PERÚ Ministerio de la Producción

IMARPE INSTITUTO DEL MAR DEL PERÚ

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Jack Mackerel Benchmark Workshop (SCW16)

SPRFMO

South Pacific Regional Fisheries Management Organisation

Standardization of Catch-per-unit-effort (CPUE) for Jack Mackerel (2015-2025) in Peruvian national jurisdictional waters

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Objectives

- To retrieve data from 2015-2025, including latitude, longitude, and trip duration.
- To standarize CPUE for the 2015-2025 period by incorporating environmental variables.
- To present the impact on Jack mackerel national stock assesstment.

Data

- Fishery data: Catch per trip, year, month, latitude, longitude, distance to the coast, hold capacity, fleet type, and trip duration (days).
- Environmental data: sea surface temperature (sst) and salinity (so).

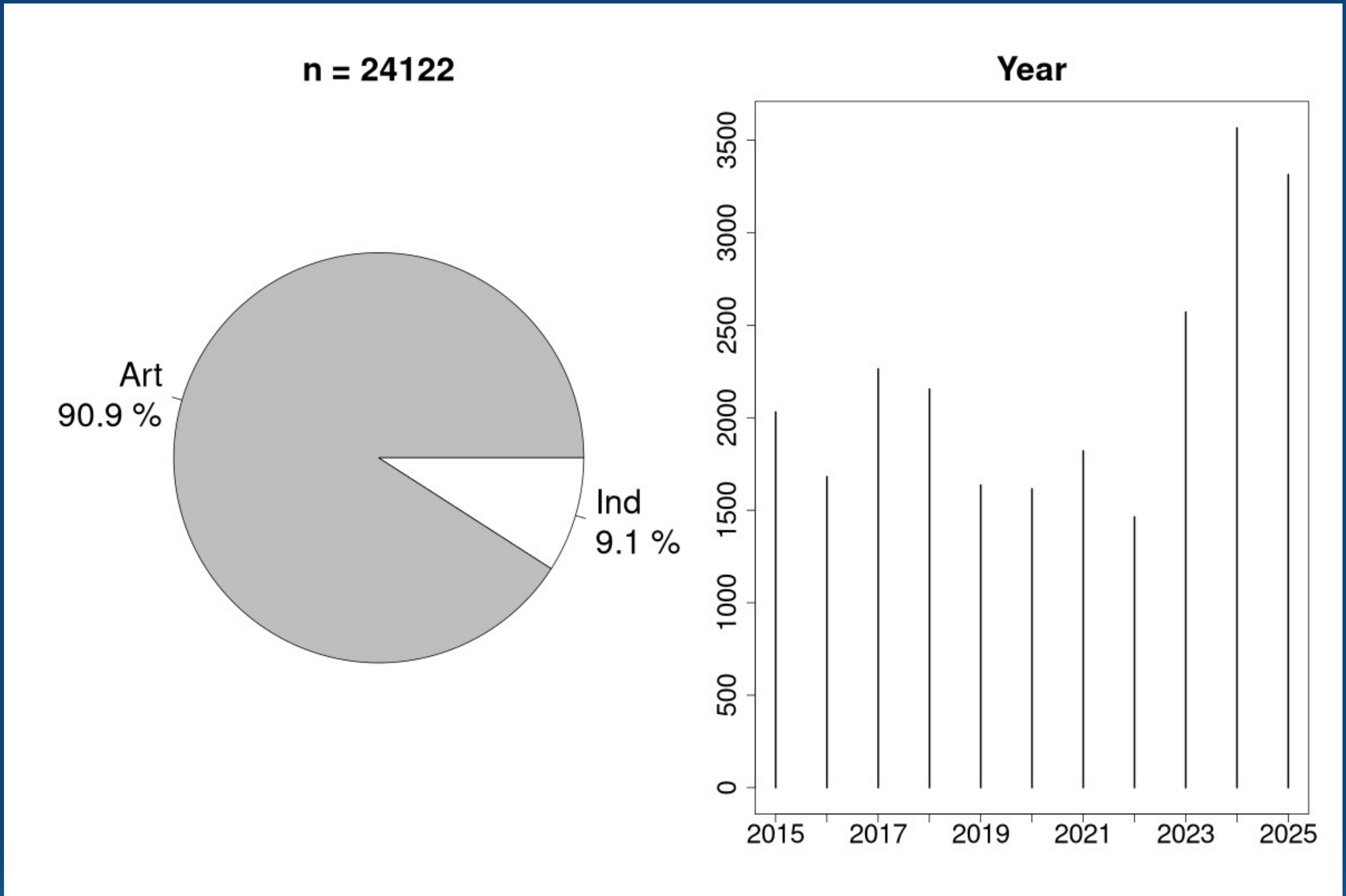
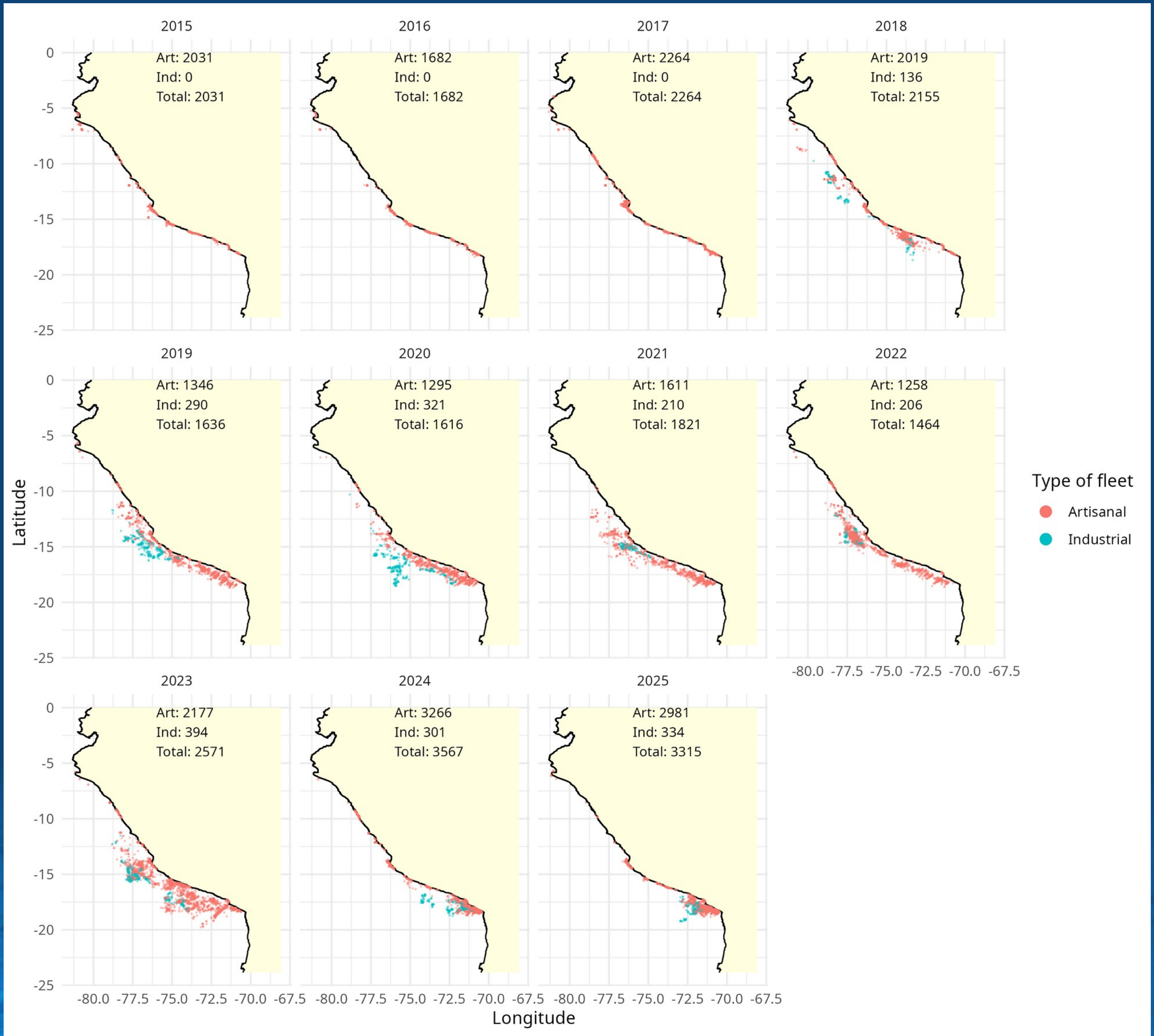


Fig.1. Distribution of Jack Mackerel records by fleet type and year.

```
# A tibble: 11 × 4
   year     catch Landing pctj_catch
   <fct>    <dbl>   <dbl>      <dbl>
 1 2015     5231.   23036       22.7
 2 2016     3528.   15121       23.3
 3 2017     5601.   10094       55.5
 4 2018    41751.   58356       71.5
 5 2019    90302.  139811       64.6
 6 2020   106248.  158880       66.9
 7 2021    79406.  118096       67.2
 8 2022    83626.  167297       50.0
 9 2023   157823.  240571       65.6
10 2024   144421.  235117       61.4
11 2025   125456.  176240       71.2
```

Around 65% since 2018

Fig.2 Spatial distribution of the data



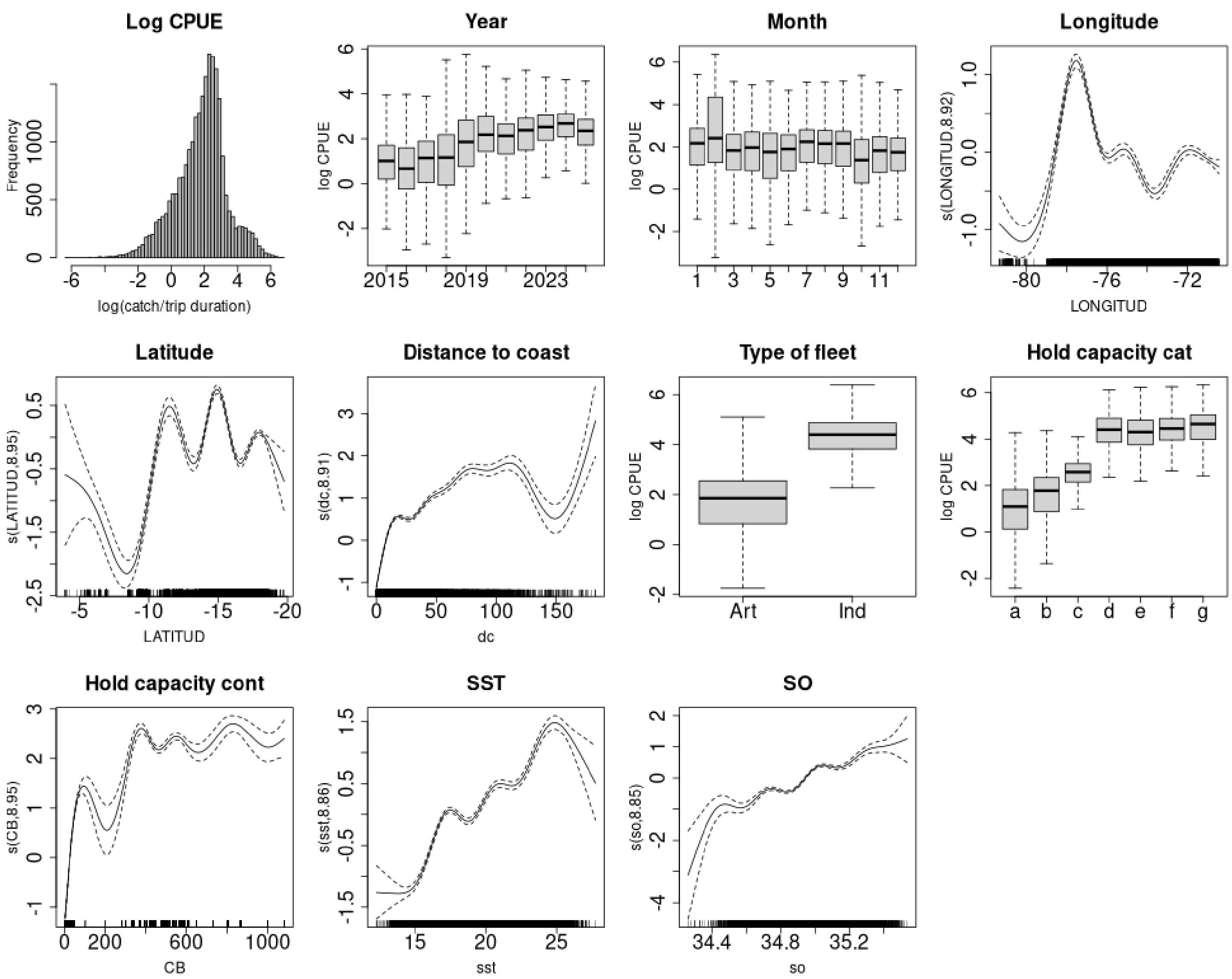


Fig. 3 Bivariate exploratory analysis of CPUE.

Implemented models

Catch per trip ~ variables + offset(log(effort))

Effort is defined as trip duration. Catch per trip is assumed to follow a Gamma distribution with a log link.

Table 1. Implemented models.

Candidate GAM models grouped by family

Model	Model structure	AIC	Deviance explained (%)	Total EDF	N	Residual DF
HC continuous						
A1	year + month + s(lat) + s(dc) + s(HC) + s(sst) + s(so)	158,972.06	60.63	65.69	24122	24,056.31
A2	year + month + te(lon, lat) + s(HC) + s(sst) + s(so)	158,780.93	60.92	70.16	24122	24,051.84
A3	year + month + te(dc, lat) + s(HC) + s(sst) + s(so)	158,988.85	60.66	71.40	24122	24,050.60
A4	year + month + te(dc, lat) + s(HC) + te(sst, so)	158,991.35	60.72	77.86	24122	24,044.14
HC categorical						
B1	year + month + s(lat) + s(dc) + HC_cat + s(sst) + s(so)	159,541.72	60.07	55.20	24122	24,066.80
B2	year + month + te(lon, lat) + HC_cat + s(sst) + s(so)	159,286.78	60.45	67.45	24122	24,054.55
B3	year + month + te(dc, lat) + HC_cat + s(sst) + s(so)	159,481.10	60.17	68.92	24122	24,053.08
B4	year + month + te(dc, lat) + HC_cat + te(sst, so)	159,493.65	60.22	75.34	24122	24,046.66
Fleet type						
C1	year + month + s(lat) + s(dc) + type_fleet + s(sst) + s(so)	162,155.53	56.15	57.46	24122	24,064.54
C2	year + month + te(lon, lat) + type_fleet + s(sst) + s(so)	161,992.27	56.35	62.03	24122	24,059.97
C3	year + month + te(dc, lat) + type_fleet + s(sst) + s(so)	162,003.67	56.42	62.90	24122	24,059.10
C4	year + month + te(dc, lat) + type_fleet + te(sst, so)	162,024.49	56.48	69.58	24122	24,052.42

Table 1. Models grouped into three families: CB continuous (A), CB categorical (B), and fleet type (C).

Table 2. Model ordered by AIC.

Ranking of candidate GAM models

Model	Model structure	AIC	Deviance explained (%)	Total EDF	N	Residual DF	Rank	ΔAIC
A2	**year + month + te(lon, lat) + s(HC) + s(sst) + s(so)**	**158,780.93**	**60.92**	**70.16**	**24122**	**24,051.84**	**1**	**0.00**
A1	year + month + s(lat) + s(dc) + s(HC) + s(sst) + s(so)	158,972.06	60.63	65.69	24122	24,056.31	2	191.14
A3	year + month + te(dc, lat) + s(HC) + s(sst) + s(so)	158,988.85	60.66	71.40	24122	24,050.60	3	207.92
A4	year + month + te(dc, lat) + s(HC) + te(sst, so)	158,991.35	60.72	77.86	24122	24,044.14	4	210.43
B2	year + month + te(lon, lat) + HC_cat + s(sst) + s(so)	159,286.78	60.45	67.45	24122	24,054.55	5	505.85
B3	year + month + te(dc, lat) + HC_cat + s(sst) + s(so)	159,481.10	60.17	68.92	24122	24,053.08	6	700.17
B4	year + month + te(dc, lat) + HC_cat + te(sst, so)	159,493.65	60.22	75.34	24122	24,046.66	7	712.72
B1	year + month + s(lat) + s(dc) + HC_cat + s(sst) + s(so)	159,541.72	60.07	55.20	24122	24,066.80	8	760.79
C2	year + month + te(lon, lat) + type_fleet + s(sst) + s(so)	161,992.27	56.35	62.03	24122	24,059.97	9	3,211.34
C3	year + month + te(dc, lat) + type_fleet + s(sst) + s(so)	162,003.67	56.42	62.90	24122	24,059.10	10	3,222.74
C4	year + month + te(dc, lat) + type_fleet + te(sst, so)	162,024.49	56.48	69.58	24122	24,052.42	11	3,243.57
C1	year + month + s(lat) + s(dc) + type_fleet + s(sst) + s(so)	162,155.53	56.15	57.46	24122	24,064.54	12	3,374.61

Models ranked from lowest to highest AIC. Best-supported model highlighted in green.

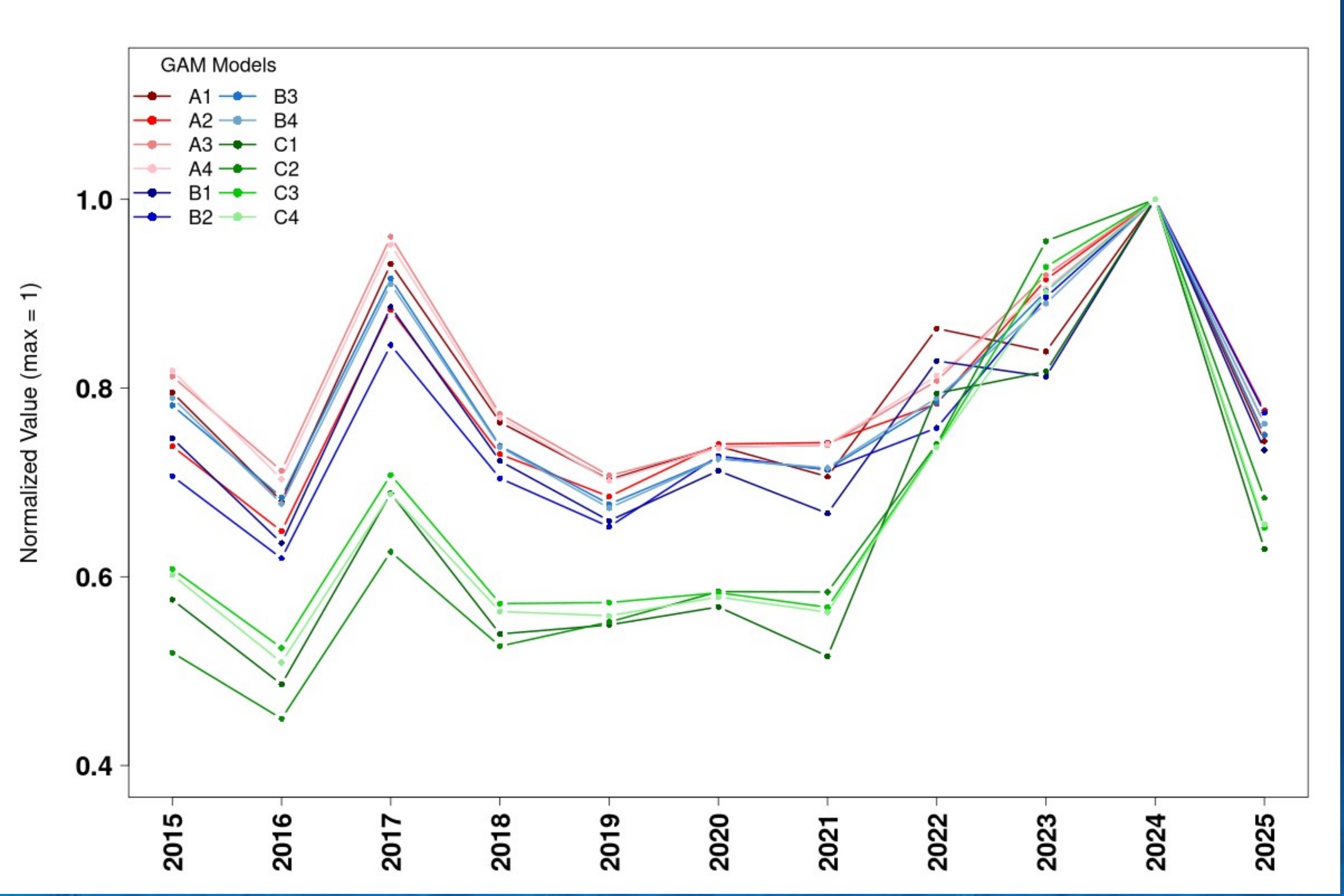


Fig. 3. Standardized time series for models A, B, and C.

Final model: A2

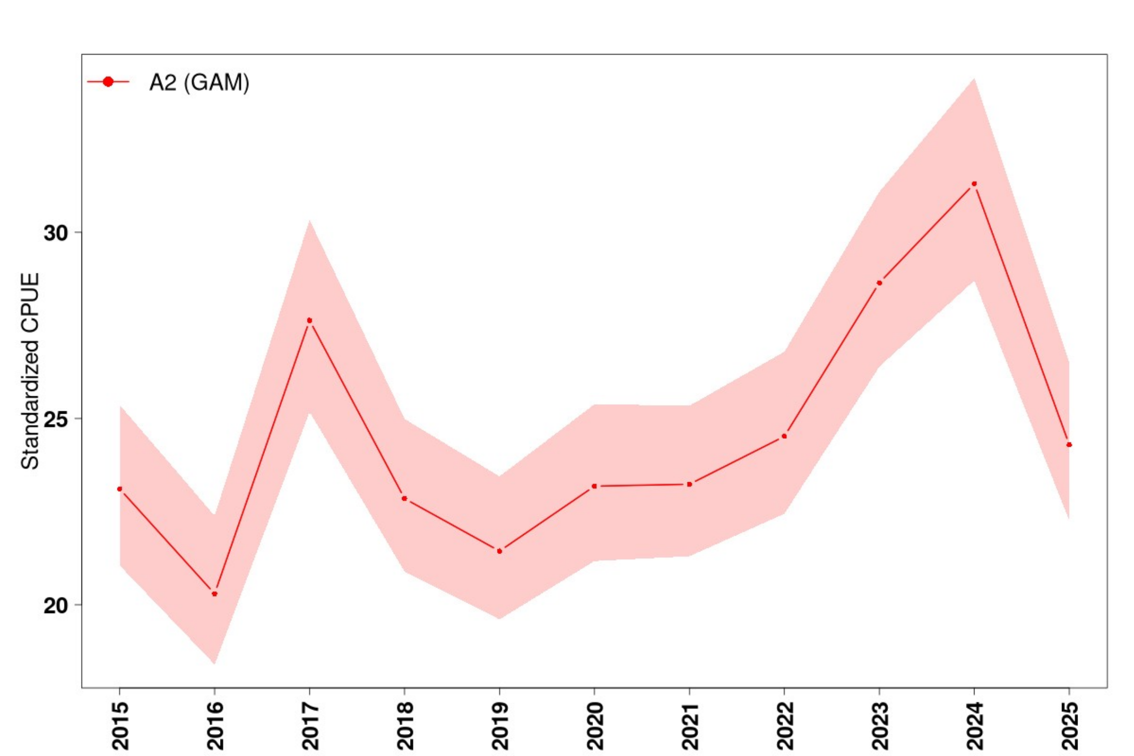


Fig. 4. Standardized time series for final model.

GAM A2	
Variable	% Explained
Year	20.92
Month	9.03
Spatial effect	13.51
Hold capacity	17.31
SST	0.09
Salinity	0.08
Total	**60.92**

Table 3. Contribution of each variable to model A2.

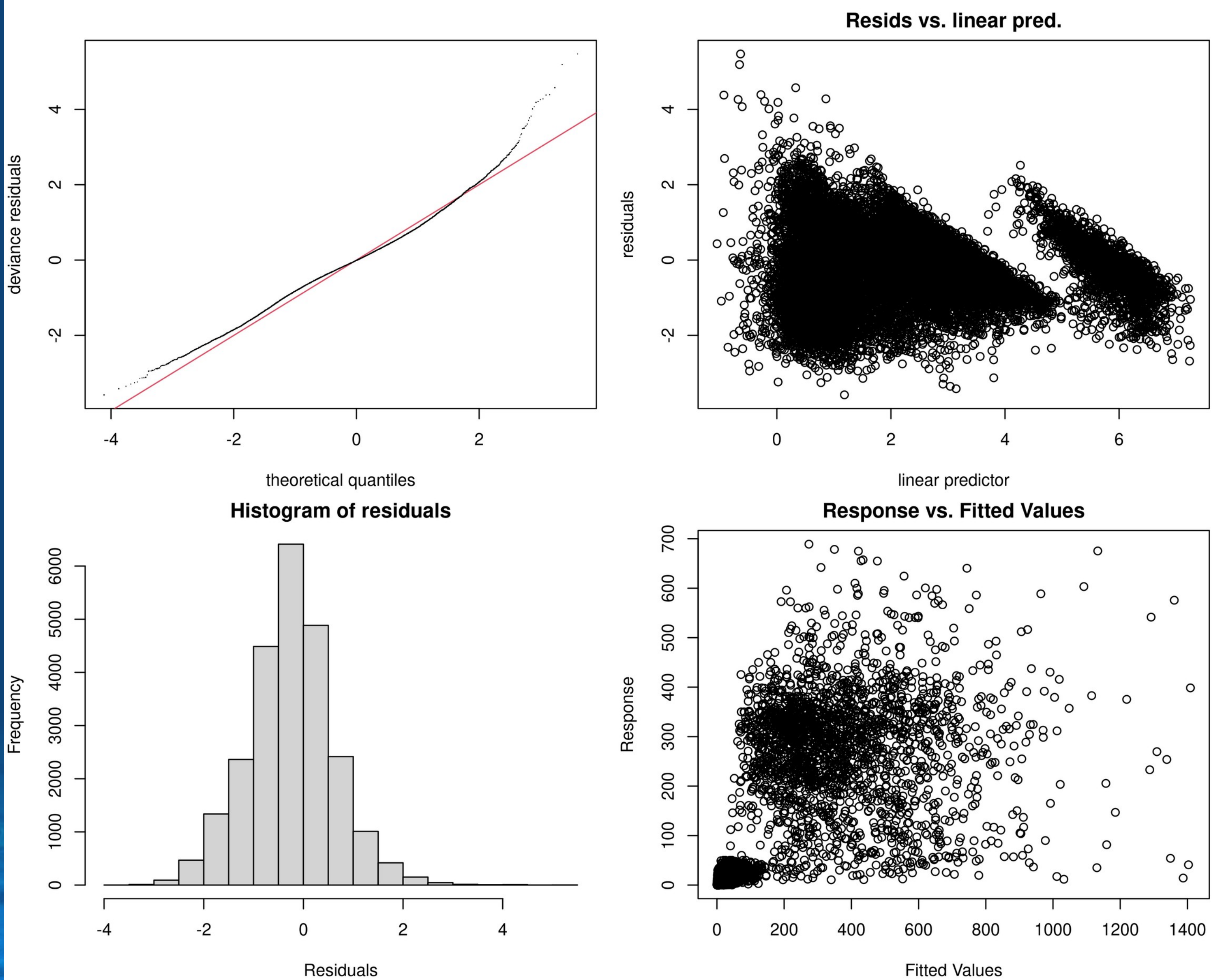


Fig. 5. Final model: A2. Residuals.

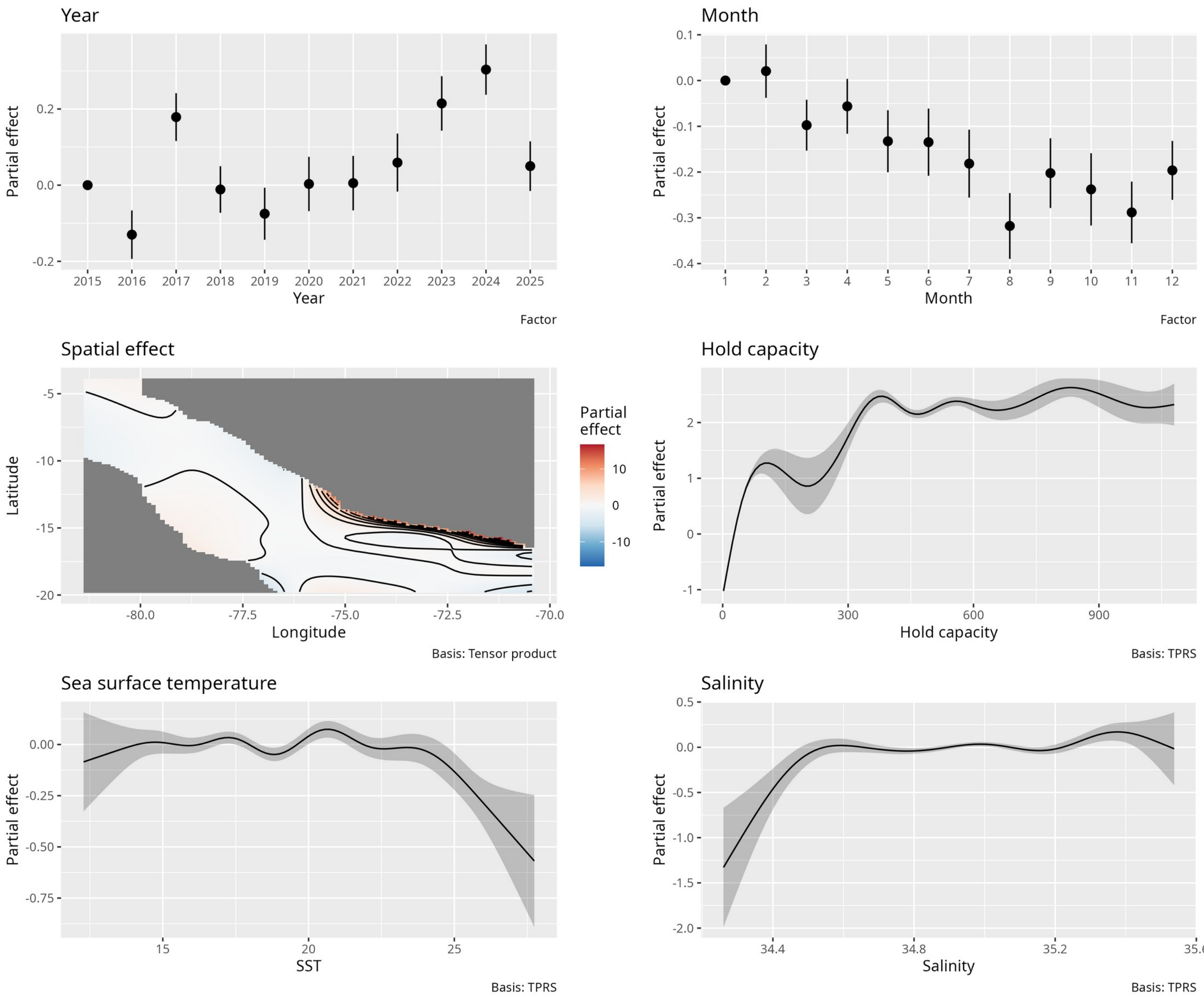


Fig. 6. Final model: A2.
Partial effects.

Old CPUE (quota 2026) vs new CPUE

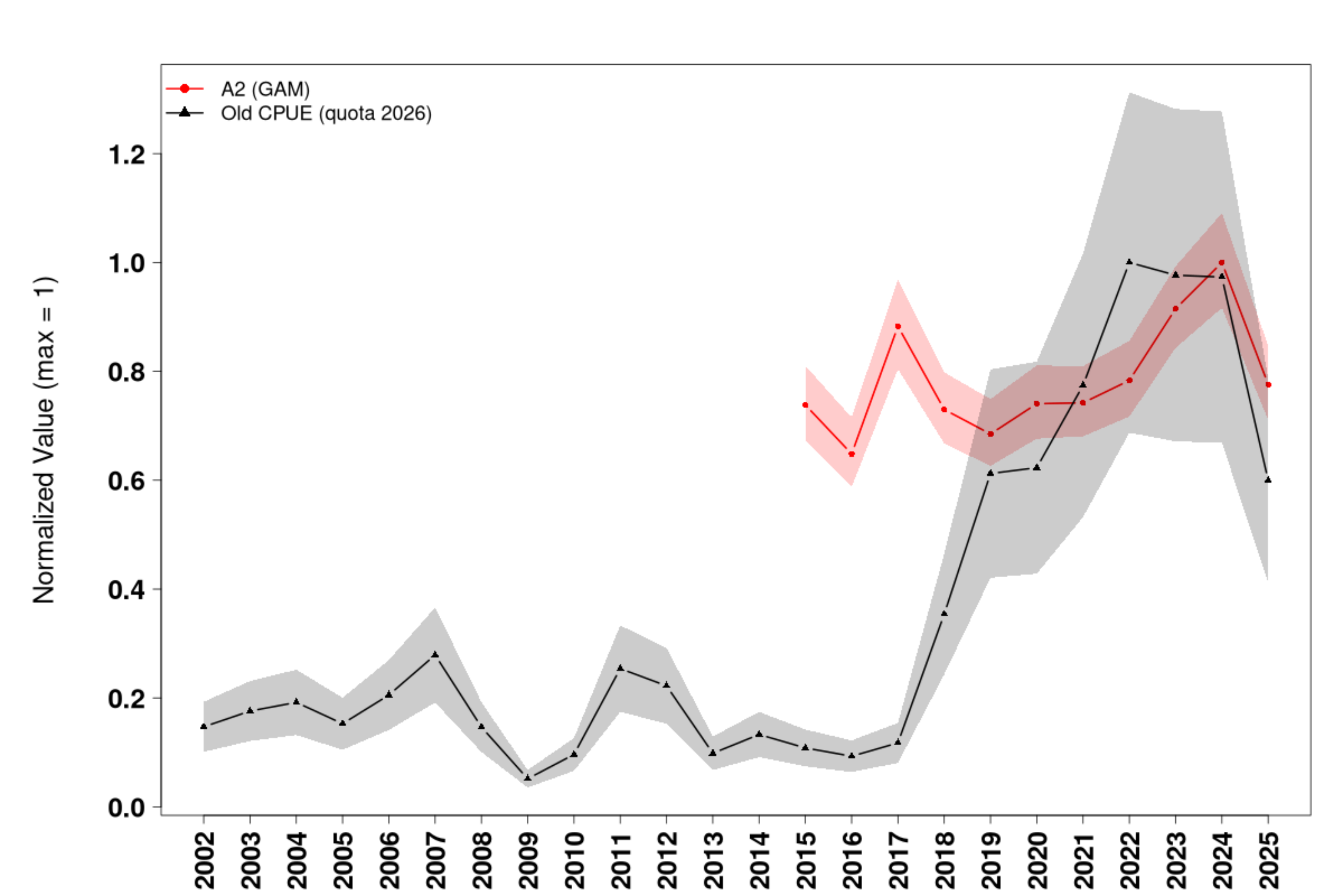


Fig. 7 Old vs new CPUE.

About national stock assessment (Far-north stock)

Models:

Mod0.0: As quota 2026 (2025 assessment) information up to november 2025 (block 1: CV=0.2 for 2002-2017, block 2: CV = 0.3 for 2018-2025).
Mod1.0: As mod0.0 but with updated catches and length frequencies up to december 2025.
Mod2.0: As mod1.0 but with 3 abundance indices: acoustic (1985 - 2008, 2010 - 2013), old cpue 2002-2014 and new cpue 2015-2025.
Mod3.0: As mod2.0 with standard error estimated.

Results:

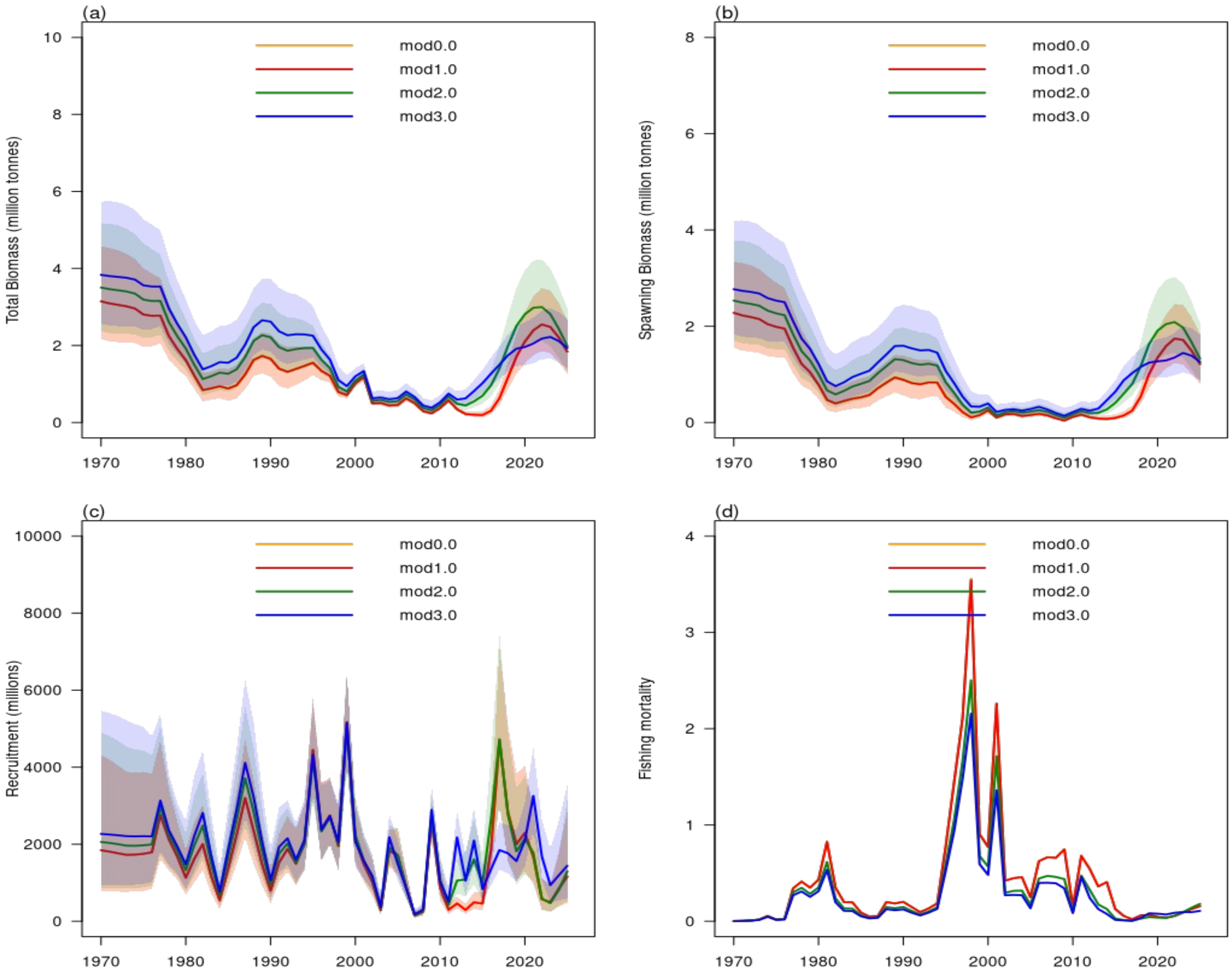
Reference points:

	MSY	Bmsy	Fmsy
mod0.0	108.5607	171.3867	0.3089178
mod1.0	108.5758	171.6350	0.3084322
mod2.0	141.8781	248.7763	0.2764119
mod3.0	142.1437	283.4693	0.2494133

	MSY_last	Bmsy_last	Fmsy_last	Capt. Fmsy
mod0.0	103.6826	174.3801	0.30567	216.698
mod1.0	103.6913	174.6235	0.30517	219.342
mod2.0	135.2025	251.9360	0.27374	183.896
mod3.0	135.6407	285.6519	0.24800	252.904

Likelihood contributions:

	mod0.0	mod1.0	mod2.0	mod3.0
catch_like	0.93	0.93	0.66	0.86
age_like_fsh	0.00	0.00	0.00	0.00
length_like_fsh	452.32	451.74	479.43	561.57
sel_like_fsh	11.60	11.60	11.45	10.16
ind_like	58.07	58.09	66.91	56.87
age_like_ind	0.00	0.00	0.00	0.00
length_like_ind	0.00	0.00	0.00	0.00
sel_like_ind	0.00	0.00	0.00	0.00
rec_like	26.75	26.56	15.40	4.13
fpen	0.06	0.06	0.03	0.03
post_priors_indq	0.04	0.04	0.04	0.04
post_priors	0.00	0.00	0.00	0.00
residual	0.17	0.17	0.07	0.07
total	549.96	549.20	574.00	633.72


(a)
Total Biomass (million tonnes)
mod0.0
mod1.0
mod2.0
mod3.0
(b)
Spawning Biomass (million tonnes)
mod0.0
mod1.0
mod2.0
mod3.0
(c)
Recruitment (millions)
mod0.0
mod1.0
mod2.0
mod3.0
(d)
Fishing mortality
mod0.0
mod1.0
mod2.0
mod3.0

Conclusions and perspectives

- We standardized the CPUE for the 2015-2025 period. The best-performing model included year, month, the interaccion between latitude and longitude, and continuous HC as the main explanatory variables.
- Future work will focus on recovering data to complete the 2002–2025 time series.
- Spatiotemporal approaches using tools like INLA or sdmTMB, will be evaluated to better account for spatial and temporal variability in CPUE standardization.

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