declivis

Min. – Max.
0.032-
0.056
Range of average spawning fraction

31.2- 17.8 d
Spawning intervals in days

T. symmetricus

Min. – Max.
0.143-
0.235
Range of average spawning fraction

7- 4.2 d
Spawning intervals in days

T. mediterraneus

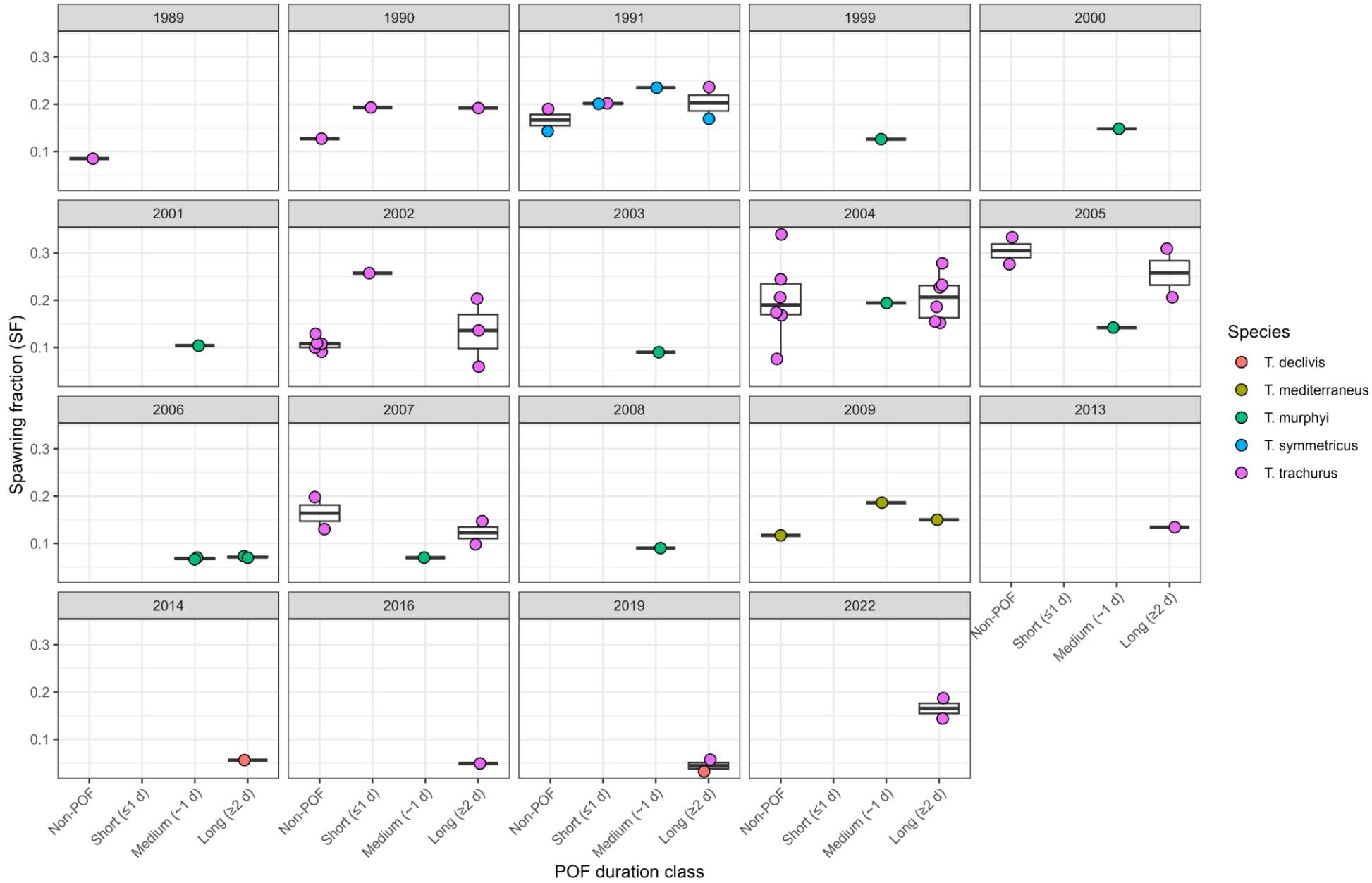
Min. – Max.
0.117-
0.186
Range of average spawning fraction

8.5- 5.4 d
Spawning intervals in days

High Variance in intra-species level

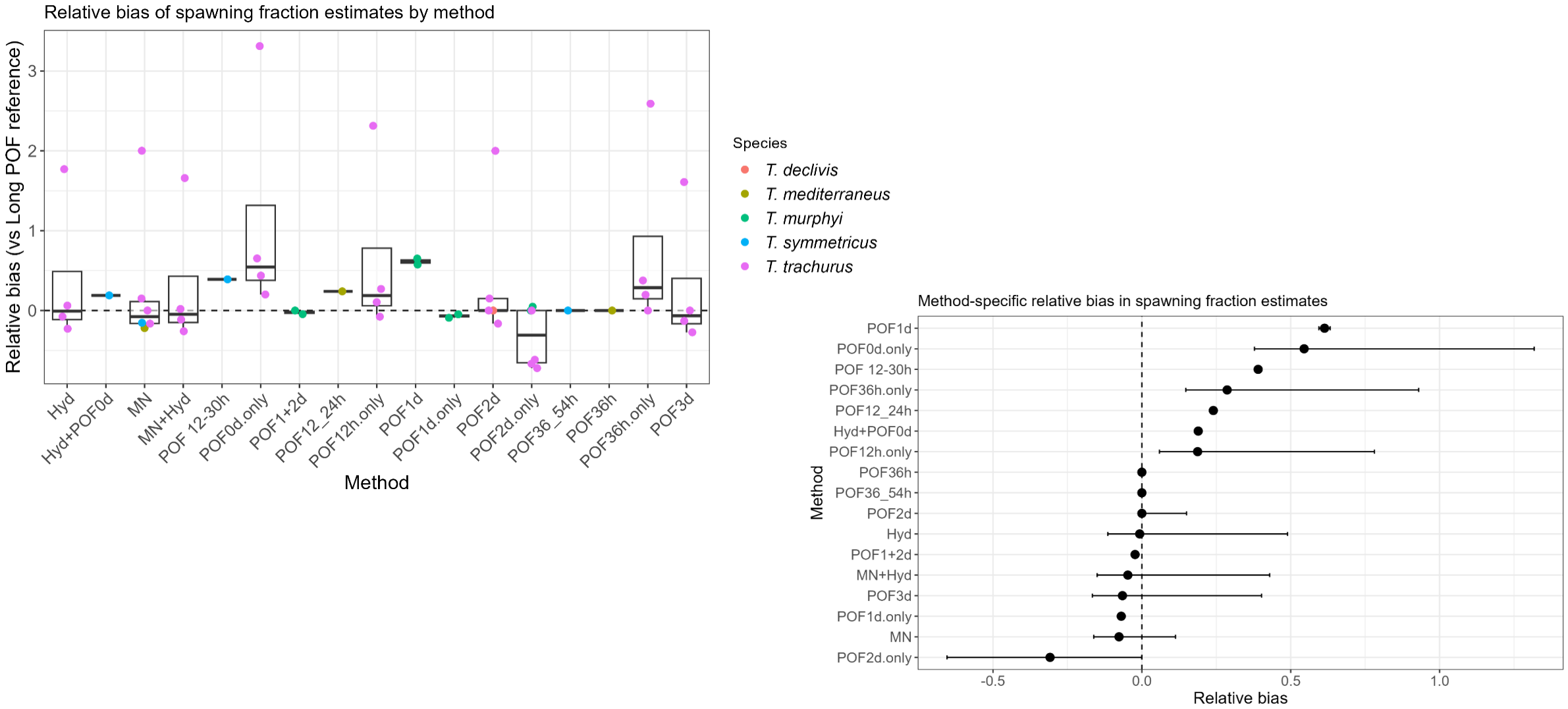
Let's explore further

Meta-analysis



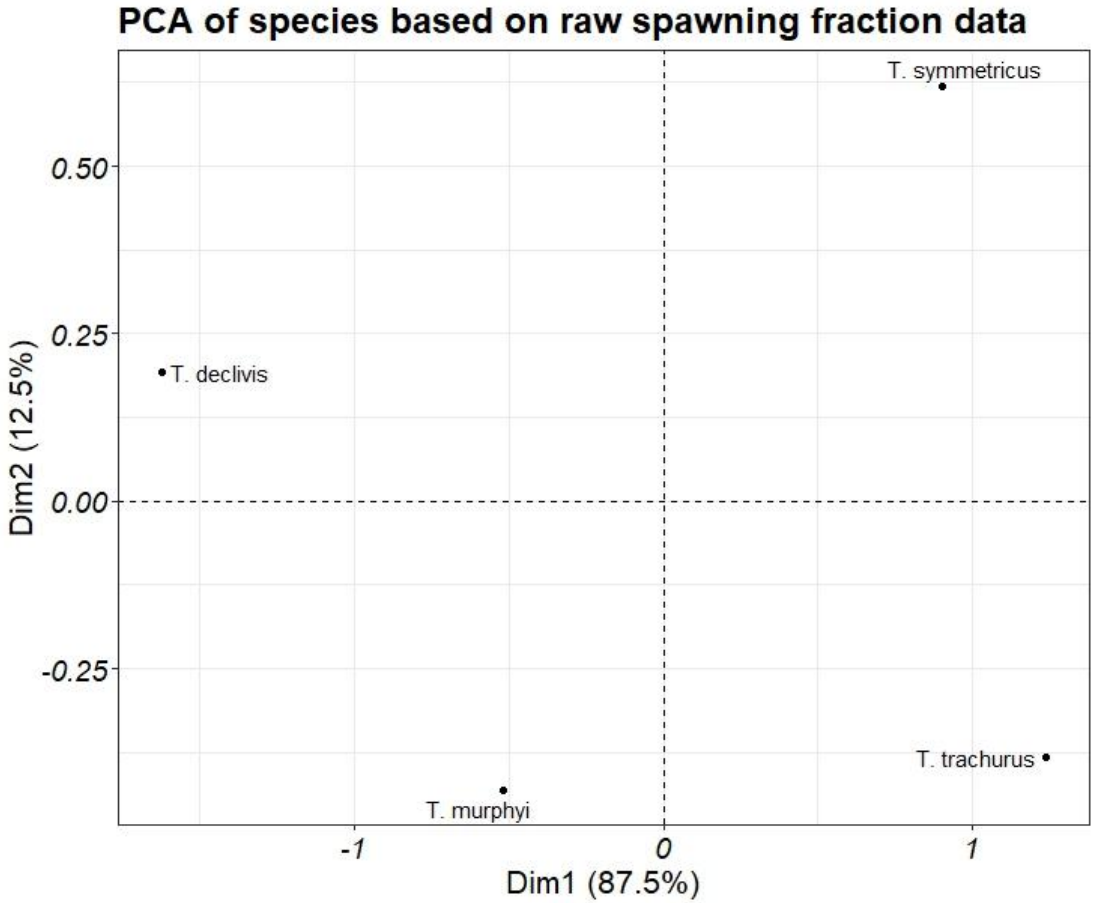
Meta-analysis

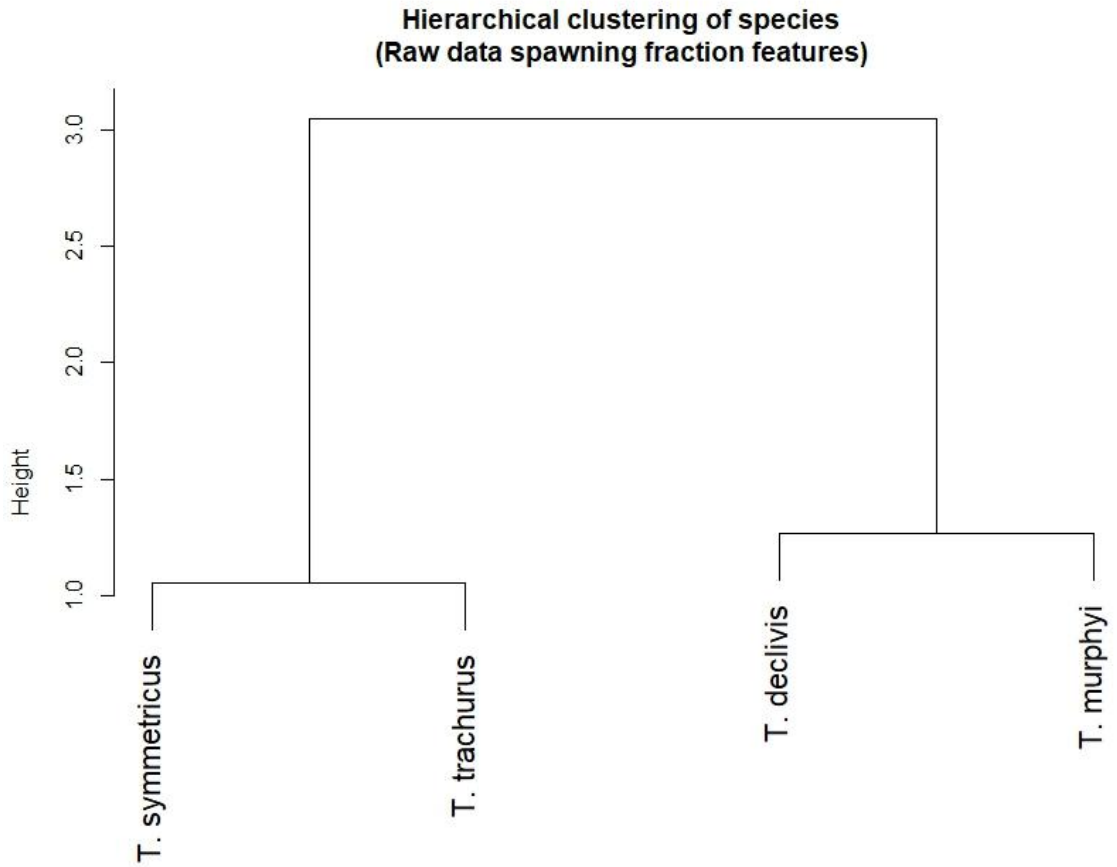
1st Approach: Relative bias



2nd Approach: PCA Clustering and hierarchical clustering

- **Literature data and uncertainty (SE) by Species**
- **Long duration POFs** : Spawning fraction and Standard error adjusted





3rd Approach: Bayesian Meta-analysis Multilevel Model

Response: Logit-transformed **Spawning fraction** (yi_logit),
Logit-transformed **Standard Error adj.** Literature (**sei_logit)** chain=4, interaction=4000

Observations: 39
Studies: 7
Methods: 11

Model:

$$yi\_logit \mid se(sei\_logit) \sim Species + Year\_c + (1 \mid StudyID) + (1 \mid StudyID{:}MethodID)$$

Fixed effects (population-level)

Parameter	Posterior mean	95% Credible interval	Interpretation
Intercept (*T.declivis*)	−2.18	[−2.70, −1.58]	Low baseline spawning fraction for reference species at mean year
Year (centred)	**−0.06**	**[−0.09, −0.03]**	**Strong evidence for temporal decline**
T. murphyi	−0.16	[−0.85, 0.54]	No clear difference from reference species
T. symmetricus	−0.08	[−0.83, 0.68]	No clear difference from reference species
T. trachurus	0.45	[−0.19, 1.01]	Tends higher, but uncertainty overlaps zero

Random effects (hierarchical variation)

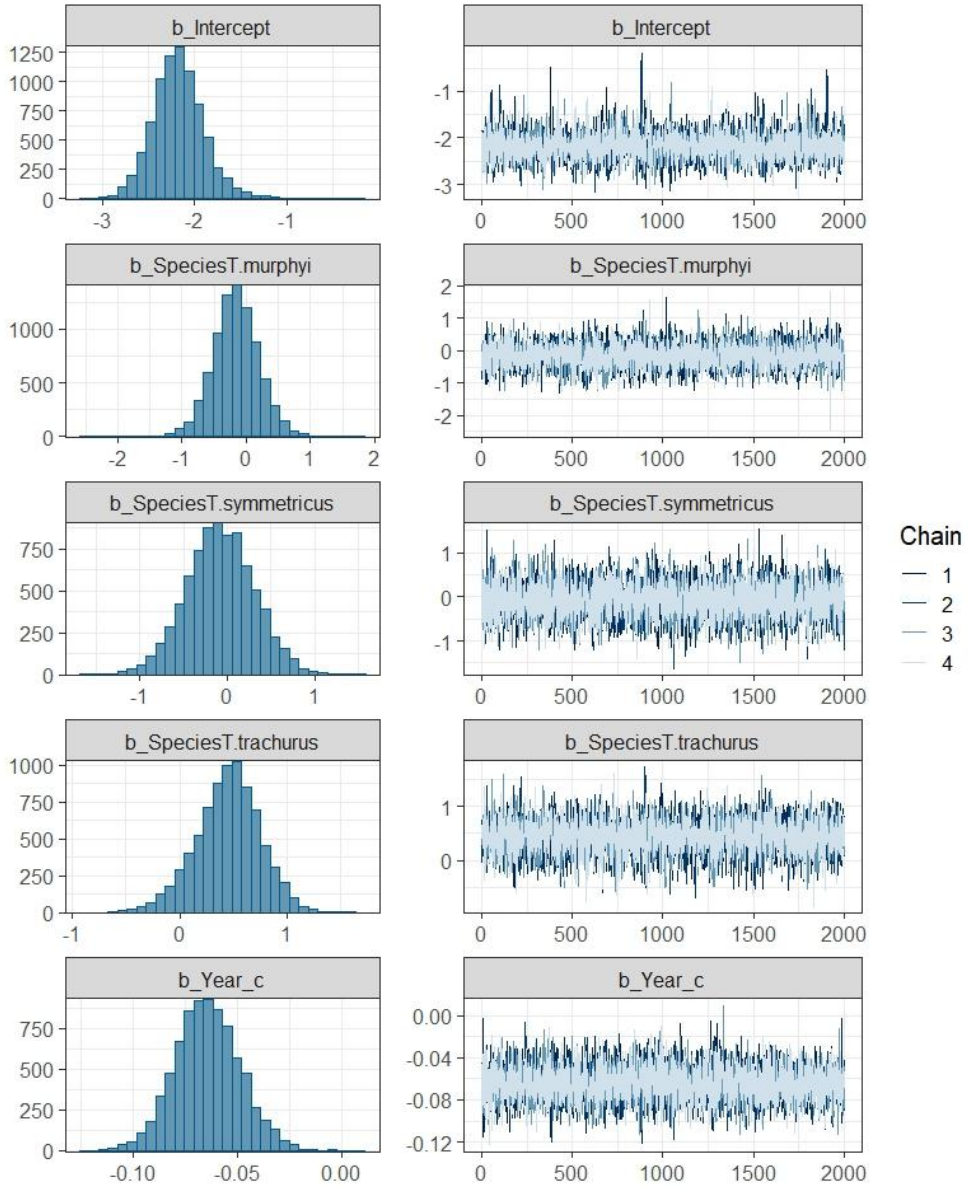
Random effect	SD (posterior mean)	95% Credible interval	Interpretation
Study	0.31	[0.02, 0.85]	Substantial between-study heterogeneity
Method within study	0.33	[0.17, 0.56]	Strong methodological variability

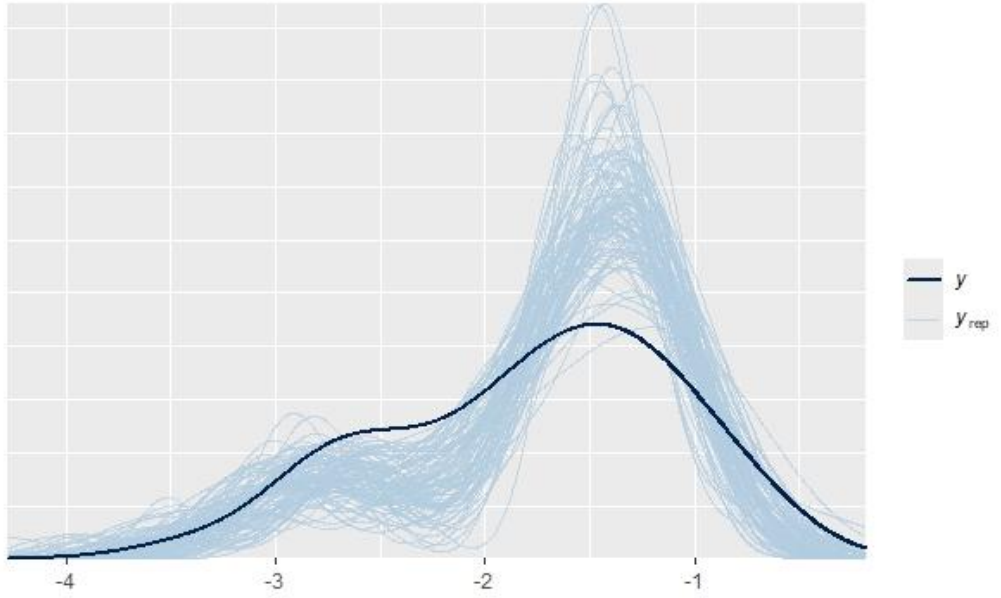
Model diagnostics

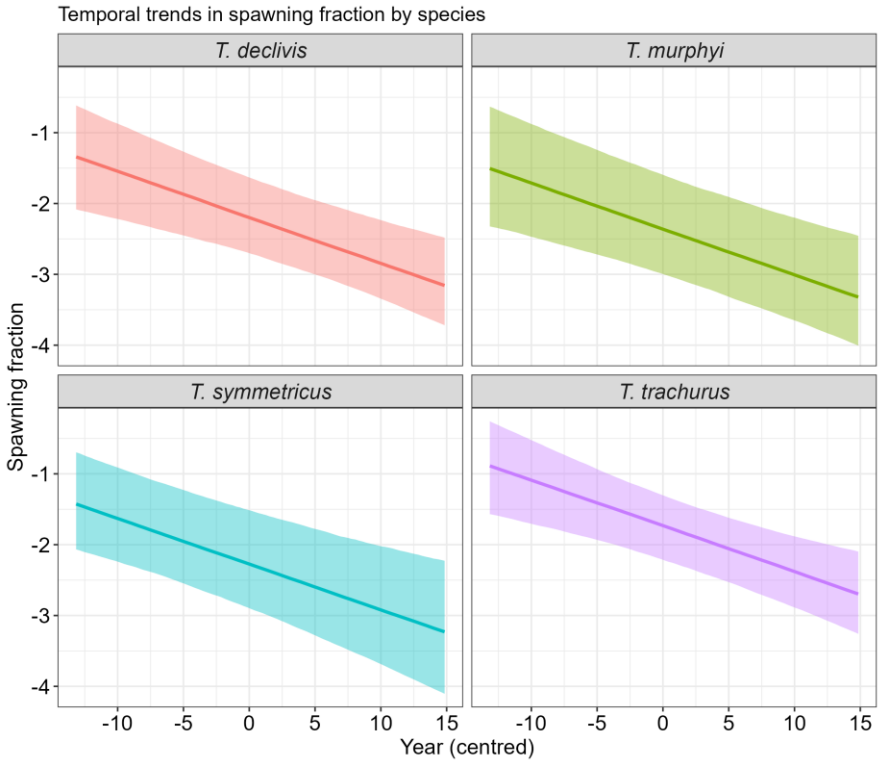
Metric	Result	Conclusion
$\hat{R}$	1.00 (all parameters)	Excellent convergence
ESS	High (>3000)	Stable posterior estimates
Residual variance (σ)	≈ 0	Because the SE of each study and method has been provided

Bayesian Multilevel Model

Results:

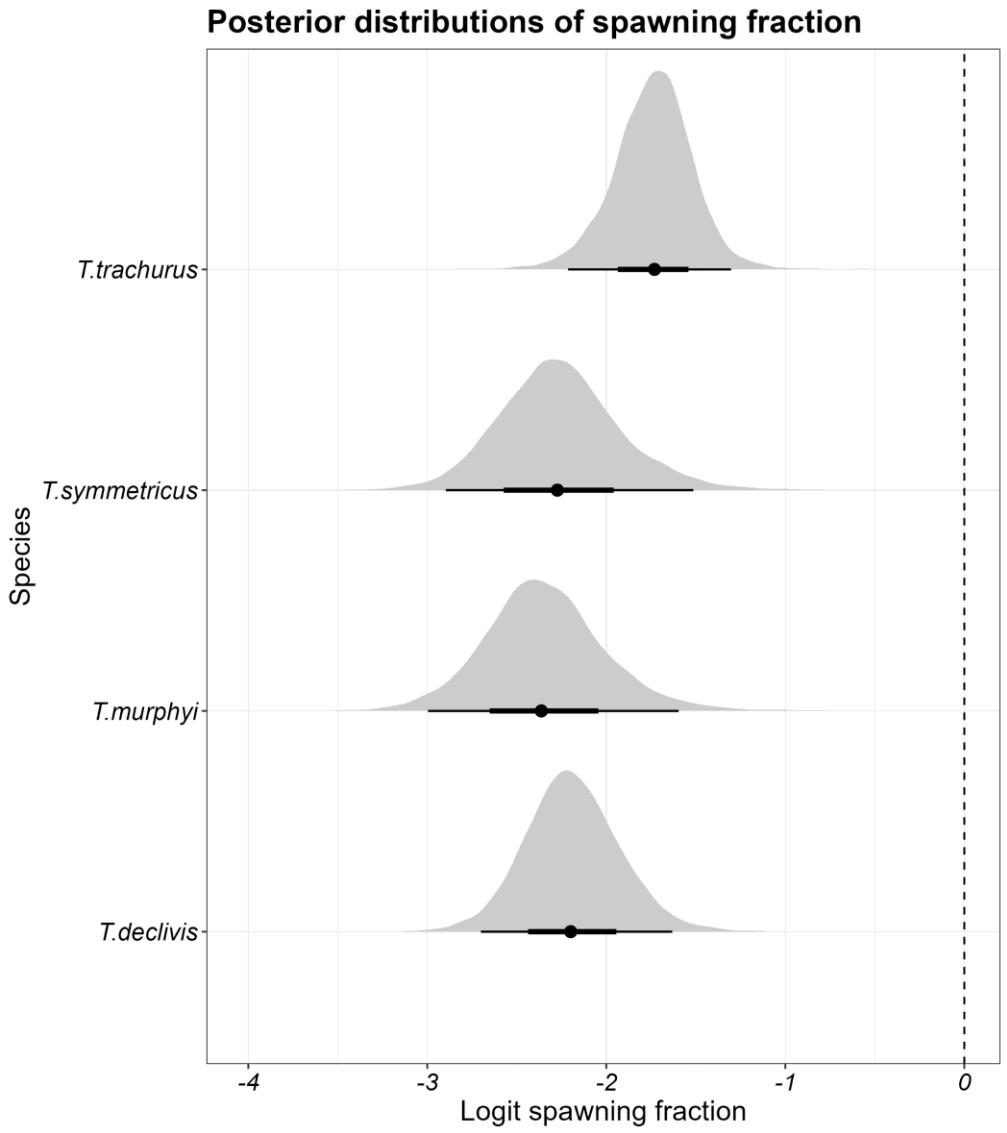


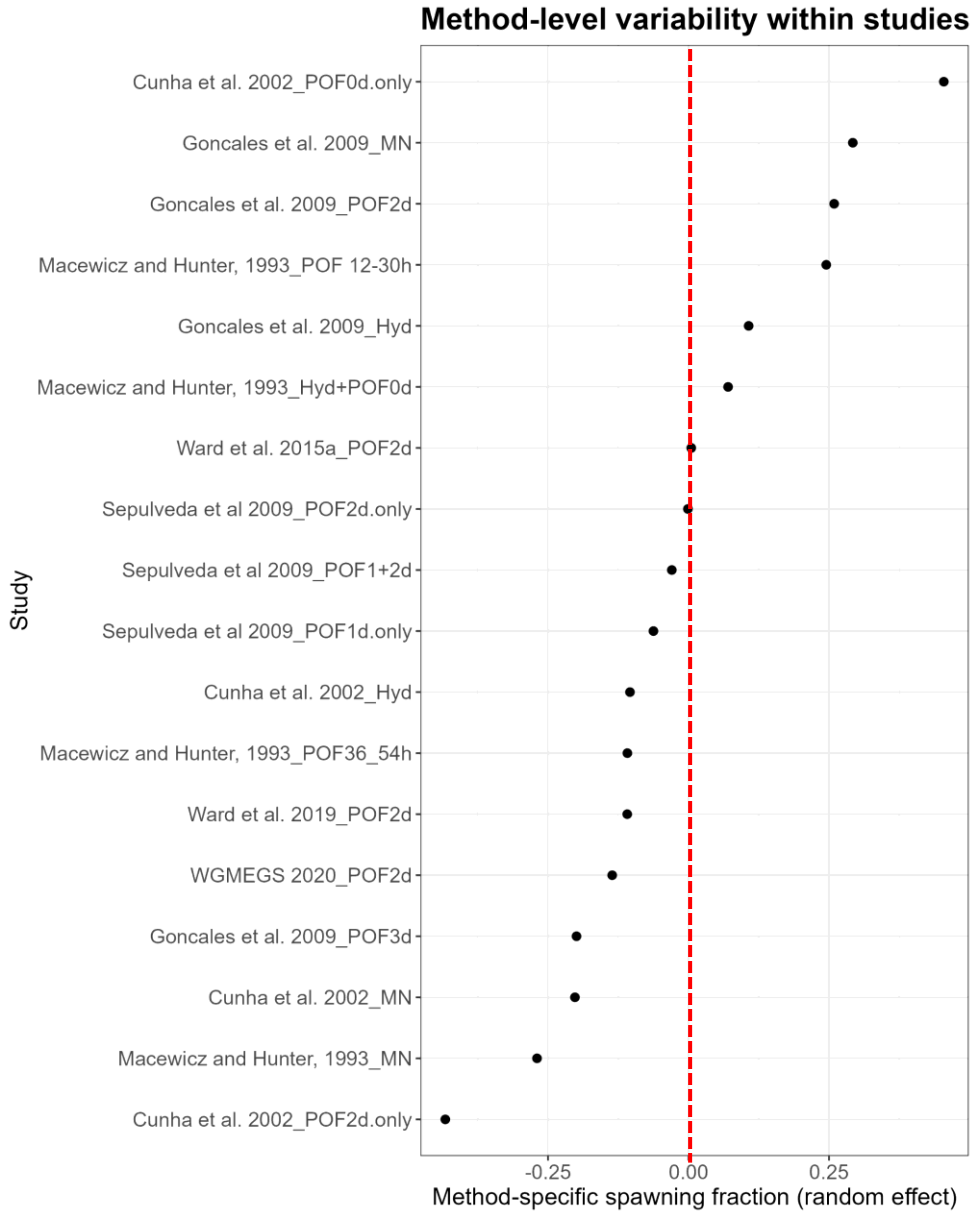




Bayesian Multilevel Model

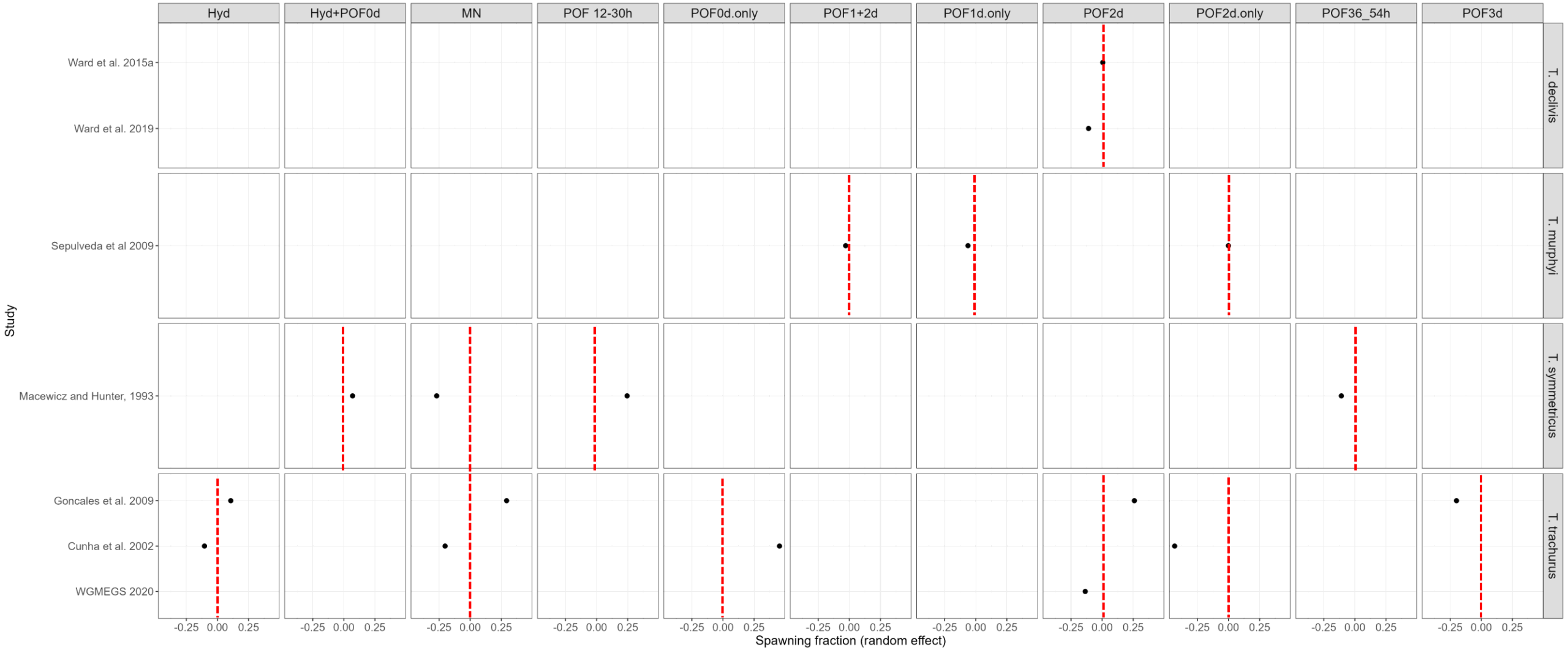
Results:





Bayesian Multilevel Model

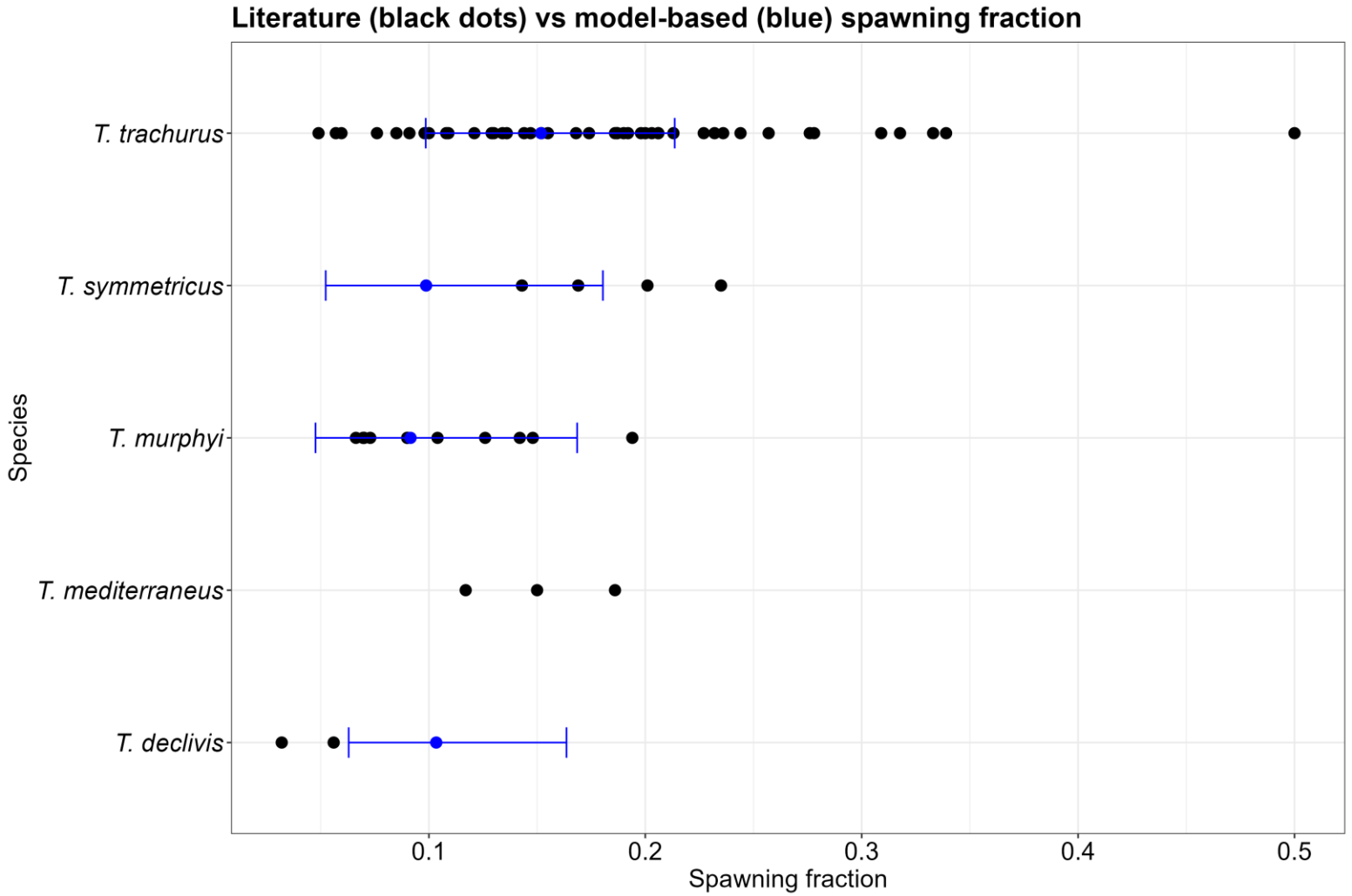
Results:



Method choice strongly affects S, even within the same study and species

Species-Level Spawning Fraction Estimates

(Adjusted for Study, Method, and Temporal effects, unequal precision)

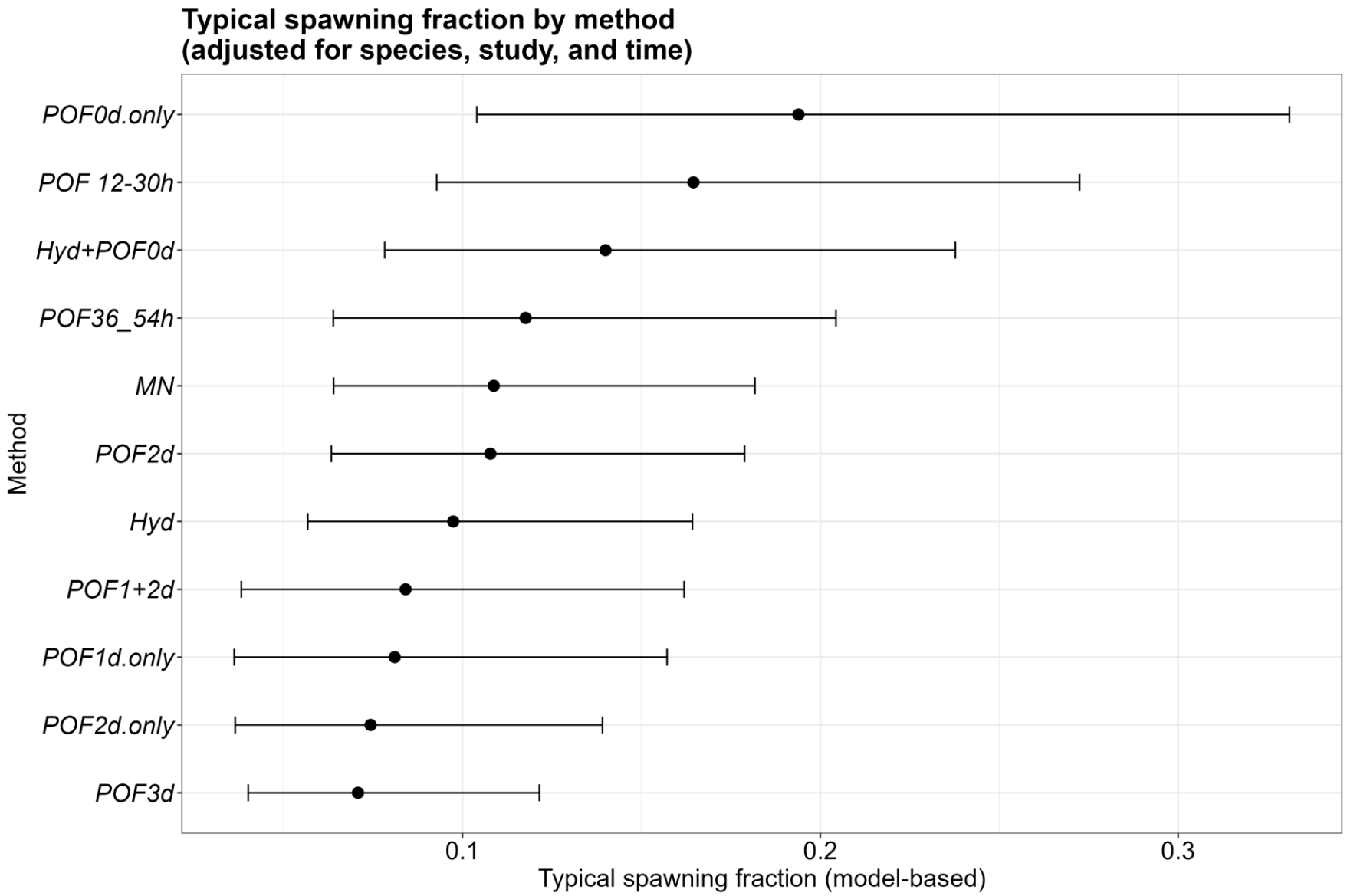


Species	Model-Based Spawning Fraction	95% Credible interval (Lower)	95% Credible interval (Upper)
T. declivis	0.103	0.063	0.164
T. murphyi	0.092	0.048	0.168
T. symmetricus	0.099	0.052	0.180
T. trachurus	0.152	0.098	0.214

Species	Literature Spawning fraction
T. declivis	0.044
T. murphyi	0.104
T. symmetricus	0.187
T. trachurus	0.185

Method-Level Spawning Fraction Estimates

(Adjusted for Study, Species, and Temporal effects, unequal precision)



Key takeaway

Species → Differences exist but are **weak and highly overlapping**

Literature/Study → Strong between-study heterogeneity exists even after adjustment

→ Study context (location, period, sampling design) matters

Methodology → Some methods **inflate** spawning fractions, others **deflate** them

→ Method effects are **large, structured, and consistent**

Temporal → Spawning fraction declines through time across species

↓

Shift of spawning season? Climate change?

Next steps

- Spawning markers (POFs) duration and Temperature
- Spawning fraction and regions (inter-species level)
- Other species

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